V. International Architectural Sciences Congress (IArcSC-2025)

OCTOBER 29-30-31, 2025 / DEMRE, ANTALYA, TÜRKIYE



PROCEEDINGS BOOK

Editors

Prof. Dr. Atila GÜL
Prof. Dr. Öner DEMIREL
Dr. Alina AMANZHOLOVA
Dr. Sibel AKTEN
Neriman Gül ÇELEBİ
İskender Emre GÜL

ISBN: 979-8-89695-259-6
DOI: https://doi.org/10.5281/zenodo.17937655
December 15, 2025

Copyright © Liberty

Liberty Publishing House
Water Street Corridor New York, NY 10038
www.libertyacademicbooks.com
+1 (314) 597-0372

ALL RIGHTS RESERVED NO PART OF THIS BOOK MAY BE REPRODUCED IN ANY FORM, BY PHOTOCOPYING OR BY ANY ELECTRONIC OR MECHANICAL MEANS, INCLUDING INFORMATION STORAGE OR RETRIEVAL SYSTEMS, WITHOUT PERMISSION IN WRITING FROM BOTH THE COPYRIGHT OWNER AND THE PUBLISHER OF THIS BOOK.

© Liberty Academic Publishers 2025

The digital PDF version of this title is available Open Access and distributed under the terms of the Creative Commons Attribution-Non-Commercial 4.0 license (http://creativecommons.org/licenses/by-nc/4.0/) which permits adaptation, alteration, reproduction and distribution for noncommercial use, without further permission provided the original work is attributed. The derivative works do not need to be licensed on the same terms.

adopted by Mariam Rasulan

ISBN: 979-8-89695-259-6
DOI: https://doi.org/10.5281/zenodo.17937655

ISSUED: December 15, 2025

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

PROCEEDINGS BOOK

(Abstracts & Full Texts)

Editors

Prof. Dr. Atila GÜL
Prof. Dr. Öner DEMIREL
Dr. Alina AMANZHOLOVA
Dr. Sibel AKTEN
Neriman Gül ÇELEBİ
İskender Emre GÜL

Congress Coordinator

Dr. Atabek MOVLYANOV
Dr. Alina AMANZHOLOVA

Cover Design

Dr. Atabek MOVLYANOV

ISBN: 979-8-89695-259-6

DOI: https://doi.org/10.5281/zenodo.17937655

ISSUED: December 15, 2025

**All rights of this book belongs to Liberty Publishing House.
Without permission can't be duplicate or copied.
Authors of chapters are responsible both
ethically and juridically.**

Konu : Bilimsel Etkinlik Hk.
Sayı : AE-3 12.04.2025

İLGİLİ MAKAMA

10 Eylül 2024 tarihinde saat 13.30'da "Bilimsel Etkinlik Düzenlenmesi ve Görevlendirmeler" gündemi ile toplanan Yönetim Kurulumuz'un 2024/E2 sayılı kararı ile 29-31 Ekkim 2025 tarihleri arasında Antalya'da

"5. Uluslararası Mimarlık Bilimleri Kongresi" düzenlenmesine karar verilmiştir

İlgili kararın ifası için görevlendirilen düzenleme kurulu üyeleri unvan ve isimleri aşağıda belirtilmiş olup bilim ve danışma kurulunun düzenleme kurulu tarafından teşekkül ettirilmesi ile kongreye bizzat iştirak edecek düzenleme kurulu üyelerinin yolluk ve gündeliklerinin saymanlığımız tarafından ilgili harcama kaleminden ödenmesi

Arz rica olunur

Sefa Salih BİLDİRİCİ
Başkan Yardımcısı

Düzenleme Kurulu Üyeleri
Prof. Dr. Atila GÜL - Süleyman Demirel Üniversitesi
Prof. Dr. Öner DEMİREL - Kırıkkale Üniversitesi

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

CONTENTS

Titles	Page Numbers
Congress ID	1-2
Organizing Board and Science & Advisory Board	3-13
Congress Schedule	14-66
Congress Photos	67-72
Abstract List	73-86
Abstract Contents	87-224
Full Text List	225-237
Full Text Contents	238-1738

CONGRESS ID

Congress Title

V. International Architectural Sciences Congress

(IArcSC-2025)

Date and Place

October 29-30-31, 2025, Demre, Antalya, Türkiye

Organizing

Demre Deputy Demre-Antalya, Türkiye

https://demre.bel.tr/

The Editorial Board of the Journal of Architectural Sciences and Applications, Isparta, Türkiye. (https://dergipark.org.tr/en/pub/mbud)

Black Sea Nature and Environment Association (KADOÇED)

https://kadoced.org/associations/kadoced/

Institute of Economic Development and Social Research (IKSAD) Ankara, Türkiye. (https://www.iksadinstitute.org/)

Liberty Publishing House (www.libertyacademicbooks.com)

Architectural Sciences Platform

Evaluation Process and Policies

All applications have undergone double blind peer review process. In addition, each paper was accepted and the process of publishing in the book was carried out through editorial oversight.

The published papers were presented and discussed at the meeting.

Full texts and abstracts published in accordance with the Congress Policy have been prepared in accordance with ethical rules and APA standards.

All authors are responsible for the content and format of their articles, both ethically and legally. The Editors and Publisher are not responsible in any way for articles published in the Congress Proceedings.

Presentation

Oral and Online Presentations

Aim of The Congress

This Symposium aims to bring together qualified scientists from Türkiye and abroad on a common international platform under the umbrella of Architectural Sciences and to enable different disciplines to share their valuable research.

Topics of The Congress

- Planning (Planning theories, planning paradigms, types of planning, regional planning, watershed planning, landscape planning, urban planning, rural planning, planning and protection, spatial and temporal changes, site selection methods, etc.)
- Design (Design theories, Space, Building, Urban, Landscape, Rural, Village, Tourism, Recreational, Environment, Interial Architecture, Plantation, Industrial Products, Ecological, Universal, Disabled, etc.)
- Sociology / Psychology / Art / Philosophy / History / Identity / Theory / Aesthetics
- Protected Areas / Natural and Cultural Heritage Protection / Documentation / Renovation / Repair / Restoration / Soil sealing
- Tourism / Recreation / Cultural Tourism / Nature Tourism / Ecotourism / Archeology
- Climate Change / Renewable Energy / Energy saving / Energy Transition / Water / Sustainability / Ecology/ Environment / Sustainable Development
- Smart and Ecological Cities / Urbanizm / Landscape / Open and Green Spaces / Green infrastructure / Transportation / Urban Agriculture / Urban Renewal / Transformation
- Building Materials / Green Buildings / Urban Accessories and Furniture / Landscape materials/ Landscape Plant Materials and Using/ Plant Cultivation and Use
- Technology / Artificial Intelligence / Digital Architecture and 3D Software and Printer, GIS, Remote sensing
- Health / Pandemic / Food / Occupational Health and Safety
- Higher Education in Architectural Sciences / R&D / Scientific Researches / Publications
- Future of Architectural Sciences / Utopia / Space Architecture / Water Architecture
- Economic / Policies / Legislation / Management / Governance / Practices / Sectoral Problems

Participants Countries

Algeria, Azerbaijan, Bangladesh, Ethiopia, Italy, Iran, India, Malaysia, Moldova, Morocco, Nigeria, Northern Cyprus, Pakistan, Poland, Romania, Türkiye, Ukraine

Total Accepted Articles: 265

Number of Rejected Papers: 25
The Number of Accepted Papers from Türkiye: 119
The Number of Accepted Full Papers from Other Countries: 146

Index in

Index of Academic Documents (IAD), Open AIRE, Google Scholor, ResearchGate, Britishindex Scientific Database

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

Honorary Board

- **Emin BAĞLI**

Demre District Governor, Demre Türkiye

- **Fahri DURAN**

Mayor of Demre Municipality, Demre, Türkiye

Head of the Organising Committee

- **Prof. Dr. Atila GÜL**

Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye

Vice Heads of the Organising Committee

- **Prof. Dr. Öner DEMİREL**

Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye

- **Prof. Dr. Şule ORMAN**

Akdeniz University Demre Dr. Hasan Unal Vocational School Director, Demre, Türkiye

- **Prof. Dr. Ümit ARPACIOĞLU**

Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, Department of Building Physics and Materials, Istanbul - Türkiye

- **Prof. Dr. Nevzat ÇEVİK**

Akdeniz University Department of Archaeology Antalya, Türkiye

- **Salih GÜNAY**

Demre Deputy Mayor, Demre, Türkiye

- **Osman YATKIN**

Demre Deputy Mayor, Demre, Türkiye

- **Assoc. Prof. Dr. Ebru Fatma FINDIK**

Hatay Mustafa Kemal University, Faculty of Science and Letters, Department of Art History, Hatay- Türkiye

- **Çağrı YOLUK**

Demre Municipality Park and Gardens Manager, Demre, Türkiye

- **Assist. Prof. Dr. Ahmet FİDAN**

Chairman of Federation of Culture-Art, Research, Nature and Environment Associations (KADOÇED) Ordu-Türkiye

- **Assist. Prof. Dr. Mert ÇAKIR**

Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye

- **Assist. Prof. Dr. Gizem DİNÇ**

Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye

SYMPOSIUM COORDINATORS

Dr. Atabek MOVLYANOV (IKSAD Scientific Support Coordinator)

Dr. Alina AMANZHOLOVA (IKSAD Scientific Support Coordinator)

Organizing Board Members

- Prof. Dr. Asena SOYLUK - Gazi University, Faculty of Architecture, Department of Architecture, Ankara-Türkiye
- Prof. Dr. Ayfer Aybike KARADAĞ - Düzce University, Faculty of Forestry, Department of Landscape Architecture, Düzce- Türkiye
- Prof. Dr. Ertan DÜZGÜNEŞ - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Prof. Dr. Hilal Tendü GÖKTUĞ - Adnan Menderes University, Faculty of Agriculture, Department of Landscape Architecture, Aydın-Türkiye
- Prof. Dr. Kağan GÜNÇE - Eastern Mediterranean University, Department of Architecture, Interior Architecture, Famagusta- North Cyprus
- Prof. Dr. Murat AKTEN - Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
- Prof. Dr Murat ZENGİN - Pamukkale University, Faculty of Architecture ve Design, Department of Architecture, Denizli-Türkiye
- Prof. Dr. Niyazi Uğur KOÇKAL - Akdeniz University, Faculty of Engineer, Department of Civil Engineering, Antalya- Türkiye
- Prof. Dr. Ömer ATABEYOĞLU - Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
- Prof. Dr. Saniye Gül GÜNEŞ - Unıversity of Cappadocia, Faculty of Architecture, Design and Fine Arts, Cappadocia-Türkiye
- Prof. Dr. Sedef DOĞANER - Wentworth Institute of Technology, USA
- Prof. Dr. Sevgi YILMAZ - Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, Erzurum-Türkiye
- Prof. Dr. Şebnem ERTAŞ BEŞİR - Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya- Türkiye
- Prof. Dr. Şükran ŞAHİN - Ankara University, Faculty of Agriculture, Department of Landscape Architecture, Ankara- Türkiye
- Prof. Dr. Ufuk ÇOŞGUN - Karabük University, Faculty of Forestry, Department of Forestry, Karabük- Türkiye
- Prof. Dr. Vibhavari JANI - Kansas State University, College of Architecture, Planning and Design, Department of Interior Architecture & Product Design, USA

- Assoc. Prof. Dr. Ahmet Erkan METİN - Uşak University, Banaz Vocational School, Forestry and Forest Products Program, Uşak- Türkiye
- Assoc. Prof. Dr Ahmet BENLİAY - Akdeniz University, Faculty of Architecture, Department of Landscape Architecture, Antalya- Türkiye
- Assoc. Prof. Dr. H. Berk TÜRKER - Uşak University, Faculty of Architecture and Design, Department of City and Regional Planning, Uşak- Türkiye
- Assoc. Prof. Dr. Elif SÖNMEZ - Altınbaş University, Faculty of Engineering and Natural Sciences, Department of Interior Architecture and Environmental Design, İstanbul- Türkiye
- Assoc. Prof. Dr. Elif TOKDEMİR DEMİREL - Kırıkkale University, Faculty of Arts and Sciences, Department of Translation and Interpretation, Türkiye
- Assoc. Prof. Dr. Emine Seda ARSLAN - Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
- Assoc. Prof. Dr. Engin KEPENEK - Akdeniz University, Faculty of Architecture, Department of City and Regional Planning, Antalya-Türkiye
- Assoc. Prof. Dr. Hayriye Hale KOZLU - Erciyes University, Faculty of Architecture, Department of Architecture, Kayseri- Türkiye
- Assoc. Prof. Dr. Meryem Bihter BİNGÜL BULUT - Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye
- Assoc. Prof. Dr. Sultan Sevinç KURT KONAKOĞLU - Amasya University, Faculty of Architecture, Department of Urban Design and Landscape Architecture, Amasya-Türkiye
- Assoc. Prof. Dr. Şirin Gülcen EREN - Süleyman Demirel University, Faculty of Architecture, Department of City and Regional Planning, Isparta- Türkiye
- Assist. Prof. Dr. Bilgenur AK - Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye
- Assist. Prof. Dr. Floriana ZUCARO - The University of Naples Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli- Italy
- Assist. Prof. Dr. Pelin KARAÇAR - Istanbul Medipol University, Faculty of Fine Arts Design and Architecture, Department of Architecture, İstanbul- Türkiye
- Dr. Lilli GARGİULO - University of Naples Federico II, Naples, Italy
- Dr. Pelin FIRAT ÖRS - Onsekiz Mart University, Faculty of Architecture ve Design, Department of Architecture, Çanakkale- Türkiye
- Dr. Sibel AKTEN - Isparta University of Applied Sciences, Department of Park and Horticulture, Isparta- Türkiye
- Dr. Çağla AYDEMİR - Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
- Dr. Orhan ALAV - Süleyman Demirel University, Isparta- Türkiye
- Dr. Halime GÖZLÜKAYA - Süleyman Demirel University, Faculty of Architecture, Department of City and Regional Planning, Isparta- Türkiye
- Neriman Gül ÇELEBİ - Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Building Physics and Materials Istanbul - Türkiye
- Dr. Hakan LEVENTOĞLU - Businessman, Higher Agricultural Engineer
- Hatice Eda GÜL - Master's Student, Dokuz Eylül University, Institute of Science, Department of Architecture, İzmir- Türkiye
- İskender Emre GÜL -PhD. Student, Akdeniz University, Sciences Institute, Department of Civil Engineer, Antalya - Türkiye
- Tuba Gizem AYDOĞAN - Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye
- Seniye Ela GÜL- Student, Demokrasi University, Faculty of Architecture, Department of Architecture, İzmir - Türkiye

- M. A. Doğa Armağan DEMİREL-Johann Wolfgang Goethe-Universitat Frankfurt (Goethe University) Anglophone Literatures, Cultures and Media
- Fadime ÖNCÜ -Cultural Heritage Expert
- Hüseyin Batuhan DÜNDAR –Master's Student, Suleyman Demirel University, Sciences Institute, Department of Landscape Architecture, Isparta-Türkiye
- Ozan YILMAZ – Master's Student, Suleyman Demirel University, Sciences Institute, Department of Landscape Architecture, Isparta-Türkiye

Science and Advisory Board

- Abdullah KELKİT - Onsekiz Mart University, Faculty of Architecture ve Design, Department of Landscape Architecture, Çanakkale- Türkiye
- Adeb QAID - Department of Architectural Engineering, Kingdom University, Riffa, Kingdom of Bahrain
- Afer ELIFOV - Bakü Engineering University, Faculty of Architecture, Bakü- Azerbaijan
- Ali KAYGISIZ - Sütçü İmam University, Faculty of Forestry, Department of Agriculturali Kahramanmaraş-Türkiye
- Alper BÜYÜKKARAGÖZ - Gazi University Faculty of Technology Department of Civil Engineering, Ankara- Türkiye
- Alpe SAĞLIK - Onsekiz Mart University, Faculty of Architecture ve Design, Department of Landscape Architecture, Çanakkale- Türkiye
- Altuğ SARIYAR - Istanbul Esenyurt University, Faculty of Engineering and Architecture, Department of Interior Architecture, Istanbul-Türkiye
- Andjela JAKSİC STOJANOVİC - Univerzitet Mediteran Podgorica, Montenegro
- Arif MISIRLI - Trakya University, Faculty of Architecture, Department of Architecture, Edirne-Türkiye
- Arzu MEMMEDOVA - Baku Engineering University, Baku- Azerbaijan
- Arzu ÇAĞLAR - Ahi Evran University, Faculty of Engineering-Architecture, Department of Architecture Kırşehir, Türkiye
- Aslan NAYEB - Yeditepe University, Faculty of Architecture, Department of Interior Architecture, Istanbul-Türkiye
- Aslı Güneş GÖLBEY - İzmir Democracy University, Faculty of Archıtecture, Department of Landscape Architecture, İzmir-Türkiye
- Aylin SALICI - Hatay Mustafa Kemal University, Faculty of Architecture, Department of Landscape Architecture, Hatay-Türkiye
- Ayşe Esra CENGİZ - Çanakkale 18 Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale-Türkiye
- Aziz Cumhur KOCALAR - Nigde Omer Halisdemir University. Faculty of Architecture. Department of City and Regional Planning. Department of Urbanism, Nigde-Türkiye
- Bader ALATAWNEH - Department of Architecture, Palestine Polytechnic University, Palestine
- Banu APAYDIN - Istanbul Okan University, Department of Interior Architecture and Environmental Design, İstanbul-Türkiye
- Banu ÇELEBİOĞLU - Yıldız Technical University, Department of Architecture, Istanbul-Türkiye
- Banu Çiçek KURDOĞLU - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon -Türkiye
- Banu ÖZTÜRK KURTASLAN - Selçuk University, Faculty of Architecture and Design, Department of Landscape Architecture, Konya-Türkiye
- Barbara ŻARSKA - Warsaw University, Poland

- Berna GÜÇ - Süleyman Demirel University, Faculty of Architecture, Department of Architecture, Isparta-Türkiye
- Betül BİLGE ÖZDAMAR - Baskent University, Faculty of Fine Arts, Design and Architecture, Department of Interior Architecture and Environmental Design Ankara-Türkiye
- Bilge ÇAKIR - Hatay Mustafa Kemal University, Faculty of Architecture, Department of City and Regional Planning, Hatay- Türkiye
- Bilgen DÜNDAR - Beykent University, Faculty of Engineering and Architecture, Department of Architecture, Istanbul-Türkiye
- Bilgenur AK - Kırıkkale University Faculty of Fine Arts Departmentof Landscape Architecture, Kırıkkale-Türkiye
- Buket Özdemir IŞIK - Trabzon University, Faculty of Sports Sciences, Department of Recreation, Trabzon-Türkiye
- Burçin EKİCİ - Namık Kemal University, Faculty of Fine Arts, Design and Architecture, Department of Landscape Architecture, Tekirdağ-Türkiye
- Bülent YILMAZ - İnönü University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya- Türkiye
- Cahide AYDIN İPEKÇİ - Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
- Carmen GUIDA - The University of Naples Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli, Italy
- Cem ALPAY - Istanbul Technical University, Department of Industrial Design, Istanbul-Türkiye
- Cem BEYGO - Istanbul University, Department of City and Regional Planning, Istanbul -Türkiye
- Cem Tilki - Final International University, School of Tourism and Culinary Arts, Department of Gastronomy, TRNC
- Cengiz TAVŞAN - Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon- Türkiye
- Cengiz YÜCEDAĞ - Mehmet Akif University, Faculty of Engineering-Architecture, Department of Landscape Architecture, Burdur- Türkiye
- Ceren SELİM - Akdeniz University, Faculty of Architecture, Department of Landscape Architecture, Antalya-Türkiye
- Claudia JUROWSKY - Northern Arizona University, USA
- Demet DEMİROĞLU - Kilis 7 Aralık University, Faculty of Agriculture, Department of Horticulture, Kilis-Türkiye
- Deniz HASIRCI - Izmir University of Economics, Faculty of Fine Arts and Design, Department of Interior Architecture and Environmental Design, İzmir -Türkiye
- Dicle AYDIN - Necmettin Erbakan University, Faculty of Fine Arts and Architecture, Department of Architecture, Konya Türkiye
- Didem DİZDAROĞLU - Bilkent University Faculty of Fine Arts, Design and Architecture Department of Urban Design and Landscape Architecture, Ankara-Türkiye
- Doruk Görkem ÖZKAN - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Drahşan UĞURYOL - Yıldız Technical University, Faculty of Architecture, Department of Conservation and Restoration of Cultural Heritage, Istanbul-Türkiye
- Duygu DOĞAN - Pamukkale University, Faculty of Architecture and Design, Department of Landscape Architecture, Denizli-Türkiye
- Ebru DOĞAN - Malatya Turgut Özal University Faculty of Art, Design, and Architecture Department of Architecture, Malatya-Türkiye
- Elçin NOYAN - Alanya Hamdullah Emin Pasa University, Alanya Türkiye
- Elif AKPINAR KÜLEKÇİ - Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture

- Elif BAYRAMOĞLU - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Elif Ebru ŞİŞMAN - Tekirdağ Namık Kemal University, Faculty of Fine Arts, Design and Architecture, Department of Landscape Architecture, Tekirdağ-Türkiye
- Elif Merve ALPAK - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Elif ÖZER YÜKSEL - Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
- Elif SAĞLIK - Çanakkale 18 Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale-Türkiye
- Elif ŞATIROĞLU - Recep Tayyip Erdogan University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Rize-Türkiye
- Emel AKIN - Atılım University GSTMF Department of Architecture, Türkiye
- Emine AKCAN ŞİRİN - Mimar Sinan Fine Arts University, Institute of Science, Istanbul-Türkiye
- Emine DAĞTEKİN - Dicle University, Faculty of Architecture, Department of Architecture, Diyarbakır-Türkiye
- Emine KELEŞ - Trakya University Faculty of Architecture, Department of Landscape Architecture, Edirne-Türkiye
- Erdinç ÇAKMAK - Breda University of Applied Sciences, Netherlands.
- Esra LAKOT ALEMDAĞ - Recep Tayyip Erdogan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
- Farzad SAFAEIMANESH - Final International University, School of Tourism and Culinary Arts, Department of Tourism, TRNC
- Federica GAGLIONE - The University of Sannio, Department of Engineering, Benevento, Italy
- Feran AŞUR - Yuzuncu Yıl University, Faculty of Architecture and Design, Department of Landscape Architecture, Van-Türkiye
- Filiz KARAKUŞ - Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Department of Architecture, Ankara-Türkiye
- Filiz TAVŞAN - Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture, Trabzon-Türkiye
- Foad IRANI - Final International University, School of Tourism and Culinary Arts, Department of Tourism, TRNC
- Funda TAN - Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
- Gamze Fahriye PEHLİVAN - Sivas Cumhuriyet University, Faculty of Architecture, Fine Arts and Design, Department of Architecture, Sivas-Türkiye
- Gerardo CARPENTIERI - The University of Naples Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli, Italy
- Gonca BÜYÜKMIHÇI - Erciyes University, Faculty of Architecture, Department of Architecture, Kayseri-Türkiye
- Gözde ÇAKIR KIASIF - Haliç University, Faculty of Architecture, Department of Architecture, Istanbul-Türkiye
- Gülçöhre MEMMEDOVA - Azerbaijan Architecture and Construction University, Baku-Azerbaijan
- Gülferah ÖRS ÇORAPÇIOĞLU - Istanbul Arel University Faculty of Engineering and Architecture Department of Architecture, Istanbul-Türkiye
- Gülhan BENLİ - Istanbul Medipol University Faculty of Fine Arts Design and Architecture, İstanbul, Türkiye
- Gizem ERDOĞAN - İzmir Demokrasi University, Faculty of Architecture, Department of Urban and Regional Planning, İzmir -Türkiye

- H. Burçin HENDEN ŞOLT - Zonguldak Bulent Ecevit University. Alaplı Vocational School Department of Architecture and Urban Planning, Zonguldak-Türkiye
- Hakan ALPHAN - Çukurova University, Faculty of Architecture, Department of Landscape Architecture, Adana- Türkiye
- Hasan HAŞTEMOĞLU - Süleyman Demirel University, Faculty of Architecture, Department of Architecture, Isparta- Türkiye
- Hasan Tezcan YILDIRIM - Istanbul University-Cerrahpasa, Faculty of Forest, Department of Forestry Engineering, Department of Forest Policy and Management, İstanbul, Türkiye
- Hasan ÖZÇELİK - Süleyman Demirel University, Faculty of Science and Literature, Department of Biology, Isparta-Türkiye
- Hasan YILMAZ - Atatürk University, Faculty of Architecture ve Design, Department of Architecture, Erzurum-Türkiye
- Hatice ÇINAR - Selcuk University, Faculty of Architecture and Design, Department of Interior Architecture, Konya-Türkiye
- Hilal KAHVECİ - Bilecik Şeyh Edebali University, Faculty of Fine Arts and Design, Department of Interior Architecture and Environmental Design, Bilecik-Türkiye
- Hilal TUNCER - Mehmet Akif University, Faculty of Engineering-Architecture, Department of Architecture, Burdur- Türkiye
- Hüccet VURAL - Bingol University Faculty of Agriculture, Department of Landscape Architecture, Bingol-Türkiye
- Isidora KARAN - The University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Republic of Srpska, Bosnia, and Herzegovina
- Işıl KAYMAZ - Ankara University, Faculty of Agriculture, Department of Landscape Architecture, Ankara-Türkiye
- İ. Emre KAVUT - Mimar Sinan Fine Arts University, Department of Interior Architecture, Istanbul-- Türkiye
- İlkay Maşat ÖZDEMİR - Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon -Türkiye
- İsmail KILIÇ - Kırklareli University, Faculty of Engineering, Department of Civil Engineering, Kırklareli-Türkiye
- Julide EDİRNE - Haliç University, Faculty of Architecture, Department of Architecture, İstanbul-Türkiye
- Kasım ÇELİK - Çukurova University, Faculty of Architecture, Department of Architecture, Adana-Türkiye
- Koray VELİBEYOĞLU - İzmir Institute of Technology, Faculty of Architecture, Department of City and Regional Planning, İzmir -Türkiye
- Kübra MÜEZZİNOĞLU - Selcuk University, Faculty of Architecture and Design, Department of Interior Architecture, Konya-Türkiye
- Levent ARIDAĞ - Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli, Türkiye
- Leyla KADERLİ - Erciyes University, Faculty of Architecture, Kayseri, Türkiye
- Leyla SURİ - İstanbul Ticaret University, Faculty of Architecture, İstanbuk, Türkiye
- M. Serhat YENİCE - Hasan Kalyoncu University, Faculty of Fine Arts and Architecture, Gaziantep-Türkiye
- Mahmut TUĞLUER - Sütçü İmam University, Faculty of Forestry, Department of Landscape Architecture, Kahramanmaraş-Türkiye
- Mahşid MIKAEILI - Atatürk University, Faculty of Architecture and Design, Department of Architecture, Erzurum-Türkiye
- Mehmet Akif IRMAK - Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, Erzurum-Türkiye

- Mehmet Ali YÜZER - Istanbul Technical University, Faculty of Architecture, Department of City and Regional Planning, Istanbul -Türkiye
- Mehmet Doruk ÖZÜGÜL - Yıldız Technical University, Faculty of Architecture, Department of City and Regional Planning, Istanbul-Türkiye
- Mehmet Fırat BARAN - Siirt University, Faculty of Agriculture, Department of Biosystem Engineering-Siirt-Türkiye
- Mehmet Sinan YUM - Istanbul Commerce University, Faculty of Architecture and Design, Industrial Design Undergraduate Program, Istanbul, Türkiye
- Mehmet TUNCER - Çankaya University, Faculty of Architecture, Department of City and Regional Planning, Çankaya-Türkiye
- Mehmet UĞURYOL - Yıldız Technical University, Faculty of Architecture, Department of Conservation and Restoration of Cultural Heritage, Istanbul-Türkiye
- Melda Açmaz ÖZDEN - Çanakkale Onsekiz Mart University, Faculty of Architecture and Design, Department of City and Regional Planning, Çanakkale-Türkiye
- Melih KURNALI - Konya Technical University, Faculty of Architecture and Design, Department of Interior Architecture, -Türkiye
- Meltem GÜNDOĞDU - Kırklareli University, Faculty of Architecture, Department of Urban and Regional Planning, Kırklareli -Türkiye
- Meltem ÖZÇAKI - Tekirdağ Namık Kemal University, Faculty of Fine Arts, Design and Architecture, Department of Architecture, Tekirdağ-Türkiye
- Merih KASAP - Altınbaş University, Faculty of Engineering and Natural Sciences, Department of Interior Architecture and Environmental Design, İstanbul- Türkiye
- Merve KARAOĞLU CAN - Kütahya Dumlupınar University, Faculty of Architecture, Department of Interior Architecture, Kütahya-Türkiye
- Mete ünal GİRGEN - Final International University, School of Tourism and Culinary Arts, Department of Tourism Management, TRNC
- Metin DEMİR - Atatürk University, Faculty of Architecture ve Design, Department of Architecture, Erzurum-Türkiye
- Mine SUNGUR - Selcuk University, Faculty of Architecture and Design, Department of Interior Architecture, Konya-Türkiye
- Mine Hashas-DEĞERTEKİN - North Carolina State University, Community and Environmental Design Program. USA.
- Mohammad Jafar CHAMANKAR - The Department of History of Urmia University, Iran
- Mohammad WAHEEB - Department of Cultural Resource Management (CRM), Queen Rania Faculty of Tourism and Heritage (QRFTH), The Hashemite University
- Muhammet KURUCU - Fırat University, Faculty of Architecture, Diyarbakır -Türkiye
- Murat DOĞRUYOL - Siirt University, Faculty of Engineering, Department of Civil Engineering, Siirt-Türkiye
- Murat ZENGİN - Pamukkale University, Faculty of Architecture ve Design, Department of Architecture, Denizli-Türkiye
- Mustafa GÜLEN - Van Yüzüncü Yıl University, Faculty of Architecture and Design, Department of Architecture, Van-Türkiye
- Mustava VAR - Yıldız Technical University, Faculty of Architecture, Department of City Regional Planning, İstanbul - Türkiye
- Mustafa KORUMAZ - Konya Technical University, Faculty of Architecture and Design, Department of Architecture, Konya-Türkiye
- Müberra PULATKAN - Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon- Türkiye
- Nafiya GÜDEN - School of Tourism and Culinary Arts, Final International University, Girne -TRNC

- Naif HADDAD - Department of Conservation Science, Queen Rania Faculty of Tourism and Heritage, Hashemite University, Jorda
- Nermeen Adnan DALGAMONİ - Jordan University of Science and Technology, Department of City Planning and Design, Irbid, Jordan
- Neslihan DALKILIÇ - Dicle University, Institute of Science and Technology, Department of Architecture, Diyarbakır-Türkiye
- Neslihan YILDIZ - Istanbul Gedik University Faculty of Fine Arts and Architecture Department of Architecture, Istanbul-Türkiye
- Neşe Yılmaz BAKIR - Erciyes University, Faculty of Architecture, Department of City and Regional Planning, Kayseri -Türkiye
- Nihal Arda AKYILDIZ - Balıkesir University, Faculty of Architecture, Department of Architecture, Balıkesir-Türkiye
- Nilay COŞGUN - Gebze Technical University, Faculty of Architecture, Department of Architecture, Gebze-Türkiye
- Nilgün GÖRER TAMER - Gazi University, Department of City and Regional Planning, Ankara-Türkiye
- Nilüfer KART AKTAŞ - Istanbul University-Cerrahpasa, Faculty of Forest, Department of Landscape Architecture, Istanbul -Türkiye
- Nur BELKAYALI - Kastamonu University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Kastamonu-Türkiye
- Nur ÇAĞLAR - TOBB ETU Faculty of Architecture and Design, Architecture, Ankara- Türkiye
- Nuray BENLİ YILDIZ - Düzce University, Faculty of Art and Design, Department of Architecture, Düzce-Türkiye
- Nurdil ESKİN - Istanbul Technical University, Department of Mechanical Engineering, Istanbul, Türkiye
- Nusret ALGAN - Mersin University Faculty of Fine Arts Ceramics Department, Mersin-Türkiye
- Oğuz KURDOĞLU - Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon -Türkiye
- Oleksandr ZINENKO - V. Karazin Kharkiv National University, Kharkiv, 61022, Ukraine
- Osman ARAYICI - Mimar Sinan Fine Arts University, Department of Interior Architecture, Istanbul-Türkiye
- Osman ATTMANN - The University of Colorado Denver, College of Architecture and Planning, Department of Architecture, Denver-USA
- Ömer Faruk UZUN - Sakarya App. Sciences Univ. Faculty of Agriculture, Department of Landscape Architecture, Sakarya-Türkiye
- Ömer Lütfü ÇORBACI - Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Rize-Türkiye
- Ömer MİMAROĞLU - Istanbul Sabahattin Zaim University Faculty of Engineering and Natural Sciences Department of Architecture, Türkiye
- Önder KÜÇÜKERMAN - Haliç University, Faculty of Architecture, Department of Industrial Design, İstanbul-Türkiye
- Özgü ÖZTURAN - Akdeniz University, Department of Interior Architecture, Antalya-Türkiye
- Özgür YILDIZ - Malatya Turgut Özal University Faculty of Art, Design, and Architecture Department of Architecture, Malatya-Türkiye
- Özlem BOZKURT - Tekirdağ Namık Kemal University, Vocational School of Technical Sciences, Department of Materials and Materials Processing Technologies, Tekirdag-Türkiye
- Özlem SAĞIROĞLU - Gazi University, Faculty of Architecture, Department of Architecture, Ankara-Türkiye
- Pelin ŞAHİN KÖRMEÇLİ - Çankırı Karatekin University, Faculty of Forestry, Department of Landscape Architecture, Çankırı-Türkiye

- Pınar KILIÇ ÖZKAN - İzmir Demokrasi University, Faculty of Architecture, Department of Architecture İzmir -Türkiye
- Pervin YEŞİL - Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
- Piyush SHARMA - Amity University, Hindistan/ Prof. Dr., Amity University, India
- Ruhan Aşkın UZEL - Yasar University, Director of Vocational College, İzmir Türkiye
- Rosa Anna LA ROCCA - The University of Naples Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli, Italy
- Rolando VOLZONE DINÂMIA'CET - iscte | ISCTE-Instituto Universitário de Lisboa, Lisboa, Portugal
- Rüya ARDIÇOĞLU - Firat University, Faculty of Architecture, Department of Architecture, Elazig-Türkiye
- Sadia FAROOQ - University of Home Economics, Lahore, Pakistan
- Salih SALBACAK - Fatih Sultan Mehmet Vakif University, Department of Interior Architecture, Türkiye
- Saliha TAŞÇIOĞLU - Kilis 7 Aralik University Technical Sciences Vocational School Department of Park and Horticulture - Türkiye
- Sara DEMİR - Bursa Technical University, Faculty of Forestry, Department of Landscape Architecture, Bursa -Türkiye
- Seden ACUN ÖZGÜNLER - Istanbul Technical University, Faculty of Architecture, Department of Architecture, Building Science Program, İstanbul-Türkiye
- Seden TURAMBERK ÖZERDEN - Final International University, Girne -TRNC
- Seema Mehra PARIHAR - Department of Geography, Kirori Mal College, University of Delhi, India
- Serap KAYASÜ - Middle East Technical University, Faculty of Architecture, Department of City and Regional Planning Ankara-Türkiye
- Serdar SELİM - Akdeniz University Faculty of Science, Department of Space Science and Technologies, Department of Distance Education, Antalya-Türkiye
- Serdar Oktay - Final International University, School of Tourism and Culinary Arts, Department of Tourism, TRNC
- Serpil ÖNDER - Selçuk University, Faculty of Architecture and Design, Department of Landscape Architecture, Konya-Türkiye
- Shirin IZADPANAH - Antalya Bilim University, Department of Interior Architecture and Environmental Design, Antalya -Türkiye
- Sibel ACAR - TOBB ETU Faculty of Architecture and Design, Architecture, Ankara-Türkiye
- Silvia ROSSETTI - The University of Parma, Department of Engineering and Architecture, Parma Italy
- Sima POUYA - İnönü University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya-Türkiye
- Soad ABOKHAMIS MOUSAVI - Final International University, Faculty of Architecture and Fine Arts, Department of Architecture
- Swetha MADHUSUDANAN - GR University, School of Architecture, Chennai, India
- Şevket ALP - Van Yüzüncü Yıl University, Faculty of Architecture and Design, Department of Landscape Architecture, Van-Türkiye
- Şeyda EMEKCİ - Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Architecture Department, Ankara- Türkiye
- Şirin DÖNMEZ - Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
- Şule KISAKÜREK - Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Department of Landscape Architecture, Kahramanmaraş-Türkiye

- Şükran ŞAHİN - Ankara University, Faculty of Agriculture, Department of Landscape Architecture, Ankara- Türkiye
- Taner ÖZDİL - The University of Texas, College of Architecture, Planning and Landscape Architecture, Arlington-ABD
- Tonguç AKIŞ - İzmir Institute of Technology, Faculty of Architecture, Department of Architecture, İzmir -Türkiye
- Tonguç TOKOL - Marmara University, Department of Interior Architecture, Istanbul-Türkiye
- Tuğba DÜZENLİ - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Umut Tuğlu KARSLI - Istanbul University, Faculty of Architecture, Department of Interior Architecture and Environmental Design, Istanbul -Türkiye
- Ümit YURT - Düzce University, Düzce Vocational School Construction Technology Department, Düzce-Türkiye
- Vagif MEMMEDOV - Baku Engineering University, Baku- Azerbaijan
- Yasin XƏLİLOV - Baku Engineering University, Baku- Azerbaijan
- Yasin ÜNAL - Isparta University of Applied Sciences, Department of Wildlife Ecology and Management, Isparta- Türkiye
- Yenal AKGÜN - Dokuz Eylül University Faculty of Architecture, Department of Architecture, İzmir -Türkiye
- Yılmaz ARI - Bandırma Onyedi Eylül University Faculty of Humanities and Social Sciences, Head of Geography Department, Bandırma/Balıkesir- Türkiye.
- Zeidan KAFAFI - Emeritus of Archaeology of Yarmouk University, Jordan
- Zeliha ŞAHİN ÇAĞLI - Ostim Technical University, Faculty of Architecture and Design, Department of Industrial Design, Ankara-Türkiye
- Zeynep PİRSELİMOĞLU BATMAN - Uludağ University, Faculty of Forestry, Department of Landscape Architecture, Bursa -Türkiye
- Zuhal KAYNAKÇI ELİNÇ - Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya Türkiye

V. International Architectural Sciences Congress

"IArcSC-2025"

October 29-30-31, 2025

https://www.iarcsas.org

Face to face and online

CONGRESS SCHEDULE

Join Zoom Meeting

https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1

Meeting ID: 859 7119 7642
Passcode: 293031

PARTICIPATING COUNTRIES (17)

Algeria, Azerbaijan, Bangladesh, Ethiopia, Italy, Iran, India, Malaysia, Moldova, Morocco, Nigeria, Northern Cyprus, Pakistan, Poland, Romania, Türkiye, Ukraine

TOTAL ACCEPTED ARTICLES: 265

Türkiye: 119
Other Countries: 146

Congress General Program Framework

October 29, 2025 (Wednesday)

Join Zoom Meeting

https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1

Meeting ID: 859 7119 7642

Passcode: 293031

	OPENING SPEECHES (Demre Municipality Cultural Center Conference Hall) Demre Belediyesi Kültür Merkezi Konferans Salonu
Antalya (Demre)-Türkiye Time 12:00-13:00	Prof. Dr. Atila GÜL Dr. Mustafa Latif EMEK Prof. Dr. Nevzat ÇEVİK Assist. Prof. Dr. Ahmet FİDAN Prof. Dr. Öner DEMİREL Fahri DURAN Emin BAĞLI Ertuğrul GÜNAY

12:30- 12:50	Presentation of Plaques (Plaket Takdimi)

Antalya (Demre)-Türkiye Time 14:00-16:00	**PANEL** *Sustainable and Resilient City Strategies in the Climate Change Adaptation Process in Demre* *(Demre Özelinde İklim Değişikliği Uyum Sürecinde Sürdürülebilir ve Dirençli Kent Stratejileri)*			
	(Face to Face and Online) Congress Venue: Demre Municipality Cultural Center Conference Hall, Demre Antalya (Demre Belediyesi Kültür Merkezi Konferans Salonu)			
Moderator	Prof. Dr. Şule ORMAN			
Invited Speakers	Prof. Dr. Kağan GÜNÇE	Prof. Dr. Atila GÜL	Prof. Dr. Nihat DİPOVA	İbrahim IRMAK
16:00-16:15 Tea Break				

October 30, 2025 (Thursday)
(Face to Face)

Congress Venue:

Mediterranean Fisheries Research, Production and Training Institute Directorate Demre Training Centre-Demre, Antalya

(Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezi- Demre, Antalya)

Antalya (Demre)-Türkiye Time	Face to Face SESSIONS October 30, 2025 (Thursday)		
9:00-10:45	SESSION 1 (LİKYA HALL)	SESSION 2 (MYRA HALL)	SESSION 3 (KEKOVA HALL)
Moderators	Öner Demirel	Şirin Gülcen Eren	Murat Akten
11:00-12:45	SESSION 4 (LİKYA HALL)	SESSION 5 (MYRA HALL)	SESSION 6 (KEKOVA HALL)
Moderators	Berrin Şahin Diri	Ufuk Coşgun	Ahmet Fidan
13:00-14:00	Lunch (Öğle Yemeği)		

October 31, 2025 (Friday) (Online)

Join Zoom Meeting

https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1

Meeting ID: 859 7119 7642

Passcode: 293031

Antalya (Demre)-Türkiye Time	SESSION 7 (Online)	SESSION 8 (Online)	SESSION 9 (Online)	SESSION 10 (Online)	SESSION-11 (Online)	SESSION 12 (Online)
9:00-10:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Ertan Düzgüneş	Ümit Turgay Arpacıoğlu	Gizem Dinç	Aissam Gaagai	Moses Adeolu Agoi	Bhawana Pal
Antalya (Demre)-Türkiye Time	SESSION 13 (Online)	SESSION 14 (Online)	SESSION 15 (Online)	SESSION 16 (Online)	SESSION-17 (Online)	SESSION 18 (Online)
11:00-12:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Dr. Feran Aşur	Hayriye Hale Kozlu	Asena Soyluk	Hachimi Dahhaoui	Marcelina Krupa-Małkiewicz	N.G. Kalyan Reddy
Antalya (Demre)-Türkiye Time	SESSION 19 (Online)	SESSION 20 (Online)	SESSION 21 (Online)	SESSION 22 (Online)	SESSION 23 (Online)	SESSION 24 (Online)
13:00-14:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Banu Çiçek Kurdoğlu	Elif Sağlık	M. Bihter Bingül Bulut	B. Mahadevan	Aicha Belgacem	Melik Sami
Antalya (Demre)-Türkiye Time	SESSION 25 (Online)	SESSION 26 (Online)	SESSION 27 (Online)	SESSION 28 (Online)	SESSION-29 (Online)	SESSION 30 (Online)
15:00-16:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Sevgi Yılmaz	Aybike Ayfer Karadağ	Melik Sami	Popescu Gh. Cristina Raluca	Sándor Földvári	Kazem Golizadeh
Antalya (Demre)-Türkiye Time	SESSION 31 (Online)	SESSION 32 (Online)	SESSION 33 (Online)	SESSION 34 (Online)	SESSION-35 (Online)	SESSION 36 (Online)
17:00-18:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Floriana Zucaro	Soad Abokhamis Mousavi	Sultan Sevinc Kurt Konakoğlu	M. Fathrezza Imani	Laura Diaconu (Maxim)	Aliyu Hashimu Isah
Antalya (Demre)-Türkiye Time	SESSION 37 (Online)	SESSION 38 (Online)	SESSION 39 (Online)	SESSION 40 (Online)	SESSION 41 (Online)	SESSION 42 (Online)
19:00-20:45	HALL-1	HALL-2	HALL-3	HALL-4	HALL-5	HALL-6
Moderators	Neriman Gül Çelebi	Ahmet Benliay	S. Shakthi Sree	Ananda Majumdar	Maryam Moslehi	Subhashish Dey

IMPORTANT

- To be able to make a meeting online, log in via **https://zoom.us/join** site, enter ID instead of "Meeting ID or Personal link Name'' and solidify the session.
- **Each presentation is limited to a maximum of 15 minutes.**
- **Session times should never be exceeded. It must be completed on time before the next session starts.**
- **Presentations can be presented in "English or Turkish". However, visual presentations must be "English text".**
- The Zoom application is free and no need to create an account.
- The Zoom application can be used without registration.
- The application works on tablets, phones, and PCs.
- Speakers must be connected to the session **15 minutes before** the presentation time.
- All Symposium participants can connect live and listen to all sessions.
- During the session, your camera should be turned on at least %70 of the session period
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

TECHNICAL INFORMATION

- Make sure your computer has a microphone and is working.
- You should be able to use the screen sharing feature in Zoom.
- Attendance certificates will be sent to you as a pdf at the end of the Symposium.

Before you, log in to Zoom indicate Session and Hall number and your surname
(SESSION 1-HALL-1, XXXX)

Important Notice:

• The Protocol Opening and Panel event on October 29, 2025, in the Congress Program will take place at the Demre Municipality Culture Center Conference Hall.

•The in-face to face sessions of the Congress (October 31, 2025) will be held at the accommodation venue, the Mediterranean Fisheries Research, Production, and Education Institute Directorate Demre Education Center (Demre, Antalya).

ÖNEMLİ

- Sempozyumda Yazım Kurallarına uygun gönderilmiş ve bilim kurulundan geçen bildiriler için online (video konferans sistemi üzerinden) sunum imkanı sağlanmıştır.
- Online sunum yapabilmek için **https://zoom.us/join** sitesi üzerinden giriş yaparak "Meeting ID or Personal Link Name" yerine ID numarasını girerek oturuma katılabilirsiniz.
- **Her bir sunum en fazla 15 dakika ile sınırlandırılmıştır.**
- **Oturum süreleri kesinlikle aşılmamalıdır. Bir sonraki oturum başlamadan önce zamanında tamamlanmalıdır.**
- **Sunumlar "İngilizce veya Türkçe" sunulabilir. Ancak görsel sunumlar mutlaka "İngilizce metin" olmalıdır.**
- Zoom uygulaması ücretsizdir ve hesap oluşturmaya gerek yoktur.
- Zoom uygulaması kaydolmadan kullanılabilir.
- Uygulama tablet, telefon ve PC'lerde çalışmaktadır.
- Sunum yapacakların sunum saatinden **15 dk önce** oturuma bağlanmış olmaları gerekmektedir.
- Tüm katılımcılar oturumlara online katılıp dinleyebilir.
- Oturumdaki sunumlardan ve bilimsel tartışmalardan (soru-cevap) oturum başkanları sorumludur.

TEKNİK BİLGİLER

- Bilgisayarınızda çalışır durumda mikrofon bulunmalıdır.
- Zoom'da ekran paylaşma özelliği kullanılabilmelidir.
- Katılım belgeleri Sempozyum sonunda tarafınıza pdf olarak gönderilecektir.
- Sempozyum programında yer ve saat değişikliği gibi talepler dikkate alınmayacaktır.

Zoom'a girişte sırayla Oturum ve Salon numarasını ve Soyadınızı yazınız
(OTURUM 1-SALON-1, XXXXX)

Önemli Açıklama:

- **Kongre Programındaki 29 Ekim 2025 tarihindeki Protokol Açılışı ve Panel etkinliği Demre Belediyesi Kültür Merkezi Konferans Salonunda gerçekleşecektir.**
- **Kongrenin Yüzyüze Oturumları ise Konaklama yeri olan Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezinde (Demre, Antalya) gerçekleştirilecektir.**

OPENING SPEECHES

Date: October 29, 2025

Antalya (Demre)-Türkiye Time: 11:30 -12:30

Face to Face and Online

Join Zoom Meeting
https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1
Meeting ID: 859 7119 7642
Passcode: 293031

Congress Venue:

Demre Municipality Cultural Center Conference Hall, Demre Antalya
(Demre Belediyesi Kültür Merkezi Konferans Salonu)

	SPEAKERS	AFFILIATION
Antalya (Demre)-Türkiye Time 11:30-12:30	Prof. Dr. Atila GÜL	*President of the Organizing Board (IArcSC-2025) and Chief Editor, Journal of Architectural Sciences and Applications, Isparta-Türkiye*
	Dr. Mustafa Latif EMEK	*President of the Economic Development and Social Research Association (IKSAD), Türkiye*
	Prof. Dr. Nevzat ÇEVİK	*Akdeniz University Department of Archaeology Antalya, Türkiye and Director of Excavations at the Ancient City of Myra*
	Assist. Prof. Dr. Ahmet FİDAN	*Chairman of Federation of Culture-Art, Research, Nature and Environment Associations (KADOÇED) Ordu-Türkiye*
	Prof. Dr. Öner DEMİREL	*Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye*
	Fahri DURAN	*Mayor of Demre Municipality, Demre, Türkiye*
	Emin BAĞLI	*Demre District Governor, Demre Türkiye*
	Ertuğrul GÜNAY	*Former Minister of Culture and Tourism of Türkiye*
12:30- 12:50	Presentation of Plaques (Plaket Takdimi)	

Invited Speakers for IArcSC- 2025 PANEL

***October* 29, 2025 (Wednesday) Antalya Time: 14:00 -16:00**

Sustainable and Resilient City Strategies in the Climate Change Adaptation Process in Demre

(Demre Özelinde İklim Değişikliği Uyum Sürecinde Sürdürülebilir ve Dirençli Kent Stratejileri)

Join Zoom Meeting
https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1
Meeting ID: 859 7119 7642, Passcode: 293031
Congress Venue:
Demre Municipality Cultural Center Conference Hall, Demre Antalya
(Demre Belediyesi Kültür Merkezi Konferans Salonu)



Moderator

Prof. Dr. Şule ORMAN
(Director of Demre Dr. Hasan Ünal Vocational School in Akdeniz University)

			
Prof. Dr. Kağan GÜNÇE	**Prof. Dr. Atila GÜL**	**Prof. Dr. Nihat DİPOVA**	**İbrahim IRMAK**
Sürdürülebilir Kalkınma Hedefleri Çerçevesinde Dirençli Kentlerin Tasarımında Mimarlığın Rolü	**Demre Kentsel Yeşil Alanların İklim Değişikliği Uyum Sürecindeki Önemi ve Stratejik Eylemler**	**Demre ve Civarının Deprem Tehlikesi: Ne Yapmalı? Nasıl Yapmalı?**	**Demre'de Tuzluluk ve Su Krizi**
The Role of Architecture in Designing Resilient Cities within the Framework of Sustainable Development Goals	**The Importance of Urban Green Areas in Demre (Antalya) in the Climate Change Adaptation Process, and Strategic Actions**	**Earthquake Risk in Demre and Surrounding Areas: What to Do? How to Do It?**	**Salinity and Water Crisis in Demre**
Eastern Mediterranean University, Faculty of Architecture, Famagusta/North Cyprus.	Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta Türkiye	Akdeniz University Faculty of Engineering, Department of Civil Engineering, Türkiye	Antalya Provincial Directorate of Agriculture and Forestry, Head of Coordination and Agricultural Data Department, Türkiye

FACE TO FACE SESSIONS

October 30, 2025 (Thursday)

Congress Venue: Mediterranean Fisheries Research, Production and Training Institute Directorate Demre Training Centre- Demre, Antalya
(Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezi- Demre, Antalya)

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time: 9:00-10:45 (Face to Face)		
SESSION-1, LİKYA HALL / OTURUM-1, LİKYA SALONU • MODERATOR: Prof. Dr. Öner DEMİREL		
TITLE	**AUTHORS**	**AFFILIATION**
Development of Hospital Garden Design	• Melike Sağlam • Sima Pouya	Inonu University, Türkiye
Expert Opinions and Evaluation Within the Scope of Urban Forest Management	• Öner Demirel • Bilgenur Ak • Meryem Bihter Bingül Bulut	Kırıkkale University, Kırıkkale-Türkiye
Current Status and Analysis of Demre (Antalya) Urban Green Areas	• Atila Gül • Sibel Akten • Hüseyin Batuhan Dündar • Çağrı Yoluk	Süleyman Demirel University, Türkiye Isparta University of Applied Sciences, Türkiye Director of Parks and Gardens at Demre Municipality Demre, Antalya, Türkiye
Acoustic Identity in Cultural Landscapes: Local Sounds, Memories, and Spatial Attachment	• Sıla Günaçan Odabaşı • Ebru Erbaş Gürler	Istanbul Medipol University, Türkiye
	•	
	•	

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time 9:00-10:45 (Face to Face)		
SESSION-2, MYRA HALL / OTURUM-2, MYRA SALONU MODERATOR: Assoc. Prof. Dr. Şirin Gülcen Eren		
TITLE	**AUTHORS**	**AFFILIATION**
Reimagining the City: Utopian and Dystopian Perspectives in Contemporary Urban Planning	• Mehmet Can Akdağ • Şirin Gülcen Eren	Süleyman Demirel University, Türkiye
An Evaluation of The Conservation Hıstory, Archaeological Findings, and The "Heritage For The Future" Project of The Church of St. Nicholas	• Ebru Fatma Findik	Hatay Mustafa Kemal University, Türkiye
Analysis of the Relationship Between Perception, Experience, Image, and Memory in the Context of Fictional Spaces in the Film "Room"	• Esra Tokuç • Serhat Anıktar	İstanbul Sabahattin Zaim University, Türkiye
Mobility As Cultural Heritage: Rethinking Yörük Settlements Through Spatial Practices	• Uğur Efe Uçar • Ethem Gürer	Istanbul Technical University, Türkiye
Forms of Influence of Financial Infrastructure on Entrepreneurship in The Republic of Azerbaijan	• Vuqar Nazarov	Azerbaijan University of Tourism and Management
	•	

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time 9:00-10:45 (Face to Face) SESSION-2,KEKOVA HALL / OTURUM-3, KEKOVA SALONU MODERATOR: Prof. Dr. Murat Akten		
TITLE	**AUTHORS**	**AFFILIATION**
Integration of Eye Tracking Technology Into the Urban Green Space Planning	• Murat Yeşil • Mesut Güzel • Rabia Nurefşan Açıkgözü • Eda ŞentürK	Ordu University, Türkiye
Voicenote: Mobile App for Taking Voice and Written Notes	• Ceydanur Duman, • Büşra Takgil	Düzce University, Türkiye
Iot and Mobile Application Based Smart Environment Monitoring and Drug Deterioration Prediction System Design	• Bedirhan Korkmaz, • Büşra Takgil	Düzce University, Türkiye
Enhancing Urban Microclimate Through a Digital Twin–Based Approach: The Case Study of Kaymakkapı Square, Isparta	• Aslı İlayda Koçak • Murat Akten	Süleyman Demirel University, Türkiye
Thematic Review of Machine Learning Methods in Landscape Planning Processes	• Aslı İlayda Koçak • Murat Akten	Süleyman Demirel University, Türkiye
HVAC Condensate Landscape Applications and Water–Energy–Carbon Impacts	• Buğrahan Çetinkaya • Murat Akten	Süleyman Demirel University, Türkiye

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Face to Face)		
SESSION-4, LİKYA Hall / OTURUM-4, LİKYA SALON MODERATOR: Assoc. Prof. Dr. Berrin Şahin Diri		
TITLE	**AUTHORS**	**AFFILIATION**
The Lifecycle Assessment Analysis: Recycled Concrete Aggregate Incorporating Boron	• Seda Nur Alkan • Gamze Doğdu Yücetürk • Özkan Şengül	İstanbul Medipol University, Türkiye Bolu Abant İzzet Baysal University, Türkiye İstanbul Technical University, Türkiye
Comparison of Survey Results on the Use of External Wall Filling Materials and the Usage Trends of These Materials in the Construction Sector in Türkiye	• Berrin Şahin Diri • Ahmet Cüneyd Diri	Mimar Sinan Fine Arts University, Türkiye
Innovations Brought by 3D Printing Technology to Concrete Element Production	• Berrin Şahin Diri	Mimar Sinan Fine Arts University, Türkiye
From Cognitive Tool to Pedagogical Assistant: Rethinking AI in Interior Design Education Through Student Insights	• Gözde Gökdemir • Hande Zeynep Kayan	Istanbul Technical University, Türkiye
An Investigation into the Potential of Artificial Intelligence Applications in Low Earth Orbit Satellite Systems for Urban Planning Applications	• Elif Eda Takgil • Ali Çalhan • Murtaza Cicioğlu	Düzce University, Türkiye
Rainwater Design and Management in Housing Estate Gardens	• Melisa Eken • Irem Kaya • Ece Yıldız • Hatice Ada	Süleyman Demirel University, Türkiye

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Face to Face)		
SESSION-5, MYRA HALL / OTURUM-5, MYRA SALONU MODERATOR: Prof. Dr. Ufuk Coşgun		
TITLE	**AUTHORS**	**AFFILIATION**
Principles and Guidelines for Planning Restoration in Forest Fire-Affected Areas	• Ufuk Coşgun • Sohaib K M Abujayyab	Karabük University, Türkiye
Child-Friendly Street Designs in Urban Areas	• Habibe Atak • Gülbin Çetinkale Demirkan	Niğde Ömer Halisdemir Üniversitesi, Türkiye
Therapeutic Garden Designs as Support in Oncology Hospitals	• İpek İpekli • Gülbin Çetinkale Demirkan	Niğde Ömer Halisdemir Üniversitesi, Türkiye
A Sustainable Development Allegory: Entelköy Efeköy'e Karşı and SDGS	• Pınar Zeğerek Altunbey	Nigde Omer Halisdemir University, Türkiye
Effects of Climate Change on the Physiology of Ornamental Plants	• Bahar Sancar	Düzce University, Türkiye
Stress Tolerance in Ornamental Plants	• Bahar Sancar	Düzce University, Türkiye

THURSDAY – October 30, 2025 Antalya (Demre)-Türkiye Time 11:00-13:00 (Face to Face)		
SESSION-6, KEKOVA HALL / OTURUM-6, KEKOVA SALON • MODERATOR: Assist Prof. Dr. Ahmet Fidan		
TITLE	**AUTHORS**	**AFFILIATION**
Classification of Kinetic Building Components in Contemporary Architecture	• Hatice Eda Gül • Nazire Tuğçe Yenice • Yenal Akgün	Dokuz Eylül University, Türkiye
The Assessment of Key Factors Sustainable Smart Cities	• Ahmet Fidan • Esra Bayır • Pelin Karaçar • Aysun Ferrah Güner	Ordu University, Türkiye İstanbul Medipol University, Türkiye
Spatial Distributions of Land Use/Land Cover (LULC) in the Demre Stream Corridor: Assessment of Current Issue	• Hüseyin Batuhan Dündar • Atila Gül • Sibel Akten	Süleyman Demirel University, Türkiye Isparta University of Applied Sciences, Türkiye
Determining Route Selection Criteria for the Creation of a Bicycle Route in the Context of Diversifying Cultural Tourism	• Sibel Akten • Atila Gül • Hüseyin Batuhan Dündar	Isparta University of Applied Sciences, Türkiye Süleyman Demirel University, Türkiye
Examining Secondary School Landscape Spaces from a Design Perspective in the Climate Change Adaptation Process	• Sibel Akten • Atila Gül	Isparta University of Applied Sciences, Türkiye Süleyman Demirel University, Türkiye
Reflections of the Bauhaus Approach to Materials in Modern and Contemporary Architecture	• İskender Emre Gül • Şebnem Ertaş Beşir	Akdeniz University, Türkiye
An Evaluation of The Restoratıon of Seyh Mehmet Emin Efendi Lodge to Create An Effective Protection-Use Balance by Re-Functioning	• Eyüp Salih Elmas	Ministry of Environment, Urbanization and Climate Change, Istanbul Provincial Directorate, Istanbul-Türkiye

ONLINE SESSIONS

October 31, 2025 (Friday)

Join Zoom Meeting

https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1

Meeting ID: 859 7119 7642
Passcode: 293031

FRIDAY–October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-7, HALL-1 / OTURUM 7, SALON-1 • MODERATOR: Prof. Dr. Ertan Düzgüneş		
TITLE	**AUTHORS**	**AFFILIATION**
Local Implementation Challenges of Sustainable Campus Certification Systems: A Critical Analysis in the Context of Turkey	• Ertan Düzgüneş • Beyzanur Akkuş	Karadeniz Technical University, Türkiye
Rural Decline and Revival: Alternative Living Models for the Revitalisation of Migration-Affected Settlements	• Melike Aksakal • Büşra Yılmaz Erdoğan	KTO Karatay University, Türkiye
From Cultural Memory to Contemporary Design: Traces of Nomadic Structures in Sustainability	• Rümeysa Üzüm • Büşra Yılmaz Erdoğan	KTO Karatay University, Türkiye
Reflections of Designer Identity on Architecture: Analyses on Peter Zumthor and Kengo Kuma	• Pınar Taslı • Hare Kılıçaslan	Karadeniz Technical University, Türkiye
Spatial and User-Centered Evaluation of The Main Entrance at Karadeniz Technical University Department of Architecture	• Sevde Dinçer • Hare Kılıçaslan	Karadeniz Technical University, Türkiye
Marine Protected Areas and Protection Strategies	• Ertan Düzgüneş • Duygu Karabıçak Günaydın	Karadeniz Technical University, Türkiye Nevşehir Hacı Bektaş Veli University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-8, HALL-2 / OTURUM 8, SALON-2 • MODERATOR: Prof. Dr. Ümit Turgay Arpacıoğlu		
TITLE	**AUTHORS**	**AFFILIATION**
Development of Lignin-Modified Phenol-Formaldehyde Resins: Sustainability Effect in The Furniture Industry	• Fatma Pınar Senkon, • Busra Şimşek, • Franz Zeppetzauer, • Birgit Kamm, • Arif Akıllılar	Tosunogullari Furniture Industry and Trade Inc., Department of R&D, Konya-Türkiye Necmettin Erbakan University, Türkiye Kompetenzzentrum Holz GmbH- Wood K plus, Linz, Austria
A Study on The Use of Parametric Design Tools in Architectural Education	• Berfin Yılmaz • Ümit Arpacıoğlu	Istanbul Aydın University, Türkiye Mimar Sinan Fine Arts University, Türkiye
An Examination of Lighting Use in Exhibition Spaces Within the Context of Refunctioned Museum Buildings Through Sample Studies	• Kübra Civelek Kalınca • Menşure Kübra Müezzinoğlu	Firat University, Türkiye
The Impact of the White Cube Paradigm on Interior Design in Contemporary Art Museums: A Comparative Analysis of İstanbul Modern and New York Moma	• Sena Yılmaz • Menşure Kübra Müezzinoğlu	Firat University, Türkiye
Investigating The Effects of Transport Factor on Structural Systems' Life Cycle Environmental Performance	• Neriman Gül Çelebi • Ümit Arpacıoğlu	Mimar Sinan Fine Arts University, Türkiye
The Effects of Material on Spatial Atmosphere in Architectural Design Approaches Adopting a Minimalist Attitude	• İremnur Muslu • Ümit Turgay Arpacıoğlu	Mimar Sinan Fine Arts University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-9, HALL-3 / OTURUM 9, SALON-3 •MODERATOR: Assist Prof. Dr. Gizem Dinç		
TITLE	**AUTHORS**	**AFFILIATION**
Architectural Creativity Through Generative Ai: Evaluating Dall·E, Midjourney, And Stable Diffusion	•Minel Kurtuluş	Istanbul Gelisim University, Türkiye
The Impact of Flexible Classrooms on Learning in Scandinavian Schools from an Ant Perspective	•Nihansu Kücü •Sıdıka Benan Çelikel • Şebnem Ertaş Beşir	Akdeniz University, Türkiye
The Impact of Female Patrons on Urban Form in the Principalities and Ottoman Periods: The Manisa Example	•Yağmur Burcu Güneş •Şebnem Çakaloğulları	Izmir Democracy University, Türkiye Manisa Celal Bayar University, Türkiye
An Examination of Post-Disaster Housing Design in The Context of Regional and Climatic Adaptation	•Emine Şeyma Erkan •Nilay Coşgun •Elif Özer Yüksel	Istanbul Rumeli University, Türkiye Gebze Technical University, Türkiye
Adaptive Reuse of Dead Malls Into Healthcare Facilities	•Dilara Berk Coşkun •Kunter Manisa	Yildiz Technical University, Türkiye
Cappadocia of Traces: Temporary and Permanent Layers	•Emine Akcan Şirin	İstanbul Ticaret University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-10, HALL-4 / OTURUM 10, SALON-4 **MODERATOR: Aissam Gaagai**		
TITLE	**AUTHORS**	**AFFILIATION**
From Farm to Cup: The Interplay of Sustainability and Governance in Ethiopia's Coffee Value Chain for Sustainable Development	• Sintayehu Assefa Yirga	Hawassa University, Ethiopia
Utilizing Recycled Aggregate Concrete	• ChayarajuBalaSai • Nadagouda Kalyani • K.Tharani	G. Pulla Reddy Engineering
Perceived Effects of Fuelwood Energy Exploitation on Livelihood of Farming Households in Bauchi and Gombe States, Nigeria	• Sani Madi Yakubutate • Hannatu Ohunene Yusuf • Fadlullah Olayiwola Issa • Omadachi Ogbodo Ugbabe	Federal College of Horticulture Dadin Kowa, Gombe State Ahmadu Bello University Zaria, Kaduna State
Integration of Green Jobs in Architectural Carpentry and Joinery Practices for a Sustainable Environment in Gombe State	• Dr. Sale, • Nimrod Kamo • Yakubu Molta Nitte, • Bala Japhet Amatiga	Federal College Of Education, Gidan-Madi, Sokoto State
Threads of Escape: Adaptive Reuse of Trains	• Hira Zaina • Rimsha Imran • Maha Tariq	Hira Zainab Interior Designer Lahore College for Women University, Lahore, Pakistan
Problem of the Quality of Groundwater from Doucen Plain Intended for Irrigation and Its Assessment	• Aissam Gaagai, • Mallem Salah Eddine, • Ali Athamna, • Kebaili Feriel Kheira, • Ridha Lahkel, • Aouissi Hani Amir	Scientific and Technical Research Center on Arid Regions (CRSTRA), Algeria University of Batna 2, 05078 Fesdis, Algeria. Badji Mokhtar Annaba University, Algeria
Computer Solution to Replacement Models for Items that Fails Suddenly	• Alfa Mohammed, Abdulrahman Mohammed Saba	Federal Polytechnic Bida, Nigeria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-11, HALL-5/ OTURUM 11 SALON-5 MODERATOR: Moses Adeolu Agoi		
TITLE	**AUTHORS**	**AFFILIATION**
Dam Failure Mechanisms and Risk Assessment	• Aissam Gaagai, • Mallem Salah Eddine, • Ali Athamna, • Kebaili Feriel Kheira, • Ridha Lakhel, • Aouissi Hani Amir	Scientific and Technical Research Center on Arid Regions (CRSTRA), Algeria University of Batna 2, 05078 Fesdis, Algeria. Badji Mokhtar Annaba University, Algeria
Smart Fabrıcatıon and Automated Buıldıng Technologies	• Kishore R, • Vaishnavi. K, • Keerthana. V, • Meenatchi. S, • Dr. Saravanan	Bharath Institute of Higher Education and Research, India
Quantitative Effects of Soft Skills on Project Success: Evidence from Construction Practitioners in Nigeria	• Greg Odee Ikwe	Bingham University, Nigeria
Emerging AI Regimes and Contemporary Filmmaking in Nigeria: Governance, Practice, and Creative Futures	• Rotimi-Williams Bello	University of Africa, Nigeria
Cybersecurity Rısks In Smart Building Infrastructure	• Moses Adeolu Agoı • Samuel Olayiwola Ajaga • David Oladimeji Ajıbode • Oluwanifemi Opeyemi Agoı	Lagos State University of Education, Lagos Nigeria.
Integration of Informal Interactive Space in a Design of Faculty of Architecture	• Muhammed Abdullahi Adoku	Federal University of Technology Minna, Nigeria
Assessment of Aquifer Protective Capacity and Corrosivity Around Solid Waste Dumpsites in Parts of Minna Metropolis, North-Central, Nigeria	• Balarabe J.J., • Rafiu A.A., • Adetona A., • Shehu J., • Salihu, Y.L.	Federal University of Technology Minna, Niger State, Nigeria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 09:00-10:45 (Online)		
SESSION-12, HALL-6/ OTURUM 12 SALON-6 MODERATOR: Dr. Bhawana Pal		
TITLE	**AUTHORS**	**AFFILIATION**
On The Influence of the Number and Location of Elliptical İnclusions on the Deformation Process of a Cylindrical Shell With a Circular Hole	• Eteri Hart • Oleksandr Shebanov	Oles Honchar Dnipro National University, Dnipro, Ukraine
A Holistic Conceptual Framework for Biophilic Design in Healthcare Environments: Enhancing Elderly Well-Being Through Environmental Integration	• Aylar Ranjbarian, • Mehrdad Karimimoshaver	Bu-Ali Sina University, Hamedan, Iran
Integrating Spatial and Environmental Needs in Architectural Education Design	• A.J. Simon, • D. O Alonge, • E. Udoko	Federal University of Technology, Minna, Nigeria
Sick Building Syndrome and Toxıcological Assessment of Constructıon Materials Among Workers and Residents in Dutse Metropolıs, Jıgawa State, Nigeria	• Bate Garba Barde	Federal University Dutse, Jigawa State, Nigeria
Contribution of Rural Infrastructure Development Fund (RIDF) in rural prosperity in India	• Bhawana Pal	Bankers Institute of Rural Development, Kolkatai India
Effect of Green Wall on Residential Property Values in Ibadan, Nigeria	• Nnaemeka Bethel Ezeokoli, • Ayooluwa Adeboye Adelakun • Dorcas Popoola	Federal University of Technology Akure, Nigeria
The Role of Artificial Intelligence in Creating Public Value in Local Government: Evidence from Hyderabad City, Pakistan	• Dr. Liaquat Ali Rahoo • Dr. Muhammad Nawaz Tunio	Mehran University of Engineering and Technology, Jamshoro University of Sufism and Modern Sciences, Bhitshah

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-13, HALL-1 / OTURUM 13, SALON-1 MODERATOR: Assoc. Prof. Dr. Feran Aşur		
TITLE	**AUTHORS**	**AFFILIATION**
In Search of Thermal Comfort: Forgotten Design and Planning Principles for Cities	• Nursevil Yuca • Feran Aşur	Van Yüzüncü Yil University, Türkiye
Climate-Concerned Urban Furniture in the Urban Landscape	• Feran Aşur • Nursevil Yuca	Van Yuzuncu Yil University, Türkiye
Comparative Performance of Adaptive Façade Systems in Different Climate Types: An Evaluation of Three Buildings	• Esra Nur Arvas • Ümit Turgay Arpacıoğlu	Mimar Sinan Fine Arts University, Turkey
Reclaiming Urban Squares: A Citizen-Centered Assessment of Aliağa Democracy Square in İzmir	• Pelin Özden	İzmir Kavram Vocational School, Türkiye
The Role of Light Shelf Systems in Architectural Design: An Examination in The Context of Visual Comfort and Energy Efficiency	• Sümeyra Akgün • Ümit Arpacıoğlu	Altınbas University, Türkiye Mimar Sinan Fine Arts University, Türkiye
Sinan & Zaha: Shaping the Urban Skyline Through the “Art of Structure & Geometry”	• Ürün Biçer • Serkan Yaşar Erdinç	İstanbul Beykent University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-14, HALL-2 / OTURUM 14, SALON-2 • MODERATOR: Assoc. Prof. Dr. Hayriye Hale Kozlu		
TITLE	**AUTHORS**	**AFFILIATION**
Technical Contributions of Civil Engineering in the Intervention Processes for the Conservation of Historical and Cultural Heritage and the Comparative Analysis of the Role of Related Courses in Architectural Graduate Programs	• Pınar Arık • Hayriye Hale Kozlu	Erciyes University, Türkiye
Daylight Usage in Architectural Structure	• Zübeyde Çiçek • Halil Sevim	KTO Karatay University, Türkiye
Assessing Soundscape Quality in Urban Open and Green Spaces	• Gizem Delikan • Sima PouyA	Inönü University, Türkiye
Human-Centered Approaches to Educational Furniture Design: Ergonomic Analysis of Classroom Desks	• Emre Ecevit • Merve Bilgen Işik	Kayseri University, Türkiye
The Role of Streets and Avenues in The Formation of City Identity; Gaziantep Karagöz Street	• Ebru Begün Saçıkara • Meltem Barış Ararat	Hasan Kalyoncu University, Türkiye
Timber Decay in Gaziköy Houses and The Sustainability of the Rural Fabric	• Özlem Bozkurt	Tekirdağ Namık Kemal University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-15, HALL-3 / OTURUM 15, SALON-3 • MODERATOR: Prof. Dr. Asena Soyluk		
TITLE	**AUTHORS**	**AFFILIATION**
An Experience-Based Mapping of The Samsun City-Center	• Hande Asar	Ondokuz Mayıs University, Türkiye
A Discussion on the Spatial Atmosphere: The Example of Samsun Süleyman Pasha Madrasah	• Hande Asar	Ondokuz Mayıs University, Türkiye
Comparative Assessment of Simulation Tools in The Scope of Indoor Air Quality	• Rana Kibaroğlu Kantarcı • Elif Özer Yüksel	Gebze Technical University, Kocaeli-Türkiye
An Examination at the Intersection of Cinema and Architecture: The Rings of Power - The Land of Numenor	• Tolgay İnanç • Halil Sevim	KTO Karatay University, Konya- Türkiye
Digitalization of Sustainability in Steel Structure Design Projects	• Esin Şahin • Kerim Koç	Yildiz Technical University, Turkey
Evaluation of Room Acoustics in Auditoriums in the Context of Speech Intelligibility: An Examination of a University Auditorium	• Okan Şimşek	Adana Alparslan Türkeş Science and Technology University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-16, HALL-4/ OTURUM 16, SALON-4 **MODERATOR: Hachimi Dahhaoui**		
TITLE	**AUTHORS**	**AFFILIATION**
Photoresponsive Behavior of N-Acylhydrazones: A Study of Solvent-Dependent E/Z Isomerization	• Yahya Boubekri, • Siham Slassi, • Mohammed Aarjane, • Amina Amine	Université Moulay Ismail, Faculté des Sciences –Meknès, Maroc. University Hassan II of Casablanca, Casablanca, Morocco Hassan II University, Casablanca, Morocco
Integrating Sustainable Construction Practices Into Building Design Without Compromising Cost and Quality	• Amusan Timothy Oladele	Joseph Ayo Babalola University, Ikeji-Arakeji, Osun State, Nigeria
Cost And Risk Management in Ukrainian Construction Projects Through International Project Management Standards	• Volodymyr Meshcheriakov • Anastasiia Chornonoh	State Biotechnological University, Ukraine
Public Squares Along Didouche Mourad Street In Skikda: Urban Continuities and Transformations	• Boukerma Rima • Mansouri Lamia • Bouaroudj Radia • Mekki Sana • Azzam Roufaida	University of Algiers 1 Benyoucef Benkhedda
Choosing A Slope-Stability Method Under Groundwater Conditions: A Decision-Oriented Reframing of an Inter-Software Comparison	• Hachimi Dahhaoui, • Abdeldjalil Zadjaoui, • Mohammed Bekhti, • Naima Belkadi	University of Tlemcen, Algeria
Rapid Estimation of Secondary Creep in Soft Clays Using Machine Learning	• Hachimi Dahhaoui	University of Tlemcen, Algeria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-17, HALL-5 / OTURUM 17, SALON-5 • **MODERATOR: Assoc Prof. Marcelina Krupa-Małkiewicz**		
TITLE	**AUTHORS**	**AFFILIATION**
Enhanced Adsorptive Performance of Modified Clay for Efficient Dye Removal from Wastewater	• Soumaya Matchi • Adil El Yadini • Hanae Ouaddari • Abdelkbir Bellaouchou	Mohammed V University, Faculty of Sciences, Department of Chemistry, Rabat, Morocco
Development of Smart Biosensors for Real-Time Glucose Monitoring	• David.G. • Deepak.S. • Palanisamy.A. • Ravi.C. • N Jayaramakani. • R. Srinivasan	Bharath Institute of Higher Education and Research, Chennai 600073, India
Comparison of the Effectiveness of Silicon and Nanosilicon in Stimulating the Growth of Lycium Chinense Mill. Shoot Cultures in Vitro	• Marcelina Krupa-Małkiewicz • Ireneusz Ochmian	West Pomeranian University of Technology Szczecin, Poland
Conceptual Considerations on the Application of The Precautionary Principle in The Environmental Law Relationship	• Mihaela (Bejenari) Cojocaru	"Stefan cel Mare" Academy of the Ministry of Internal Affairs
Toxic Tanning: Assessing Environmental Pollution and Occupational Health Risks in the Leather Industry	• Seifeslasie Asmamaw • Esayas Shegaw	Bahir Dar University, Ethiopia Debre Tabor University, Ethiopia
Economic Implications of Climate Change on Rice *(Oryza sativa)* Production in Bangladesh	• Most. Mokarroma • Arifa Yeasmin • Md. Salauddin Sohan • Md. Sakhawat Hosen Sourav • Md.Alshahria • Md. Sazzadul Isla • Md. Mizanur Rahman	University of Rajshahi, Rajshahi, Bangladesh

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 11:00-12:45 (Online)		
SESSION-18, HALL-6/ OTURUM 18, SALON-6 MODERATOR: N.G. Kalyani Reddy		
TITLE	**AUTHORS**	**AFFILIATION**
Smart Design Solutions for University Housing: A Waste-Optimized Architectural Solution for Postgraduate Accommodation at Futminna	• Okonnah Samuel David	Federal University of Technology, Minna
Influence of Lighting Quality on Emotional And Cognitive Responses to Artworks: A Comparative Study of Prominent Art Galleries in Lagos State, Nigeria	• SA'AD Muhammad Abolakale, • Olakanbi Bolaji Abdulraheem	University of Ilorin, Kwara Nigeria University of Abuja, FCT, Abuja, Nigeria
Ai Tools in Architectural Design: Transforming Creativity, Efficiency, and Sustainability	• Abhigyan Ganguly, • Sandipan Biswas, • Nitai Paitya, • Shivnath Ghosh	Brainware University, Kolkata, India Amity Univeristy, Kolkata, India
Cybersecurity Risks in Smart Building Infrastructure	• Moses Adeolu Agoı • Samuel Olayiwola Ajaga • David Oladimeji Ajıbod • Oluwanifemi Opeyemi Agoı	Lagos State University of Education, Lagos Nigeria.
Artificial Intelligence And 3d Printing Technology in Construction: A Review	• N.G. Kalyani Reddy, • Chayaraju BalaSai, • K. Tharani	G Pulla Reddy Engineering College
From Beneficial Modulation to Adverse Toxicity: Dose-Dependent Insights into TBHQ Safety Thresholds	• Saha Anik, • Hossain Md. Tamim, • Datta Narayam, • Chowdhury Bappy, • Ranjan Acharjee Mahima, • Prank Md. Rasel, • Ahmad Monsur	Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh.

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-19, HALL-1 / OTURUM 19, SALON-1 MODERATOR: Prof. Dr. Banu Çiçek Kurdoğlu		
TITLE	**AUTHORS**	**AFFILIATION**
GIS Tools in Spatial and Temporal Analysis of Land Use and Land Cover Changes: Molusce	• Çağla Aydemir • Ömer Kamil Örücü • Seda Örücü	Süleyman Demirel University, Türkiye
Integration of Virtual Reality (Vr)-Augmented Reality (Ar) and Mobile Applications in Urban Recreation Areas	• Seyhan Seyhan • Banu Çiçek Kurdoğlu	Karadeniz Technical University, Türkiye
How Do Urban Recreation Areas Contribute to Social Solidarity and Integration?	• Seyhan Seyhan • Banu Çiçek Kurdoğlu	Karadeniz Technical University, Türkiye
The Transformation of the Rami Barracks Into a Library: An Evaluation Within the Context of Adaptive Reuse	• Miskine Akar • Derya Su	Recep Tayyip Erdoğan University, Türkiye Fatih Sultan Mehmet University, Türkiye
Public Rest Areas in Shopping Centers: Samsun Piazza Mall	• Hande Yıldırım • Serap Faiz Büyükçam	Samsun University, Türkiye Ondokuz Mayıs University, Türkiye
Current Research Trends in Interior Architecture: A Conceptual Mapping	• Serap Faiz Büyükçam • Hande Yıldırım	Ondokuz Mayıs University, Türkiye Samsun University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-20, HALL-2 / OTURUM 20, SALON-2 MODERATOR: Assoc. Prof. Dr. Elif Sağlık		
TITLE	**AUTHORS**	**AFFILIATION**
The effects and Limitations of Safety Standards on Creative Designs in Children's Play Areas	• Elif Sağlık • Efe Arda Hasanoğlu	Çanakkale Onsekiz Mart University, Türkiye
Visualizing the impact of Modularity and Mobility on Contemporary Urban Design Using AI, Inspired by Archigram.	• Elif Sağlık • Fatma Erdoğan	Çanakkale Onsekiz Mart University, Türkiye
Conceptual Transitions and Reflections from Landscape Performance Assessment to Design Practice	• Mahmut Can Ast • Elif Sağlık	Çanakkale Onsekiz Mart University, Türkiye
Nature-Based Open Space Approaches for Sustainable Campus Life	• Emirhan Aks • Alper Sağlık	Çanakkale Onsekiz Mart University, Türkiye
Contributions of the “Placemaking” Approach to the Urban Environment	• Pınar Özge Parlak • Elif Bayramoğlu	Karadeniz Technical University, Türkiye
Nature-Based and Digital Solutions for Flood-Resilient Urban Systems	• Pınar Özge Parlak • Elif Bayramoğlu	Karadeniz Technical University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-21, HALL-3 / OTURUM 21, SALON-3 • **MODERATOR: Assoc. Prof. Dr. M. Bihter Bingül Bulut**		
TITLE	**AUTHORS**	**AFFILIATION**
The Social Implications of the Climate Crisis	• Hatice Gözde Özkarakay • Murat Akten	Süleyman Demirel University, Türkiye
Ecological Compatibility and Accessible Design In Archaeological Sites	• Bilgenur Ak • Öner Demirel • M. Bihter Bingül Bulut • Tuba Gizem Aydoğan	Kırıkkale University, Türkiye
Design Principles for Urban Open Parking Lots in the Climate Change Adaptation Process: The Case of Isparta	• Fatma Özkan Bayındır • Ali Öz • Atila Gül	Süleyman Demirel University, Türkiye Mehmet Akif Ersoy University, Türkiye
Urban Green Space-Sensitive Parking Lot Planning: An AI-Supported Sustainable Approach	• Fatma Özkan Bayındır • Ali Öz • Atila Gül	Süleyman Demirel University, Türkiye Mehmet Akif Ersoy University, Türkiye
Natural Carbon Sinks and Ecosystem-Based Approaches in Combating the Climate Crisis	• Mahmut Tuğluer • Mert Çakır	Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Türkiye Süleyman Demirel University, Isparta, Türkiye
Citizen Science as a Tool for Urban Biodiversity Monitoring	• Mert Çakır • Mahmut Tuğluer	Süleyman Demirel University, Isparta, Türkiye Kahramanmaraş Sütçü İmam University, Kahramanmaraş-Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-22 HALL-4/ OTURUM 22, SALON-4 • MODERATOR: Dr.B. Mahadevan		
TITLE	**AUTHORS**	**AFFILIATION**
The Metaphysics of Form: Energy, Geometry, and Sphericity in Nature	• Yasin KHALILOV	Baku Engineering University, Hirdalan, Azerbaijan
A Performance Driven Generative Design Workflow for Optimizing Building Facades for Daylight and Energy Efficiency in a Mediterranean Climate	• Fahim Yar Bai • Samira Mehrafza	Ahlul Bayt International University, Tehran, Iran
Smart Irrigation System for Sustainable Farming	• Nithish Kumar R, • S Udhaya Kumar, • S Rakshith	R.M.K. Engıneering College
Information and Communication Technology Adoption Behaviour of Farmers in Thanjavur District: A Study	• B. Mahadevan	Vellalar College for Women (Autonomous), Thindal (Post), Erode, Tamilnadu, India.
Natural Farming a Sustainable Approach for Management of Soil Degradation and Climate Change Mitigation	• Ganesh Kumar, • R.Y Hiranmai, • Harshita Marwal, • Ajay Neeraj	Central University of Gujarat, Kundhela, Vadodara-391107 Gujarat, India
The Circular Memory of Hands: Circularity In The Domestic Wisdom Of Peoples	• Yasin Khalilov	Baku Engineering University, Hirdalan, Azerbaijan
Circular Bridge from East to West: The Global Dialogue of Cultures	• Yasin Khalilov	Baku Engineering University, Hirdalan, Azerbaijan

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-23, HALL-5 / OTURUM 23, SALON-5 **MODERATOR: Aicha Belgacem**		
TITLE	**AUTHORS**	**AFFILIATION**
Advanced And Future Ndds Concept	• V. Hariharan, • Danish khan, • G. Madhan prasadh, • S. Punithavalli, • P. Saranya • A. Vivek, • Snehamayee mahapatra, • R. Thelshath	Bharath Institute Of Higher Education And Research
Capacity Analysis of Signalized Intersections in Oran, Algeria: A Probabilistic Model for Left-Turn Movements	• Wissem Belkheir • Zahra Bounouara • Fatima Hadjadj • Wafaa Tebboune	University of Sciences and Technology of Oran-Mohamed BOUDIAF, Algeria
Integrating Traditional and Modern Sustainable Architectural Practices for Cost-Efficiency and Climate-Responsive Buildings in Niger State, Nigeria	• Muhammad Hassan Ishaq, • Bukar Ali Kime	Ahmadu Bello University Zaria, Nigeria. University of Maiduguri, Nigeria.
Effectiveness of Land Use Planning and Zoning Regulations in Controlling Urban Development in Bauchi Metropolis	• Mustapha Umar Sa'ad, • Ibrahim Muhammad Shera, • Ibrahim Idris	Abubakar Tafawa Balewa University Bauchi, Nigeria Federal University Birnin Kebbi, Nigeria
Integrating Climate-Responsive Strategies in Environmental Design for Sustainable Urban Futures	• Jibril Jamilu, • Ibrahim Khalil Adamu	American University of Nigeria Yola, Nigeria. Federal College of Education Gidan Madi Sokoto, Nigeria
Sustainable Irrigation of an Apple Orchard Using a PV Pumping System: A Case Study from Algeria	• Aicha Belgacem, • Fatima Belgacem, • Mohamed Mostefai, • Yahia Miloud	Moulay Tahar University of Saida, Algeria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-24, HALL-6 / OTURUM 24, SALON-6 **MODERATOR: Melik Sami**		
TITLE	**AUTHORS**	**AFFILIATION**
Impact of Green Finance in Sustainable Performance: Mediating the Role of CSR	•Aqsa Farooq, •Rimsha Iqbal	Riphah International University Rawalpindi
Economic Development and Sustainable Development Goals in Africa: Challenges, Opportunities, and Policy Perspectives	•Ali Jan Sharifi, •Ahmad Farid Qasemi, •Mohammad Bashir Ashrafi, •Hamed Mohammadi, •Mohammad Yasin Rezaei	International Islamic University, Islamabad, Pakistan
The Green Waqf: Financing Eco-Architecture Through Islamic Endowments	•Melik Sami, •Khelil Sara, •Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Economic Viability of Vertical Farming in Urban Architecture: A Sustainability Perspective	•Melik Sami, •Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Embedding Circular Economy Principles in Architectural Design for Sustainable Cities	•Melik Sami, •Khelil Sara, •Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Islamic Economic Principles in Eco-Mosque Architecture: A Path to Sustainability	•Melik Sami, •Khelil Sara, •Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-25, HALL-1/ OTURUM 25, SALON-1 MODERATOR: Prof. Dr. Sevgi Yılmaz		
TITLE	**AUTHORS**	**AFFILIATION**
Landscape Character Analysis Evaluation in Rural Settlements: Erzurum Palandöken Example	• Ahmet Koç • Sevgi Yılmaz	Dicle University, Türkiye Atatürk University, Türkiye
Climate-Sensitive Urban Design Approaches: The Case of Elazığ City	• Yaşar Menteş • Sevgi Yılmaz	Ministry of Agriculture and Forestry, Türkiye Atatürk University, Türkiye
Reducing the Urban Heat Island Effect with Water Surfaces: The Case of Lake Hazar	• Yaşar Menteş • Sevgi Yılmaz	Ministry of Agriculture and Forestry, Türkiye Atatürk University, Türkiye
Spatial Hybridization and The Transformation of Identity: A Study on Rural Settlements and Secondary Houses in The Edremit Gulf	• Aysu Çakır • Gaye Birol	İzmir Democracy University, Türkiye
Analysis of Studies on Transparent Wood and Its Potential Use in The Construction Industry	• Nilay Aykan • Esra Lakot Alemdağ	Recep Tayyip Erdoğan University, Türkiye
A Comparative Analysis of Similar Traditional Wall Construction Techniques in Different Regions	• Ayça Akkan Çavdar • Esra Lakot Alemdağ	Recep Tayyip Erdoğan University

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-26, HALL-2 / OTURUM 26, SALON-2 • MODERATOR: Prof. Dr. Aybike Ayfer Karadağ		
TITLE	**AUTHORS**	**AFFILIATION**
Use of Fragrant Plants Growing in Isparta in Landscape Designs	• Emine Ağlar • Şirin Dönmez	Süleyman Demirel University, Türkiye
Natural Medicinal And Aromatic Plants Growing in Konya Climatic Conditions and Their Use in Plant Design	• Nilgül Bağcı • Şirin Dönmez	Süleyman Demirel University, Türkiye
Multi-Layered Spatial Development of Konya: A Topological Analysis of The Basin at Two Scales	• Merve Alıcı Aka • Elif Yeşim Kösten • Gülşah Üner	Kocaeli University, Türkiye
The Development of Roman Bath Architecture in the Light of the Sebastopolis Roman Baths	• Akın Temür	Ondokuz Mayıs University, Türkiye
Legal Vulnerability of Ecological Assets In the Post-Disaster Period in Turkiye	• Aybike Ayfer Karadağ • Demet Demiroğlu	Düzce University Kilis 7 Aralık University, Turkiye
Urban Open- Green Spaces Within the Framework of Turkiye's Climate Law	• Demet Demiroğlu • Aybike Ayfer Karadağ	Kilis 7 Aralık University, Turkiye Düzce University, Turkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-27 HALL-3/ OTURUM 27, SALON-3 **MODERATOR: Melik Sami**		
TITLE	**AUTHORS**	**AFFILIATION**
A Holıstic Conceptual Framework For Bıiophilic Desıgn in Healthcare Environments: Enhancing Elderly Well-Beıng Through Environmental Integration	• Aylar Ranjbarian, Mehrdad Karimimoshaver	Bu-Ali Sina University, Hamedan, Iran
Urban Density, Morphology, and Soundscapes: Architectural Strategıes For Sustainable Design	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria
The Interplay of Sound and Space in Vernacular Desert Housing: Toward Sustainable Futures	• Melik Sami, • Khelil Sara, Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria
Soundscapes and Human Experıence: Archıtecture for the Ear in Urban Futures	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria
Smart Soundscapes: Acoustic Technologies for Sustainable Architectural Environments	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria
Buılding Climate Resilience Rural Settlement Design for Agricultural Communities	• Most. Mokarroma • Esita Ghosh	University of Rajshahi, Rajshahi, Bangladesh

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-28 HALL-4/ OTURUM 28, SALON-4 **MODERATOR: Popescu Gh. Cristina Raluca**		
TITLE	**AUTHORS**	**AFFILIATION**
Leadership, Communication, and Cognitive Skills as Drivers of Project Performance: Prioritizing Soft Skills in the Construction Industry	• Greg Odee Ikwe	Bingham University
Dynamics of Funeral Practices Among the Haussa Muslims of the City of Zinder	• Soumana Abdoul-Wahab • Kassou Maman • Dlawali Maman Toukour	Université André Salifou, Zinder-Niger Republic
Spaces That Enhance Well-Being in Türkiye, Ireland, Netherlands, Portugal, Spain, And United States: Designing for Health as a Holistic Approach Where Human Resources Can Thrive	• Popescu Gh. • Cristina Raluca	University of Bucharest, Bucharest, Romania and The Bucharest University of Economic Studies, Bucharest, Romania
Acoustic Planning Policies: Shaping Sustainable Urban and Architectural Environments	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Biomechanically Informed and Sustainable Architectural Design in Sports Facilities: Enhancing Athlete Performance and Spectator Experience	• Shiv Kumar	Physical Education, SBV Vikas Puri, India
Climate-Responsive Architectural Strategies for Lahore: A Bioclimatic Approach Toward Sustainable Design	• Farhana Naz	Lahore College for Women University, Pakistan

FRIDAY– October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-29, HALL-5/ OTURUM 29, SALON-5 MODERATOR: Sándor Földvári		
TITLE	**AUTHORS**	**AFFILIATION**
Echoes of the Desert: Acoustic and Spatial Responses in Vernacular Sustainable Architecture	• Melik Sami, • Khelil Sara, • Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Multiculturality of Lviv/Lemberg/Lwów, the Centre of West Ukraine, As Reflected in The Architectural History of the City	• Sándor Földvári	Debrecen University, Emeritus
Potential and Constraints of Beekeeping Development in Sri Lanka: A Review on Socioeconomic, Technological, And Environmental Perspectives	• Mahamarakkalage Nethmi Ayodya Perera	University of Ruhuna
Valuing The Intangible: An Integrated Economic Framework for Assessing the Cultural Capital of Heritage Architecture In Urban Regeneration	• Mohsen Mohammadi Khyareh • Mohadeseh Nezhadipour	Gonbad Kavous university, Gonbad Kavous, Iran
The Entrepreneurial City: Exploring The Impact of Zoning Regulations and Building Codes on Startup Ecosystems and Innovation Districts	• Mohsen Mohammadi Khyare • Mohadeseh Nezhadipour	
Achievements in the Temple to Moon God Nanna Built By King Ur Engur In 3 100 Bce in Ur in Mesopotamia	• Natela Borisovna Popkhadze	Head of Scholarly Information Center at Academy of Phasis in Tiflis in Gurcistan//Georgia Republic//Sakartvelo
Partial Replacement of Coarse Aggregate with Crumb Rubber Chips in Concrete Production	• N.G. Kalyani Reddy, Chayaraju BalaSai, K. Tharani	G Pulla Reddy Engineering College

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 15:00-16:45 (Online)		
SESSION-30, HALL-6/ OTURUM 30, SALON-6 MODERATOR: Kazem Golizadeh		
TITLE	**AUTHORS**	**AFFILIATION**
Assessing Global Covid-19 Recovery Roadmaps for Enhancing Resilience in Nigeria's Construction Sector: A Comparative Framework for Sustainable Adaptation	• Tasleemah Yusuf, • Peter Gangas Chindo, • Mustapha Abdulrazaq	Ahmadu Bello University Zaria, Kaduna – Nigeria
Evaluation of Biophilic Design Principles in The Design Proposal of 5-Star Hotel	• Safiya Bello Abdullahi	Federal University of Technology Minna
A Comparative Analysis of the Role of Rock-Cut Architecture in the Life Cycle of Rural Tourism: A Case Study of Kandovan, Iran, and Göreme, Türkiye	• Kazem Golizadeh	National University of Skills, Tehran, Iran
Architecture, Environmental Externalities, And Economic Policy for Sustainable Cities	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
The Trade-off Between Economic Growth and Environmental Architecture in Developing Regions	• Melik Sami, Khelil Sara, Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Effect of Material Suitability and Availability on Residents' Building Preferences in Nupe Land, Kwara State	• Kolo Vincent Mana, • Olakanbi Bolaji Abdulraheem	University of Ilorin, Kwara, Nigeria University of Abuja, FCT, Abuja, Nigeria
Iranian Art And Architecture	• Dr. Mehdi Shalchi Tousi	Ahle Beyte Internatinal University, Tehran, Iran

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-31, HALL-1 / OTURUM 31 SALON-1 MODERATOR: Assist. Prof. Dr. Mert Çakır		
TITLE	**AUTHORS**	**AFFILIATION**
Integration of Advanced Building-Integrated Photovoltaic (Bipv) Systems for Sustainable Architectural Design	• Muhammad Mateen Afzal Awan	University of Management and Technology Lahore, Pakistan
Smart and Ecological Cities: Pathways to Climate-Resilient and Sustainable Urban Futures	• K. R. Padma	Sri Padmavati Mahila Visvavidyalayam (Women's University) , Tirupati, AP. India
Urban Greening Transformation of Mediterranean Cities: An Application to The City of Naples	• Floriana Zucaro	University of Naples Federico II, Italy
A Machine Learning-Driven Model to Predict Urban Outdoor Thermal Comfort	• Hüseyin Ögçe • Meltem Erdem Kaya	Istanbul Technical University, Istanbul-Türkiye
Building Envelope Strategies for Enhancing Urban Thermal Comfort: A Climate-Sensitive Perspective	• Alireza Gerami, • Mehrdad Karimimoshaver	Bu-Ali Sina University, Hamedan, Iran
Evaluating Human Impact in Urban Areas, With the Example of Sofia, Bulgaria	• Stefan Stamenov • Vanya StamenoVA	Bulgarian Academy of Sciences, Sofia - Bulgaria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-32, HALL-2 / OTURUM 32, SALON-2 • MODERATOR: Assoc. Prof.Dr. Soad Abokhamis Mousavi		
TITLE	**AUTHORS**	**AFFILIATION**
Local Material Use in Interior Architecture for Thermal Comfort in arid Climates: A Case Study of Ouarzazate, Morocco	• Chaimae Kraouch • Soad Abokhamis Mousavi	Final International University, TRNC Arkin University of Creative Arts and Design, TRNC
Societal Acceptance of Thermal Storage Wall in Buildings in Mediterranean Region	• Soad Abokhamis Mousavi	Arkin University of Creative Arts and Design, TRNC
3d Topographic and Architectural Documentation of The Multi-Functional Underground Structure at Miletus Kaletepe	• Özel Teraman Hepdinçler • Nikolai Techo • Haralambos Nikolayidi • Özlem Kaya • Hasan Ersin Güvendik • Ece Kızıldağ	Mimar Sinan Fine Arts University, Türkiye Berliner Hochschule für Technik, Germany Bilecik Şeyh Edebali University, Türkiye Yıldız Technical University, İstanbul-Türkiye
Analysis of The Impact of Urban Design on Social Inequalities and Mental Health: A Case Study of Isfahan, Iran	• Parsa Barahouei • Çilen Erçin	Eastern Mediterranean University, Northern Cyprus European University of Lefke, Northern Cyprus
Transitioning from Ifc to Linked Building Data: Semantic Simplification With Bot, Product, and Props Ontologies	• Murat Aydın	Ankara University, Türkiye
Conceptual Uncertaıntıes in Semantic BIM: Achieving Definition Clarity Through Ontology Engineering	• Murat Aydın	Ankara University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-33, HALL-3 / OTURUM 33, SALON-3 • MODERATOR: Assoc. Prof.Dr. Sultan Sevinc Kurt Konakoğlu		
TITLE	**AUTHORS**	**AFFILIATION**
The Role of Green Infrastructure in Improving Air Quality: A Case Study of Kocaeli Darıca Millet Garden	• Kübra Hanoğlu • Gülnur Kardan • Sultan Sevinç Kurt Konakoğlu	Amasya University, Türkiye
Assessment of Green Infrastructure Systems Based on Ecosystem Services: The Case of Amasya Unıversity	• Mustafa Taha Keskiner • Alper Kaan Kalkan • Sultan Sevinç Kurt Konakoğlu	Amasya University, Türkiye
Rural Planning Strategies: The Case of Acıpayam, Denizli	• Mine Cengiz • Murat Akten	Süleyman Demirel University, Türkiye
Hybrid Education Spaces: Spatial Strategies and Design Perspectives	• Hatice Ceylan • Ekrem Bahadır Çalışkan	Ankara Yıldırım Beyazıt University, Ankara, Türkiye
Dwelling-Street Relations in Traditional Urban Fabrics: The Case of Famagusta Walled City	• Hasan Doğan	Harran University, Türkiye
Strategic Approaches to Climate Change Adaptation and Mitigation	• İzel Meral	KTO Karatay University, Türkiye

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-34, HALL-4/ OTURUM 34, SALON-4 MODERATOR: M. Fathrezza Imani		
TITLE	**AUTHORS**	**AFFILIATION**
Evaluation of Users' Preferred Biophilic Design Elements in Commercial Office Buildings in Abuja, Nigeria	• Adeniji Ahmed Adeola, • Muhammad Isa Bala	Federal University of Technology Minna
Intellectual Property And Design Protection	• Aswin M Nair • Payal Shukla	Sharda University, Greater Noida, India
Pekalongan City Culture and Its Nickname as the City of Batik	• M. Fathrezza Imani	UIN KH. Abdurrahman Wahid Pekalongan
Historic Monument Buildings – European Union Perspectives on Their Protection	• Voroneanu-Popa Rareș-Vasil • Richard Constantinescu	Grigore T. Popa University of Medicine and Pharmacy of Iași
Socio-Economic Dynamics and Urban Transformation in Algerian Desert Cities: An Analytical Approach to the Case of Biskra	• Mokhnane Tarek • Khiari Reguia • Adjlane Sabah	Scientific and Technical Research Center on Arid Regions CRSTRA
Exploring Evidence Based Design Strategies to Foster Healing in The Design of aPaediatric Hospital in Rigasa, Kaduna State	• Amira Abdul-Azeez	Ahmadu Bello University, Zaria, Nigeria
Artificial Intelligence Revolutions and Breakthroughs for Architecture, Engineering, Cultural Studies, and Environmental Disciplines	• Vinod Kumar Verma • Klimis Ntalianis • Chao-Tung Yang • Carlos Moreno • Eric Gamess • Monica Karel Huerta • Vimal Rau Approw	Sant Longowal Institute of Engineering and Technology, Deemed to be University, Longowal - India Deemed to be University, Longowal - India University of West Attica, Athens - Greece Tunghai University, Taichung City - Taiwan Central University of Venezuela, Carscus – Venezuela Jacksonville State University, Jacksonville, Alabama - USA Universidad Politécnica Salesiana, Cuenca- Ecuador Taylors University, Selangor - Malaysia

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-35, HALL-5/ OTURUM 35, SALON-5 **MODERATOR: Laura Diaconu (Maxim)**		
TITLE	**AUTHORS**	**AFFILIATION**
Eco-Friendly Foreign Investment: The Role of Green FDI in Sustainable Development	•Laura Diaconu (Maxim) •Mihai-Bogdan Petrișor	"Alexandru Ioan Cuza" University of Iasi, Romania
An Analytical Study of AI-Enabled Tourism and Global Integration	•Deepanjali Mishra	KIIT University, India
The Energy Affordability Crisis: Fuel Price Shocks, Urban-Rural Disparities, and the Climate Mitigation Paradox in Northern Nigeria	•Sabiu Bello Yusuf, •Ashiru Bello, •Umar Shamsudeen	Federal College of Education, Gidan Madi Urban and Regional Planning, Ahmadu Bello University, Zaria Umaru Ali Shinkafi Polytechnic, Sokoto
Legal Implications of Building Collapse in Nigeria: A Case Study Approach	•Samuel Akpadiagha Etuk, •Udeme E. Ettentuk	Akwa Ibom State Polytechnic, Ikot Osurua University of Uyo
The Architectural Philosophy of Southern Albania (15th Century – Early 20th Century)	•Vivian Mukli	Universiteti POLIS
Sustainable Concrete Design Using Low-Volume Fly Ash: Experimental Evaluation of Strength and Durability	•Marjuka Mehjabin	Hajee Mohammad Danesh Science & Technology University, Dinajpur, Bangladesh
User Accessibility in Nigerian Shopping Malls: Myth or Reality	•Chinedu Oluigbo •Rotimi-Williams Bello •Uchenna Eberendu	Niger Delta University, Nigeria University of Africa, Nigeria Federal Polytechnic, Nigeria

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 17:00-18:45 (Online)		
SESSION-36, HALL-6/ OTURUM 36, SALON-6 MODERATOR: Aliyu Hashimu Isah		
TITLE	**AUTHORS**	**AFFILIATION**
Use of Artificial Intelligence in Transport for Rural Development	• J. Salai Thillai Thilagam • Gorla Lalitha	G. Pulla Reddy Engineering College, India
Eco-Colonialism or Climate Justice? Reassessing Global Environmental Agreements from the Global South Perspective	• Astitva Kumar Rao • Anamika Prasad	Dr. B.R. Ambedkar National Law University, Sonepat, Haryana, India Amity University, Gwalior, Madhya Pradesh, India
Geological Event Modeling and Illustration	• Abdelfattah Aboulfaraj, • Abdelhalim Tabıt, • Ahmed Algoutı, • Latifa Aboulkasım	Cadi Ayyad University
Eco-Building Mortars Incorporating Sewage Sludge Ash for Sustainable Construction: A Review	• Bouslah Mahmoud • Maza Mekki • Rahmouni Zie El Abidine • Tebbal Nadia	University of M'sila, Algeria
Thermochemical Optimization of Microencapsulated Phase Change Materials (Pcms) for Passive Thermal Regulation in Heritage and Modern Architecture	• Aliyu Hashimu Isah	Federal College of Education Gidan Madi, Sokoto, Nigeria
The Architecture of Extracurricular Activities In Foreign Languages: Strategies for Developing Intercultural Competence	• Serghei Vasilachi • Djulieta Rusu	Academy of Economic Studies of Moldova, Moldova
Factors Influencing the Adoption of Green Walls in Residential Property Development in Ibadan, Nigeria	• Nnaemeka Bethel Ezeokolı • Ayooluwa Adeboye Adelakun	Federal University of Technology Akure, Nigeria.

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-37, HALL-1/ OTURUM 37, SALON-1 **MODERATOR: Neriman Gül Çelebi**		
TITLE	**AUTHORS**	**AFFILIATION**
Sustainability in Traditional Urban Form: Example of Tire	• İzzet Yüksek • Ecem Uğurlu • Yağmur Burcu Güneş	Celal Bayar University, Türkiye Izmir Democracy University, Türkiye
Adaptive Reuse of Historical Buildings as Libraries: Original Function-Based Approaches	• Rümeysa Aydın • Şebnem Ertaş Beşir	Nuh Naci Yazgan University, Türkiye Akdeniz University, Türkiye
Interior Architecture Design Suggestions in Traditional Urfa Houses: Re-Functioning	• Ayşe Gül Güzel	İstanbul Beykent University, Türkiye
Spatial And Functional Suggestions for The Sustainability of Traditional Marketplaces: From Consumption to Production	• Ayşe Seda Çalışkan • Özge Kandemir	Konya Technical University, Türkiye Eskişehir TechnicalUniversity, Türkiye
Organization of Outdoor Tourism and Planning of Outdoor Recreation Services	• Yegana Ahmadova	Azerbaijan State Pedagogical University, Azerbaijan

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-38, HALL-2 / OTURUM 38, SALON-2 **MODERATOR: Ahmet Benliay**		
TITLE	**AUTHORS**	**AFFILIATION**
Healthy Cities In Environmental Protection	• **Belgin Yıldırım** • **Seher Sarikaya Karabudak**	**Aydın Adnan Menderes University/Faculty of Nursing, Department of Public Health Nursing, Aydın, Türkiye**
The Place and Importance of Environmental Education in Nursing	• **Belgin Yıldırım** • **Seher Sarikaya Karabudak**	**Aydın Adnan Menderes University/Faculty of Nursing, Department of Public Health Nursing, Aydın, Türkiye**
The Sculptural Effect in Architecture: The Valencıa Opera House	• **Nihansu Kücü** • **Özgü Özturan** • **Şebnem Ertaş Beşir**	**Akdeniz University, Türkiye**
Media Representation of Non-Structural Elements Following the February 6 Kahramanmaraş Earthquakes in Türkiye	• **Ayşan Ilgın Polat** • **Şebnem Ertaş Beşir**	**Akdeniz University, Türkiye**
Virtual Reality (Vr) Technology and Interactive Design Processes in Landscape Design	• **Ahmet Benliay** • **Yaren Sadık**	**Akdeniz University, Antalya-Türkiye**
Comparison of 3D Modeling and Artificial Intelligence Tools in Landscape Design Visualizations	• **Türkan Azeri** • **Ahmet Benliay**	**Akdeniz University, Antalya-Türkiye**

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-39, HALL-3 / OTURUM 39, SALON-3 MODERATOR: S. Shakthi Sree		
TITLE	**AUTHORS**	**AFFILIATION**
Sustainable Urban Planning and Development	• S. Shakthi Sree	Bharath Institute of Higher Education and Research, Selaiyur, Chennai-73.
Utilisation of Restorative Design Features in The Design Proposal for Resor`T Center in Abuja, Nigeria	• Kasim Ahmed Tahir	Federal University of Technology, Minna, Nigeria
Thermal Stability of Composite Materials Using a Refined Higher Order Shear Deformation Theory	• Tebboune Wafa, Belkheir Wissem, Bounouara Zahra, Hadjaj Fatima Zohra	University of Sciences and Technology Mohamed Boudiaf, Oran, Algeria.
Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design	• Aravindhan. R Ramshin Rahiman	Private deemed university, Chennai, India
Green By Design: The Role of Urban Farming in Achieving Sustainable Cities	• Astitva Kumar Rao Anamika Prasad	Dr. B.R. Ambedkar National Law University, Sonepat, Haryana – 131029 (India) Amity University, Gwalior, Madhya Pradesh – 474005 (India)
Synthesis, characterization, and evaluation of biological activities of M(II) metal complexes (M=Co, Zn and Cu) based on a bidentate Schiff base ligand	• Ibtissam Elaaraj, Oumayma Oulidi, Asmae Nakkabi, Filippo Giarratana, Noureddine El Moualij, Mohammed Fahim	Moulay Ismail University, Kingdom of Morocco University of Messina, Italy
The Use of Berberis L. Species in the Creation and Reconstruction of Parks and Squares in the Steppe Dnipro Region	• Anatoliy M. Kabar • Tetyana Y. Lykholat • Maksim O. Kvitko • Olena A. Lykholat • Yuriy V. Lykholat	Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine Oles Honchar Dnipro National University, Dnipro, Ukraine

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-40, HALL-4 / OTURUM 40, SALON-4 **MODERATOR: Ananda Majumdar**		
TITLE	**AUTHORS**	**AFFILIATION**
Greasing The Gears of Innovation: The Role of Petroleum Chemistry in Architectural Design and Engineering	• Ibrahim Khalil Adamu, • Abdullahi Aliyu	American University of Nigeria Yola, Nigeria. Federal College of Education Gidan Madi Sokoto, Nigeria. Federal University, Birnin Kebbi, Nigeria.
The Urban Landscape of Western Europe: Impact of The Decline of The Western Roman Empire on Urbanization From AD 400 To The 17th Century	• Ananda Majumdar	Harvard University
Sustainable Urban Farming in India: Pathways to Achieving the Sustainable Development Goals (Sdgs)	• Hari Prasad Agarwal	The Assam Royal Global University, Guwahati
Integration of Digital Technologies in Landscape Design: Physics-Based Models and Technological Innovations in Agricultural Landscapes	• Ali Jan Sharifi, • Ahmad Farid Qasemi, • Mohammad Bashir Ashrafi, • Hamed Mohammadi, • Mohammad Yasin Rezaei	International Islamic University, Pakistan
Capitalizing on Local Knowledge of Tetraclinis articulata in Morocco's Central Plateau: Challenges for Conservation of an Endangered Medicinal Heritage	• Jaayefar Fatima-ezzahra, • Dahmani Jamila	Ibn Tofail University, Kenitra, Morocco
Rural Displacement and Livelihoods: A Study of Farmer-Herder Conflicts in Benue State and its Impact on Agricultural Development	• Adoga Peter Adoga • Ikyapa Peter Tertese	Bayero University Kano, Kano State, Nigeria
Iranian Art And Architecture	• Dr. Mehdi Shalchi Tousi	Ahle Beyte Internatinal University, Tehran, Iran

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-41, HALL-5 / OTURUM 41, SALON-5 **MODERATOR: Maryam MOSLEHI**		
TITLE	**AUTHORS**	**AFFILIATION**
Evaluation of Height Influence on the Seismic Behavior Factor of Reinforced Concrete Frame Structures Using Nonlinear Pushover Analysis	• Mohammed OUALI, • Mahfoud TOUHARI	Khemis Miliana University, Algeria
The Ksour of The Ksour Mountains in Algeria: An Oasian Heritage on The Path to World Recognition	• Sana MEKKI • Rima BOUKERMA • Leila SRITI	Mohamed Khider University, Biskra University of Algiers 1
Gep- Based On Modeling of Alkaline Activators Effects on Geopolymer Concrete	• Chayaraju Bala Sai • Nadagouda Kalyani • K.Tharani	G. Pullareddy Engineering college (Autonomous), Kurnool, AP, INDIA
Green Spaces: Restoring Mind and Body in Urban Life	• Maryam MOSLEHI	Natural Resources Research Department, Iran
Effects of Organic Mulch and Natural Methods on Soil Moisture Retention and Growth of Ziziphus spina christi Seedlings in Afforestation	• Maryam MOSLEHI	Natural Resources Research Department, Iran
Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design	• Aravindhan. R, • Ramshin Rahiman, • Sri Harshavarshini C •	Private deemed university, Chennai, India
Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj	• Shahriar Hasan Mridha Ratul, • Moukuri Mohim, • Ahsan Rezwan	Southeast University (SEU), Dhaka, Bangladesh University of Asia Pacific (UAP)

FRIDAY – October 31, 2025 Antalya (Demre)-Türkiye Time 19:00-20:45 (Online)		
SESSION-42, HALL-6 / OTURUM 42, SALON-6 MODERATOR: Subhashish Dey		
TITLE	**AUTHORS**	**AFFILIATION**
Strength Characteristics of M40 Grade Concrete as Partial Replacement Of Cement by Ggbs and Fine Aggregate by Crusher Dust	• Subhashish Dey	Gudlavalleru Engineering College, Andhra Pradesh, India
Forest Carbon Assessment and Modeling in Bangladesh: Pathways for Sustainable Forest Management and Climate Mitigation	• Sadid Shahriyar	Sher-e-Bangla Agricultural University
Durability of Vegetable fiber-reinforced concrete under External sulfate attack	• Imane Mihoub, • Sif Allah Meghzili, • Abderraouf ACHOUR	University Center of Morsli Abdellah Tipaza, Algeria.
Mapping Albania's Cultural Heritage: A Spatial and Typological Analysis of Tangible and Intangible Assets	• Msc. Mishela Rapo	European University of Tirana
Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj	• Shahriar Hasan Mridha Ratul, • Moukuri Mohim, • Ahsan Rezwan	Southeast University (SEU), Dhaka, Bangladesh, University of Asia Pacific (UAP)
Experimental Study on Mechanical Properties of Normal Strength Concrete by Partial Replacement of Fine Aggregate with Demolished Brick Waste	• Pathangi Eswanth, • Mahendrakar Hemanth Kumar, • Ramireddy Sushmitha	G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India
Implications and Environmental Impact of Artisanal Gold Mining on Land use Patterns in Minna Metropolis, Niger State	• Abdullahi M.I. Usman • Z.N., Ndako N., • Abdullahi M.K. • Hussaini I.	Niger State College of Education Federal University of Technology, Minna, Nigeria

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

CONGRESS PHOTOS














Prof. Dr. Atila GÜL
T.C. DEMRE BELEDİYESİ




Prof. Dr. Atila GÜL
T.C. DEMRE BELEDİYESİ


T.C. DEMRE BELEDİYESİ




T.C. DEMRE BELEDİYESİ






T.C. DEMRE BELEDİYESİ


T.C. DEMRE BELEDİYESİ








CLIMATE CHANGE


TAGEM
AR-GE & INOVASYON


TAGEM
AR-GE & INOVASYON


TAGEM
AR-GE & INOVASYON





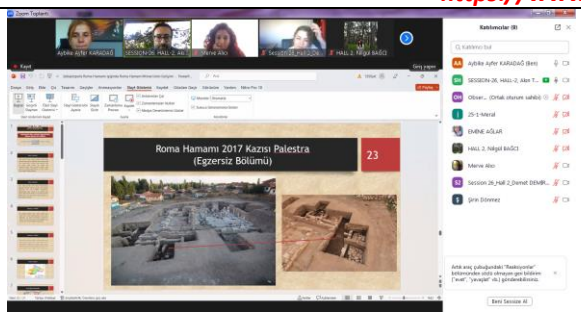


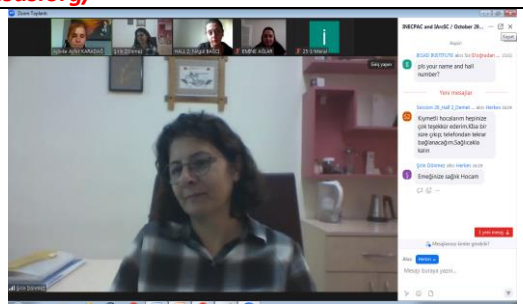


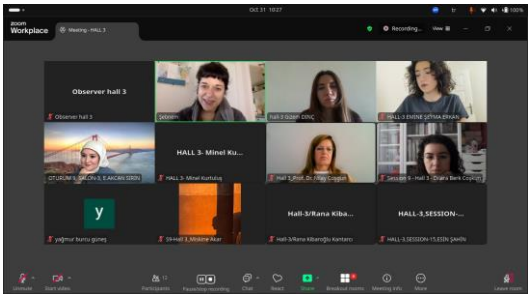



TAGEM
AR-GE & INOVASYON



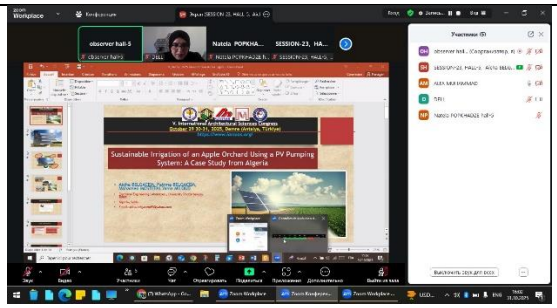

Roma Hamamı 2017 Kazısı Palestra
(Egzersiz Bölümü)
23

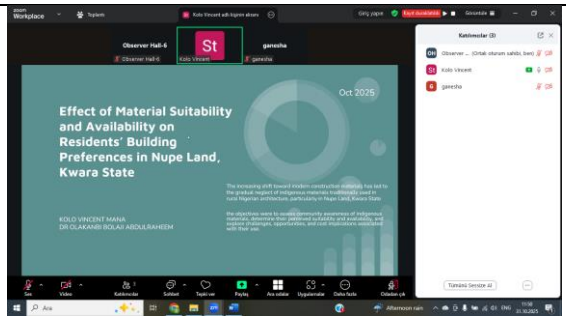



Observer hall 3
HALL 3- Minel Ku...
Hall-3/Rana Kiba...
HALL-3,SESSION-...

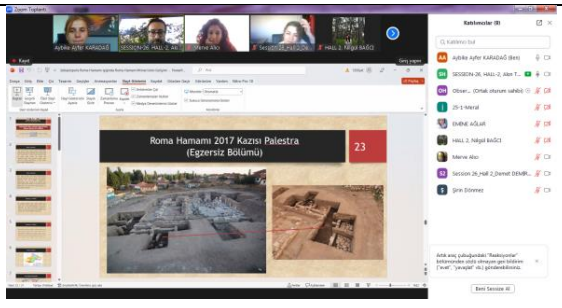

Observer hall-1


Oberver-H-2


Sustainable Irrigation of an Apple Orchard Using a PV Pumping System: A Case Study from Algeria

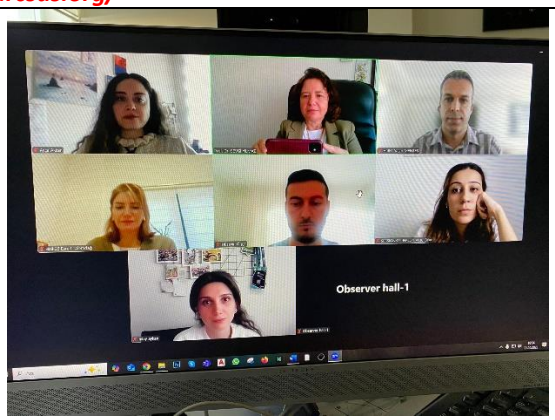

Effect of Material Suitability and Availability on Residents' Building Preferences in Nupe Land, Kwara State
Oct 2025


Observer hall-1

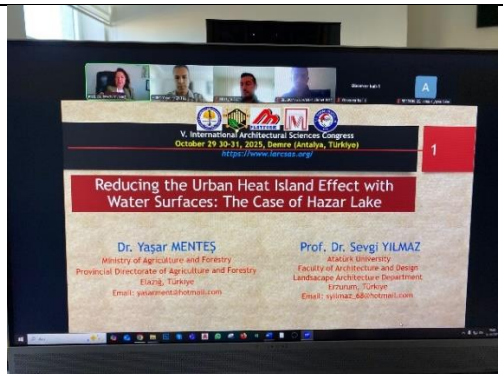

Roma Hamamı 2017 Kazısı Palestra
(Egzersiz Bölümü)
23

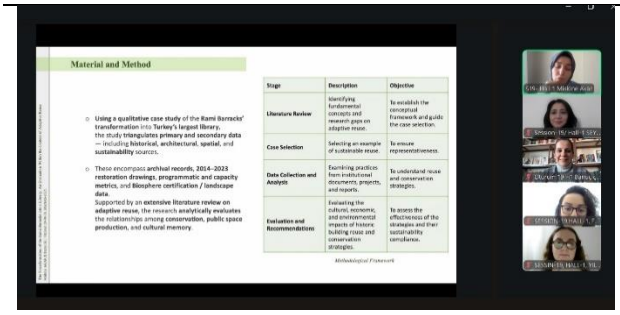


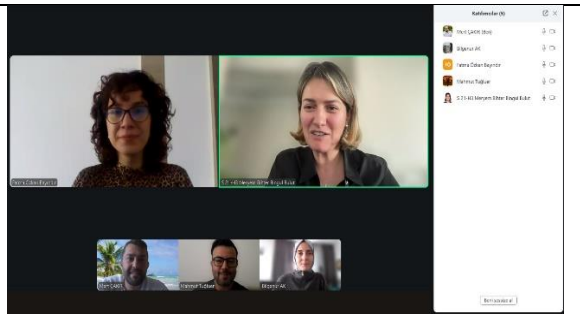

Observer hall-1
BERAT ŞAHNA
İsmail Burak Ka...
Hamza sipahi
HALL-1 Mürşit K...


Observer hall-1

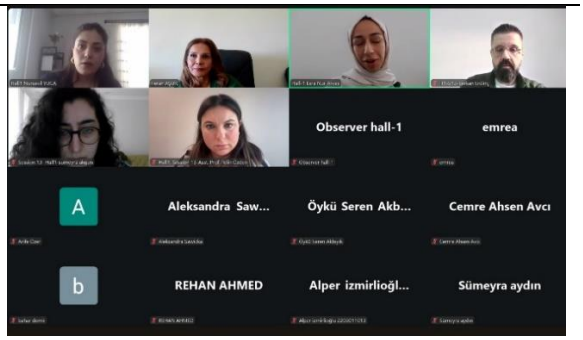

Emre Ecevit
Observer hall 2
ZÜBEYDE ÇİÇEK


V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/
1
Reducing the Urban Heat Island Effect with Water Surfaces: The Case of Hazar Lake
Dr. Yaşar MENTEŞ
Ministry of Agriculture and Forestry
Provincial Directorate of Agriculture and Forestry
Elazığ, Türkiye
Email: yasarment@hotmail.com
Prof. Dr. Sevgi YILMAZ
Atatürk University
Faculty of Architecture and Design
Landscape Architecture Department
Erzurum, Türkiye
Email: sylmaz_66@hotmail.com


Material and Method
Using a qualitative case study of the Rami Barracks' transformation into Turkey's largest library, the study triangulates primary and secondary data — including historical, architectural, spatial, and sustainability sources.
These encompass archival records, 2014–2023 restoration drawings, programmatic and capacity metrics, and Biosphere certification / landscape data.
Supported by an extensive literature review on adaptive reuse, the research analytically evaluates the relationships among conservation, public space production, and cultural memory.
Stage
Description
Objective
Literature Review
Identifying fundamental concepts and research gaps on adaptive reuse.
To establish the conceptual framework and guide the case selection.
Case Selection
Selecting an example of sustainable reuse.
To ensure representativeness.
Data Collection and Analysis
Examining practices from institutional documents, projects, and reports.
To understand reuse and conservation strategies.
Evaluation and Recommendations
Evaluating the cultural, economic, and environmental impacts of historic building reuse and conservation strategies.
To assess the effectiveness of the strategies and their sustainability compliance.
Methodological Framework




Observer hall-1
BİRLİKTE TANI: ALİAĞA DEMOKRASİ MEYDANI
BİRLİKTE-TANI ALİAĞA DEMOKRASİ MEYDANI
İzmir'in Aliağa ilçesine bağlı Kültür Mahallesi'nde yer alan Aliağa Demokrasi Meydanı Merkez Camii, Aliağa İlçe Halk Kütüphanesi, çeşitli ticaret birimleri gibi önemli işlevler ile çevrelenmiştir. Meydan kültürel, sosyal ve rekreatif kullanımlar aracılığıyla transit geçişin


Observer hall-1
emrea
Aleksandra Saw...
Öykü Seren Akb...
Cemre Ahsen Avcı
REHAN AHMED
Alper izmirlioğl...
Sümeyra aydın

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

PROCEEDINGS BOOK

Abstract List

ISBN: 979-8-89695-259-6
DOI: https://doi.org/10.5281/zenodo.17937655

ISSUED: December 15, 2025

TITLE	AUTHORS	Page No
Urban Greening Transformation of Mediterranean Cities: An Application to the City of Naples	• Floriana ZUCARO	87
Replanning Benghazi's Historic Downtown: Restoring Identity	• Fathi M. LAYAS • Ramadan E. SULEIMAN • Vail KARAKALE	88
The Sculptural Effect in Architecture: The Valencia Opera House	• Nihansu KÜCÜ • Özgü ÖZTURAN • Şebnem ERTAŞ BEŞİR	89
An Evaluation of The Restoration of Seyh Mehmet Emin Efendi Lodge to Create an Effective Protection-Use Balance by Re-Functioning	• Eyüp Salih ELMAS	90
Architectural Creativity Through Generative Ai: Evaluating Dall·E, Midjourney, and Stable Diffusion	• Minel KURTULUŞ	91
Rural Decline and Revival: Alternative Living Models for the Revitalisation of Migration-Affected Settlements	• Melike AKSAKAL • Büşra YILMAZ ERDOĞAN	92
From Cultural Memory to Contemporary Design: Traces of Nomadic Structures in Sustainability	• Rümeysa ÜZÜM • Büşra YILMAZ ERDOĞAN	93
The Lifecycle Assessment Analysis: Recycled Concrete Aggregate Incorporating Boron	• Seda Nur ALKAN • Gamze DOĞDU YÜCETÜRK • Özkan ŞENGÜL	94
A Study on Rural Resilience: The Case of Akçaabat District	• Duygu AKYOL KUYUMCUOĞLU • Tuğçe YAZICI	95
A Machine Learning-Driven Model to Predict Urban Outdoor Thermal Comfort	• Hüseyin ÖGÇE • Meltem ERDEM KAYA	96
Strategic Approaches to Climate Change Adaptation and Mitigation	• İzel MERAL	97
A Sustainable Development Allegory: *Entelköy Efeköy'e Karşı and SDGS*	• Pınar ZEĞEREK ALTUNBEY	98
Development of Hospital Garden Design	• Melike SAĞLAM • Sima POUYA	99

Assessing Soundscape Quality in Urban Open and Green Spaces	• Gizem DELİKAN • Sima POUYA	**100**
Adaptive Reuse of Dead Malls into Healthcare Facilities	• Dilara BERK COŞKUN • Kunter MANİSA	**101**
Cappadocia of Traces: Temporary and Permanent Layers	• Emine AKCAN ŞİRİN	**102**
Sick Building Syndrome and Toxicological Assessment of Construction Materials Among Workers and Residents in Dutse Metropolis, Jigawa State, Nigeria	• Bate Garba BARDE	**103**
Integration of Informal Interactive Space in A Design of Faculty of Architecture	• A. A. Muhammed • D. O. Alonge • J. A. Yusuf	**104**
Societal Acceptance of Thermal Storage Wall in Buildings in Mediterranean Region	• Soad ABOKHAMIS MOUSAVi	**105**
Local Material Use in Interior Architecture for Thermal Comfort in Arid Climates: A Case Study of Ouarzazate, Morocco	• Chaimae KRAOUCH • Soad ABOKHAMIS MOUSAVI	**106**
Voicenote: Mobile App for Taking Voice and Written Notes	• Ceydanur DUMAN • Büşra TAKGİL	**107**
Evaluation of Room Acoustics in Auditoriums in the Context of Speech Intelligibility: An Examination of a University Auditorium	• Okan ŞİMŞEK	**108**
Multi-Layered Spatial Development of Konya: A Topological Analysis of The Basin at Two Scales	• Merve ALICI AKA • Elif Yeşim KÖSTEN • Gülşah ÜNER	**109**
The Transformation of the Rami Barracks into a Library: An Evaluation Within the Context of Adaptive Reuse	• Miskine AKAR • Derya SU	**110**
IoT And Mobile Application Based Smart Environment Monitoring and Drug Deterioration Prediction System Design	• Bedirhan KORKMAZ • Büşra TAKGİL	**111**
Sinan & Zaha: Shaping the Urban Skyline Through the “Art of Structure & Geometry”	• Ürün BİÇER • Serkan Yaşar ERDİNÇ	**112**

Smart Design Solutions For University Housing: A Waste-Optimized Architectural Solution for Postgraduate Accommodation at Futminna	• OKONNAH SAMUEL David	**113**
Effect of Material Suitability and Availability on Residents' Building Preferences in Nupe Land, Kwara State	• KOLO, Vincent Mana • OLAKANBI BOLAJI Abdulraheem	**114**
Influence of Lighting Quality on Emotional and Cognitive Responses to Artworks: A Comparative Study of Prominent Art Galleries in Lagos State, Nigeria	• SA'AD Muhammad Abolakale • OLAKANBI BOLAJI Abdulraheem	**115**
A Holistic Conceptual Framework for Biophilic Design in Healthcare Environments: Enhancing Elderly Well-Being Through Environmental Integration	• Aylar RANJBARIAN • Mehrdad KARIMIMOSHAVER	**116**
Building Envelope Strategies for Enhancing Urban Thermal Comfort: A Climate-Sensitive Perspective	• Alireza GERAMI • Mehrdad KARIMIMOSHAVER	**117**
Urban Morphology and Natural Ventilation: Evaluation of Different Textures in Hot and Dry Climate Cities (Case Study: Kashan City)	• Mostafa AZAD • Mehrdad KARIMIMOSHAVER	**118**
Urban Density, Morphology, And Soundscapes: Architectural Strategies For Sustainable Design	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**119**
The Interplay of Sound and Space in Vernacular Desert Housing: Toward Sustainable Futures	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**120**
Soundscapes and Human Experience: Architecture for the Ear in Urban Futures	• Melik Sami • Khelil Sara • Tallal Abdel Karim Bouzir	**121**
Smart Soundscapes: Acoustic Technologies for Sustainable Architectural Environments	• Melik Sami • Khelil Sara • Tallal Abdel Karim Bouzir	**122**
A Performance Driven Generative Design Workflow for Optimizing Building Facades for Daylight and Energy Efficiency in a Mediterranean Climate	• Fahim Yar BAIG • Samira MEHRAFZA	**123**

Building Climate Resilience Rural Settlement Design for Agricultural Communities	• Most. MOKARROMA • Esita GHOSH	**124**
Dynamics of Funeral Practices Among the Haussa Muslims of the City of Zinder	• SOUMANA Abdoul-Wahab • KASSOU Maman • LAWALI Maman Toukour	**125**
Spaces That Enhance Well-Being in Türkiye, Ireland, Netherlands, Portugal, Spain, and United States: Designing for Health as a Holistic Approach Where Human Resources Can Thrive	• Habil. Cristina Raluca Gh. POPESCU	**126**
Acoustic Planning Policies: Shaping Sustainable Urban and Architectural Environments	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**127**
Biomechanically Informed and Sustainable Architectural Design in Sports Facilities: Enhancing Athlete Performance and Spectator Experience	• Shiv KUMAR	**128**
Climate-Responsive Architectural Strategies for Lahore: A Bioclimatic Approach Toward Sustainable Design	• Farhana NAZ	**129**
Echoes of The Desert: Acoustic and Spatial Responses in Vernacular Sustainable Architecture	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**130**
Multiculturality of Lviv/Lemberg/Lwów, The Centre of West Ukraine, as Reflected in the Architectural History of The City	• Sándor FÖLDVÁRI	**131**
Potential And Constraints of Beekeeping Development in Sri Lanka: A Review on Socioeconomic, Technological, and Environmental Perspectives	• Mahamarakkalage NETHMI AYODYA PERERA	**132**
Valuing the Intangible: An Integrated Economic Framework for Assessing the Cultural Capital of Heritage Architecture in Urban Regeneration	• Mohsen Mohammadi KHYAREH • Mohadeseh NEZHADIPOUR	**133**
The Entrepreneurial City: Exploring The Impact of Zoning Regulations and Building Codes on Startup Ecosystems and Innovation Districts	• Mohsen Mohammadi KHYAREH • Mohadeseh NEZHADIPOURr	**134**

Enhanced Adsorptive Performance of Modified Clay for Efficient Dye Removal from Wastewater	• Soumaya MATCHI • Adil El YADINI • Hanae OUADDARI • Abdelkbir BELLAOUCHOU	**135**
Achievements in the Temple to Moon God Nanna Built By Kıng Ur Engur in 3 100 Bce in Ur in Mesopotamia	• Natela Borisovna POPKHADZE	**136**
Evaluation of Biophilic Design Principles in the Design Proposal of 5-Star Hotel	• Safiya Bello ABDULLAHI	**137**
Artificial Intelligence and 3d Printing Technology in Construction: A Review	• N.G. Kalyani REDDY • Chayaraju BALASAI • K. THARANI	**138**
Perceived Effects of Fuelwood Energy Exploitation on Livelihood of Farming Households in Bauchi and Gombe States, Nigeria	• Sani Madi YAKUBU • Hannatu Ohunene YUSUF • Fadlullah Olayiwola ISSA • Omadachi Ogbodo UGBABE	**139**
A Comparative Analysis of The Role of Rock-Cut Architecture in The Life Cycle of Rural Tourism: A Case Study of Kandovan, Iran, and Göreme, Türkiye	• Kazem GOLIZADEH	**140**
Threads of Escape: Adaptive Reuse of Trains	• Hira ZAINAB • Rimsha IMRAN • Maha TARIQ	**141**
Greasing The Gears of Innovation: The Role of Petroleum Chemistry in Architectural Design and Engineering	• Ibrahim Khalil ADAMU • Abdullahi ALIYU	**142**
Architecture, Environmental Externalities, And Economic Policy for Sustainable Cities	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**143**
The Trade-off Between Economic Growth and Environmental Architecture in Developing Regions	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**144**
From Farm to Cup: The Interplay of Sustainability and Governance in Ethiopia's Coffee Value Chain for Sustainable Development	• Sintayehu Assefa YIRGA	**145**

Artificial Intelligence Revolutions and Breakthroughs for Architecture, Engineering, Cultural Studies, and Environmental Disciplines	• Vinod Kumar VERMA • Klimis NTALINIS • Chao-Tung YANG • Carlos MORENO • Eric GAMESS • Monica Karel HUERTA • Vimal Rau APPROW	**146**
Smart and Ecological Cities: Pathways to Climate-Resilient and Sustainable Urban Futures	• K. R. PADMA	**147**
Sustainable Urban Planning and Development	• S. SHAKTHI SREE	**148**
The Urban Landscape of Western Europe: Impact of the Decline of the Western Roman Empire on Urbanization from AD 400 to the 17th Century	• Ananda MAJUMDAR	**149**
Sustainable Urban Farming in India: Pathways to Achieving the Sustainable Development Goals (SDGS)	• Hari Prasad AGARWAL	**150**
Integration of Digital Technologies in Landscape Design: Physics-Based Models and Technological Innovations in Agricultural Landscapes	• Ali Jan SHARIFI • Ahmad Farid QASEMI • Mohammad Bashir ASHRAFI • Hamed MOHAMMADI • Mohammad Yasin REZAEI	**151**
Capitalizing on Local Knowledge of Tetraclinis articulata in Morocco's Central Plateau: Challenges for Conservation of an Endangered Medicinal Heritage	• Jaayefar FATIMA-EZZAHRA • et Dahmani JAMILA	**152**
Contribution of Rural Infrastructure Development Fund (RIDF) in rural prosperity in India	• Bhawana PAL	**153**
Integrating Spatial and Environmental Needs in Architectural Education Design	• A. J. SIMON • D. O. ALONGE • E. UDOKO	**154**
Pekalongan City Culture and its Nickname as the City of Batik	• M. Fathrezza IMANI	**155**
Cybersecurity Risks in Smart Building Infrastructure	• Moses Adeolu AGOI • Samuel Olayiwola AJAGA • David Oladimeji AJIBODE • Oluwanifemi Opeyemi AGOI	**156**

Historic Monument Buildings – European Union Perspectives on Their Protection	• Voroneanu-Popa Rareș-VASILE • Richard CONSTANTINESCU	**157**
Socio-Economic Dynamics and Urban Transformation in Algerian Desert Cities: An Analytical Approach to the Case of Biskra	• MOKHNANE Tarek • KHIARI Reguia • ADJLANE Sabah	**158**
Eco-Friendly Foreign Investment: The Role of Green FDI in Sustainable Development	• Laura DIACONU (MAXIM) • Mihai-Bogdan PETRIȘOR	**159**
An Analytical Study of AI-Enabled Tourism and Global Integration	• Deepanjali MISHRA	**160**
The Energy Affordability Crisis: Fuel Price Shocks, Urban-Rural Disparities, and the Climate Mitigation Paradox in Northern Nigeria	• Sabiu Bello YUSUF • Ashiru BELLO • Umar SHAMSUDEEN	**161**
Legal Implications of Building Collapse in Nigeria: A Case Study Approach	• Samuel Akpadiagha ETUK • Udeme E. ETTENTUK	**162**
The Architectural Philosophy of Southern Albania (15th Century – Early 20th Century)	• Vivian MUKLI	**163**
Sustainable Concrete Design Using Low-Volume Fly Ash: Experimental Evaluation of Strength and Durability	• Marjuka MEHJABIN	**164**
Development of Smart Biosensors for Real-Time Glucose Monitoring	• DAVID. G • DEEPAK. S • PALANISAMY. A • RAVI. C • N. JAYARAMAKANI • R. SRINIVASAN	**165**
Islamic Economic Principles in Eco-Mosque Architecture: A Path to Sustainability	• Khelil SARA • Tallal Abdel Karim BOUZIR • Melik SAMI	**166**
The Green Waqf: Financing Eco-Architecture Through Islamic Endowments	• Tallal Abdel Karim BOUZIR • Khelil SARA • Melik SAMI	**167**

Economic Viability of Vertical Farming in Urban Architecture: A Sustainability Perspective	• Melik SAMI • Khelil SARA • Tallal Abdel Karim BOUZIR	**168**
Embedding Circular Economy Principles in Architectural Design for Sustainable Cities	• Khelil SARA • Melik SAMI • Tallal Abdel Karim BOUZIR	**169**
Logistical Aspects of The Transport System Development in Zakarpattia Region (Ukraine)	• Natalia HABCHAK • Svitlana MYSHKO	**170**
Economic Development and Sustainable Development Goals in Africa: Challenges, Opportunities, and Policy Perspectives	• Ali Jan SHARIFI • Ahmad Farid QASEMI • Mohammad Bashir ASHRAFI • Hamed MOHAMMADI • Mohammad Yasin Rezaei	**171**
Sustainable Irrigation of an Apple Orchard Using a PV Pumping System: A Case Study from Algeria	• Aicha BELGACEM • Fatima BELGACEM • Mohamed MOSTEFAI • Yahia MILOUD	**172**
Integrating Climate-Responsive Strategies in Environmental Design for Sustainable Urban Futures	• Jibril JAMILU • Ibrahim Khalil ADAMU	**173**
Advanced And Future NDDS Concept	• V. HARIHARAN, • D. KHAN • G. MADHAN PRASADH • S. PUNITHAVALLI • P. SARANYA • A. VIVEK • S. MAHAPATRA • R. THELSHATH	**174**
From Beneficial Modulation to Adverse Toxicity: Dose-Dependent Insights into TBHQ Safety Thresholds	• Saha, ANIK • Datta NARAYAM • Chowdhury BAPPy • Hossain, TAMIM • Ranjan Acharjee, MAHIMA • Prank RASEL • Ahmad MONSUR	**175**

Natural Farming a Sustainable Approach for Management of Soil Degradation and Climate Change Mitigation	• Ganesh KUMAR • R.Y HIRANMAI • Harshita MARWAL • Ajay NEERAJ	**176**
Smart İrrigation System for Sustainable Farming	• Nithish KUMAR R. • S. Udhaya KUMAR • S. RAKSHITH	**177**
Iranian Art and Architecture	• Mehdi Shalchi TOUSI	**178**
Information And Communication Technology Adoption Behaviour of Farmers in Thanjavur District: A Study	• B. MAHADEVAN	**179**
Comparison of the Effectiveness of Silicon and Nanosilicon in Stimulating the Growth of *Lycium Chinense* Mill. Shoot Cultures in Vitro	• Marcelina KRUPA-MAŁKIEWICZ • Ireneusz OCHMIAN	**180**
Conceptual Considerations on the Application of The Precautionary Principle in the Environmental Law Relationship	• Mihaela (BEJENARI) • COJOCARU	**181**
Toxic Tanning: Assessing Environmental Pollution and Occupational Health Risks in the Leather Industry	• Seifeslasie ASMAMAW • Esayas SHEGAW	**182**
Economic Implications of Climate Change on Rice (*Oryza sativa)* Production in Bangladesh	• Most MOKARROMA • Arifa YEASMIN • Salauddin SOHAN • Sakhawat Hosen SOURAV • ALSHAHRIA • Sazzadul ISLAM • Mizanur RAHMAN	**183**
Capacity Analysis of Signalized Intersections in Oran, Algeria: A Probabilistic Model for Left-Turn Movements	• Wissem BELKHEIR • Zahra BOUNOUARA • Fatima HADJADJ • Wafaa TEBBOUNE	**184**
Integrating Traditional and Modern Sustainable Architectural Practices for Cost-Efficiency and Climate-Responsive Buildings in Niger State, Nigeria	• Muhammad Hassan ISHAQ • Bukar Ali KIME	**185**

Public Squares Along Di douche Mourad Street in Skikda: Urban Continuities and Transformations	• Boukerma RIMA • Mansouri LAMIA • Bouaroudj RADIA • Mekki SANA • Azzam ROUFAIDA	**186**
Choosing a Slope-Stability Method under Groundwater Conditions: A Decision-Oriented Reframing of an Inter-Software Comparison	• Hachimi DAHHAOUI • Abdeldjalil ZADJAOUI, • Mohammed BEKHTI • Naima BELKADI	**187**
Rapid Estimation of Secondary Creep in Soft Clays Using Machine Learning	• Hachimi DAHHAOUI	**188**
The Circular Memory of Hands: Circularity in the Domestic Wisdom of Peoples	• Yasin KHALILOV	**189**
Circular Bridge from East to West: The Global Dialogue of Cultures	• Yasin KHALILOV	**190**
The Metaphysics of Form: Energy, Geometry, and Sphericity in Nature	• Yasin KHALILOV	**191**
Eco-Colonialism or Climate Justice? Reassessing Global Environmental Agreements from the Global South Perspective	• Astitva Kumar RAO • Anamika PRASAD	**192**
Geological Event Modelling and Illustration	• Abdelfattah ABOULFARAJ • Abdelhalim TABIT, Ahmed ALGOUTI • Latifa ABOULKASIM	**193**
Eco-Building Mortars Incorporating Sewage Sludge Ash for Sustainable Construction: A Review	• BOUSLAH Mahmoud • MAZA Mekki • RAHMOUNI Zine EL Abidine • TEBBAL Nadia	**194**
Thermal Stability of Composite Materials Using a Refined Higher Order Shear Deformation Theory	• Tebboune WAFA • Belkheir WISSEM • Bounouara ZAHRA • Hadjaj Fatima ZOHRA	**195**
Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design	• B. S. Abdur Rahman CRESCENT	**196**
Green by Design: The Role of Urban Farming in Achieving Sustainable Cities	• Astitva KUMAR RAO	**197**

Synthesis, Characterization, and Evaluation of Biological Activities of M(Ii) Metal Complexes (M=Co, Zn and Cu) Based on a Bidentate Schiff Base Ligand	• Ibtissam ELAARAJ • Oumayma OULIDI • Asmae NAKKABI • Noureddine El MOUALIJ • Mohammed FAHIM • Filippo GIARRATANA	**198**
The Use of *Berberis* L. Species in the Creation and Reconstruction of Parks and Squares in the Steppe Dnipro Region	• Anatoliy M. KABAR • Tetyana Y. LYKHOLAT • Maksim O. KVITKO • Olena A. LYKHOLAT • Yuriy V. LYKHOLAT	**199**
The Ksour of the Ksour Mountains in Algeria: An Oasian Heritage on the Path to World Recognition	• Sana MEKKI • Rima BOUKERMA • Leila SRITI	**200**
Green Spaces: Restoring Mind and Body in Urban Life	• Maryam MOSLEHI	**201**
Effects of Organic Mulch and Natural Methods on Soil Moisture Retention and Growth of *Ziziphus spina* Christi Seedlings in Afforestation	• Maryam MOSLEHI	**202**
Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design	• ARAVINDHAN. R. • RAMSHIN R. • SRI HARSHAVARSHINI C.	**203**
Strength Characteristics of M40 Grade Concrete as Partial Replacement of Cement by GGBS and Fine Aggregate by Crusher Dust	• Subhashish DEY	**204**
Durability of Vegetable Fiber-Reinforced Concrete Under External Sulfate Attack	• Imane MIHOUB • Sif Allah MEGHZILI • Abderraouf ACHOUR	**205**
Mapping Albania's Cultural Heritage: A Spatial and Typological Analysis of Tangible and Intangible Assets	• Mishela RAPO	**206**
Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj	• Shahriar Hasan Mridha RATUL • Moukuri MOHIM • Ahsan REZWAN	**207**
Partial Replacement of Coarse Aggregate with Crumb Rubber Chips in Concrete Production	• N.G. KALYANI REDDY • Chayaraju BALASAI • K. THARANI	**208**

Implications and Environmental Impact of Artisanal Gold Mining on Land use Patterns in Minna Metropolis, Niger State	• ABDULLAHI, M.I. • USMAN, Z.N. • NDAKO N. • ABDULLAHI M. K. • HUSSAINI, I.	**209**
Assessment of Aquifer Protective Capacity and Corrosivity Around Solid Waste Dumpsites in Parts of Minna Metropolis, North-Central, Nigeria	• BALARABE, J. J. • RAFIU, A. A. • ADETONA, A. • SHEHU, J. • SALIHU, Y. L.	**210**
The Role of Artificial Intelligence in Creating Public Value in Local Government: Evidence from Hyderabad City, Pakistan	• Liaquat Ali RAHOO • Muhammad Nawaz TUNIO	**211**
The Role of Mosques and Shrines in the Socio-Political Life of Settlements and Their Influence on Urban Formation	• Mahammad BAYRAMOV	**212**
Utilizing Recycled Aggregate Concrete	• Chayaraju BALA SAI • Nadagouda KALYANI • K. THARANI	**213**
Intellectual Property and Design Protection	• Aswin M. NAIR • Payal SHUKLA	**214**
Exploring Evidence Based Design Strategies to Foster Healing in the Design of a Paediatric Hospital in Rigasa, Kaduna State	• Amira ABDUL-AZEEZ	**215**
Use of Artificial Intelligence in Transport for Rural Development	• J. Salai Thillai THILAGAM • Gorla LALITHA	**216**
GEP- Based on Modelling of Alkaline Activators Effects on Geopolymer Concrete	• Chayaraju BALA SAI • Nadagouda KALYANI • K. THARANI	**217**
Forest Carbon Assessment and Modelling in Bangladesh: Pathways for Sustainable Forest Management and Climate Mitigation	• Sadid SHAHRIYAR	**218**
Experimental Study on Mechanical Properties of Normal Strength Concrete by Partial Replacement of Fine Aggregate with Demolished Brick Waste	• Pathangi ESWANTH • Mahendrakar HEMANTH KUMAR • Ramireddy SUSHMITHA	**219**
Impact of Green Finance in Sustainable Performance: mediating the role of CSR	• Aqsa FAROOQ • Rimsha IQBAL	**220**

Smart Fabrication and Automated Building Technologies	• KISHORE. R • VAISHNAVI. K • KEERTHANA. V • MEENATCHI. S • SARAVANAN	**221**
Photoresponsive Behavior of N-Acylhydrazones: A Study of Solvent-Dependent E/Z Isomerization	• Yahya BOUBEKRI • Amina AMINE • Siham SLASSI • Mohammed AARJANE	**222**
Integration of Advanced Building-Integrated Photovoltaic (BIPV) Systems for Sustainable Architectural Design	• Muhammad Mateen AFZAL AWAN	**223**
	•	
	•	
	•	

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Greening Transformation of Mediterranean Cities: An Application to the City of Naples

Floriana ZUCARO [1*]

ORCID 1: 0000-0003-4171-3659
[1]PhD, University of Naples Federico II,
Civil, Building and Environmental Engineering Department (DICEA), Naples-Italy
floriana.zucaro@unina.it ***(**Responsible Author)

Abstract

Global warming increases the risks of heat stress in urban areas, endangering people's health and the ability of permeable surfaces to regenerate. The scarcity of green spaces, combined with the dense and compact structure of highly built-up cities like those in Europe and the Mediterranean, makes implementing mitigation measures especially difficult. These limitations greatly restrict opportunities to transform and renovate open spaces, necessitating careful and innovative approaches that balance climate effectiveness, heritage preservation, and urban usability.

As temperatures rise, it becomes essential to adapt and reorganize urban spaces and activities to ensure resilience against the unpredictable impacts of climate change, protect urban assets, and most importantly, enhance people's quality of life.

The methodology involves interconnected phases that provide knowledge and practical results by integrating GIS and microclimatic tools. This approach is applied in Naples, southern Italy, where the current baseline scenario is compared to a comprehensive greening and reforestation transformation of all open spaces, including planting 50 cm high grass and new trees.

The study shows that widespread conversion to green and permeable surfaces, even on a small scale, can significantly lower key summer comfort indices. It emphasises that priority interventions should focus not only on large parks but especially on small open spaces, mainly in the historic parts of the city. The benefits of increased greenery in reducing urban heat island effects and improving runoff management are evident in both central and peripheral areas, experiencing high energy use and flooding risks. These findings offer a strong foundation for local authorities, designers and residents to implement targeted adaptation strategies.

Keywords: Urban greening, urban reforestation, micro-climate simulations, GIS, urban planning

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Replanning Benghazi's Historic Downtown: Restoring Identity

Fathi M. LAYAS[1*]

ORCID 1: 0009-0002-6121-6924
[1]University of Benghazi, Faculty of Engineering, Civil Engineering Department, Benghazi, Libya.
*fathi.layas@uob.edu.ly **(**Responsible Author)

Ramadan E. SULEIMAN[2]

ORCID 2: 0009-0002-6121-6924
[2]University of Benghazi, Faculty of Engineering, Civil Engineering Department, Benghazi, Libya.
resuleiman@yahoo.com

Vail KARAKALE[3]

ORCID 3: 0000-0002-3799-8439
[3]Istanbul Medeniyet University, Faculty of Engineering, Civil Engineering Department, Istanbul, Türkiye.
vail.karakale@medeniyet.edu.tr

Abstract

The historic core of Benghazi, a critical and culturally rich area, has suffered extensive damage from recent conflict. Bordered by Omar Ibn Al-Aas Street to the south, Omar Al-Mukhtar Street to the north, Ben Issa Street to the east, and Gamal Abdel Nasser Street to the west, this area is in urgent need of comprehensive reconstruction. The primary goal of this effort is to create a new vision for this part of the city, one that ensures the safe return of its residents while preserving its unique cultural and historical identity.

The initiative is built on a two-phase approach. Phase one begins with a detailed damage assessment, classifying the extent of the destruction across all buildings. This crucial step provides the data needed to inform effective rehabilitation strategies, allowing planners to determine the most suitable action for each structure—whether it requires full reconstruction or restoration.

Phase two focuses on the replanning effort itself, which aims to revitalize and protect Benghazi's identity. This includes safeguarding religious sites, historical landmarks, and other defining features of the city's character. To achieve this, we will develop separate rehabilitation schemes: one specifically for ordinary buildings to meet modern needs, and another for historic structures to preserve the city's unique architectural and cultural heritage for future generations. This dual approach ensures a balanced and thoughtful reconstruction that honors the past while building a resilient future.

Keywords: Urban replanning; cultural identity; historical identity; restoration; reconstruction.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Sculptural Effect in Architecture: The Valencıa Opera House

Nihansu KÜCÜ[1*]

ORCID 1: 0009-0000-8744-8921
[1]Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya- Türkiye
nihansu.akat@gmail.com

Özgü ÖZTURAN[2]

ORCID 2: 000-0002-8639-5570
Doc. Dr., Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya- Türkiye
ozgu@hotmail.com

Şebnem ERTAŞ BEŞİR [3]

ORCID 3: 0000-0002-0568-6529
[3] Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya- Türkiye
sertasbesir@akdeniz.edu.tr

Abstract

Following the Industrial Revolution, the socio-cultural transformation accelerated the permeability between art and architecture. Within the modernist context, structure was no longer perceived merely as a load-bearing component, but rather as an aesthetic and sculptural medium. This study explores the intersection of sculpture and architecture through Santiago Calatrava's Palau de les Arts Reina Sofía (Valencia Opera House), analyzed within the framework of semiotics. The methodology relies on photographs, drawings, the architect's statements, and secondary literature. Form, the symmetrical shell structure, and the external envelope are examined as signifiers, while functional layout, circulation, and spatial experience are considered as signified.

The findings indicate that the exposed structure not only produces visual impact but also enhances spatial legibility, enriches user experience, and contributes to the building's iconization at the urban scale. The Valencia Opera House, shaped by Calatrava's biomorphic and sculptural design language, exemplifies a contemporary architectural product where engineering and art converge. The study highlights the articulation of form, structure, and meaning as key components of sculptural architecture.

Keywords: Sculptural architecture; semiotics; Santiago Calatrava; *Palau de les Arts Reina Sofía*; icon–index–symbol

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Evaluation of The Restoration of Seyh Mehmet Emin Efendi Lodge to Create an Effective Protection-Use Balance by Re-Functioning

Eyüp Salih ELMAS [1*]

ORCID 1: 0000-0002-7363-6670
[1] Dr., Provincial Manager Advisor, Ministry of Environment, Urbanization and Climate Change, Istanbul Provincial Directorate, Istanbul- Türkiye
eselmas@gmail.com

Abstract

Sufi orders which emerged alongside Sufism in the Ottoman Empire, constructed lodges to provide spiritual and moral education. Initially consisting of a single room, these lodges evolved over time to incorporate various architectural features and units.

The dervish lodge building of the subject of this study, is located in the Beykoz district of Istanbul. The lodge was established by Mehmet Emin Efendi who is a Nakşıbendi Şeyh between 1829 and 1830 and its foundation charter was drawn up between 1820 and 1821. The lodge building is a single-story, masonry structure with a mezzanine.

Following the founding of the Republic of Türkiye, the lodges considered to have completed their mission were closed in 1925. The Seyh Mehmet Emin Efendi Lodge Building which remained abandoned and neglected after the lodges were closed was demolished towards the end of the 1930's, because it was located within the section of the Bosphorus Coastal Road during the reconstruction process leaving only a portion of the main wall. The main wall traces served as an important reference point in preparing documentation and conservation projects.

Using written and visual materials (old and new buildings, aerial photographs and maps), analyses of the lodge building and its surroundings were conducted. Survey, restitution, and restoration projects were prepared by The Beykoz Municipality in 2017, during the author's tenure as a senior manager. A reconstruction decision was obtained from the relevant Cultural Heritage Preservation Board. The restoration permit and accompanying projects for the dervish lodge building deemed suitable for reuse as a cultural center were approved by the Boğaziçi Zoning Directorate. The lodge building and its surroundings were revitalized within the framework of conservation projects approved by official institutions.

Keywords: Conservation, restoration, The Seyh Mehmet Emin Efendi Lodge, re-functioning.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Architectural Creativity Through Generative Ai: Evaluating Dall·E, Midjourney, and Stable Diffusion

Minel KURTULUŞ [1*]

ORCID 1: 0000-0003-4623-0613
[1]Asst. Prof., Istanbul Gelisim University, Department of Interior Architecture, Istanbul-Türkiye
mikurtulus@gelisim.edu.tr ***(**Responsible Author)

Abstract

This study aims to examine the contributions of generative artificial intelligence (GAI) models to the processes of architectural form generation. In particular, the models DALL·E (OpenAI), Midjourney, and Stable Diffusion, which generate images from text prompts, are comparatively analyzed. The primary objective is to evaluate the potential of these models in terms of conceptual design, formal diversity, visual quality, and user control, and to determine their level of integration into the architectural design process.

A qualitative comparative methodology is adopted in this research. Architectural design prompts with identical or similar content were used with each model to generate visual outputs. These outputs were assessed based on criteria such as formal creativity, technical precision, aesthetic quality, and ease of use. Additionally, functional aspects including accessibility, controllability, and applicability in educational and research environments were analyzed.

The findings indicate that DALL·E provides a balanced approach between realistic and conceptual visualization; Midjourney stands out in producing aesthetically rich, abstract, and creative forms; while Stable Diffusion emerges as a strong alternative for experimental and research-oriented architectural productions, owing to its open-source structure and customizability. Moreover, Stable Diffusion demonstrates higher levels of prompt sensitivity and responsiveness to technical detail.

In conclusion, generative AI models can be integrated as creative and supportive tools into the architectural form-generation process. However, the choice of model should vary depending on the design objective and contextual needs.

Keywords: Artificial intelligence, architectural form generation, generative ai models, DALL·E, midjourney, stable diffusion, visualization in the design process.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Rural Decline and Revival: Alternative Living Models for the Revitalisation of Migration-Affected Settlements

Melike AKSAKAL [1*]

ORCID 1: 0009-0009-1173-5655
[1]KTO Karatay University, Faculty of Fine Arts and Design, Department of Architecture, Konya/Türkiye
melikeaksakal12@gmail.com *(Responsible Author)

Büşra YILMAZ ERDOĞAN [2]

ORCID 2: 0000-0002-2993-4240
[2]Res. Assist. Dr., KTO Karatay University, Faculty of Fine Arts and Design, Department of Architecture, Konya/Türkiye

Abstract

The population losses experienced in rural areas in recent years are not merely a numerical decline; they also signal the rapid disappearance of cultural heritage, traditional architecture, local production methods, and social fabric. However, villages that have experienced migration are not merely witnesses to the past; they are also potential spaces for alternative and sustainable living models. This study argues that rural settlements affected by migration are undergoing not only physical decline but also cultural, economic, and social disintegration. It examines the importance of revitalizing these areas from a multidimensional perspective. The potential of sustainable development tools such as agriculture-based development, women's labor-focused production networks, cooperatives, local production, eco/agro-tourism, and cultural routes is highlighted in terms of preserving rural heritage and sustaining local identity. Preserving and applying traditional construction techniques supports the continuity not only of architectural heritage but also of historical and cultural memory. Active participation of local communities enables more sustainable, need-based solutions rather than imposed models, while promotional opportunities such as digital platforms, films, and cultural events enhance the visibility and appeal of rural life. This study views abandoned rural areas not only as heritage sites to be preserved but also as potential spaces for productive, resilient living models oriented toward the future. Ultimately, it aims to contribute to emerging holistic conservation approaches by proposing a redefined understanding of rural conservation and encouraging an approach that integrates spatial improvement with social transformation.

Keywords: Abandoned villages, local participation, rural development, rural heritage, rural revitalization

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

From Cultural Memory to Contemporary Design: Traces of Nomadic Structures in Sustainability

Rümeysa ÜZÜM [1*]

ORCID 1: 0009-0005-0455-4793
[1]KTO Karatay University, Faculty of Fine Arts and Design, Department of Architecture, Konya/Türkiye
rumeysauzm0@gmail.com ***(**Responsible Author)

Büşra YILMAZ ERDOĞAN [2]

ORCID 2: 0000-0002-2993-4240
[2]Res. Assist. Dr., KTO Karatay University, Faculty of Fine Arts and Design, Department of Architecture, Konya/Türkiye

Abstract

Nomadism is a lifestyle based on the seasonal and regular movement of communities, typically rooted in pastoral animal husbandry. This way of life requires harmony with the environment, which in turn necessitates architectural structures that are portable, lightweight, durable, and temporary. In this study, the concept of nomadism is examined from cultural, economic, and social perspectives, with attention to spatial organization and usage patterns. Through literature research, portable architectural typologies emerging in different regions are analyzed; examples such as yurts, Bedouin tents, tipis, and yak hair tents are evaluated in detail. These structures share common characteristics in terms of construction techniques, materials, spatial organization, and cultural symbols, including lightness, ease of transport, quick assembly and disassembly, climate adaptability, and sustainable use of natural and local materials. Designed as single-volume, multifunctional spaces, these sustainable structures minimize environmental impact, use resources efficiently, and support communal lifestyles by strengthening social bonds. The study investigates the typological features of architectural forms developed in relation to the nomadic way of life, revealing how they have inspired contemporary approaches centered on sustainability, modularity, and temporariness. It is determined that modern solutions such as the tiny house movement, mobile structures, container homes, and disaster shelters are directly influenced by traditional nomadic architecture. The analysis of these typologies serves as a reference not only in historical and cultural contexts but also in the development of innovative, environmentally friendly designs. The study aims to offer a concrete evaluation of how these traditional principles can be integrated into contemporary architectural practice.

Keywords: Temporary shelter, nomadic architectural forms, mobile structures, mobile architecture, sustainable architecture

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Lifecycle Assessment Analysis: Recycled Concrete Aggregate Incorporating Boron

Seda Nur ALKAN [1*]

ORCID 1: 0002-3482-5348
[1]Assist Prof. Dr., İstanbul Medipol University, Faculty of Fine Arts, Design and Architecture, Department of Architecture, İstanbul-Türkiye
alkan.sedanur@gmail.com *(Responsible Author)

Gamze DOĞDU YÜCETÜRK [2]

ORCID 2: 0002-0278-8503
[2]Assoc. Prof. Dr., Bolu Abant İzzet Baysal University, Faculty of Engineering, Department of Environmental Engineering, Bolu- Türkiye

Özkan ŞENGÜL [3]

ORCID 2: 0003-3353-2516
[2]Prof. Dr., İstanbul Technical University, Faculty of Engineering, Department of Civil Engineering, İstanbul- Türkiye

Abstract

Recycling has become a critical issue considering the results of global warming, especially the depletion of natural resources. Concrete, as one of the commonly used construction materials, has been a crucial research topic in order to decrease the disadvantages of the high amount of energy consumption during the production phase and the limited recycling opportunities after destruction. After the February 6, 2023 earthquakes in Türkiye, depending on the high amount of construction and demolition waste (CDW), recycling concrete (RC) can be an efficient way in terms of preservation of natural resources and sustainability of the environment and economy. Additionally, several urban transformation projects have been planned and implemented in most of the cities of Türkiye. Accordingly, recycling CDW may play a significant role in reusing waste with an environmentally friendly approach. In this study, the equivalent CO_2 emissions of recycled concrete aggregate (RCA) incorporation of various proportions of boron were investigated by applying the Excel-based GreenConcrete LCA software developed at the University of California Berkeley Campus (UC Berkeley). Based on the analysis, it is observed that the use of RCA has a positive contribution to the environmental impacts in the LCA analysis. Furthermore, the use of concrete mixtures that contribute to the recycling of waste, boron, as admixtures contributes to reducing the environmental damage of the waste and developing material properties.

Keywords: Construction and demolition waste (CDW), boron, lifecycle assessment analysis (LCA), recycled concrete aggregate (RCA), Türkiye

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Study on Rural Resilience: The Case of Akçaabat District

Duygu AKYOL KUYUMCUOĞLU[1*]

ORCID 1: 0000-0002-7191-9343
[1]Asst.Prof., Karadeniz Technical University, Faculty of Foresty, Department of Landscape Architecture, Trabzon, Türkiye
[*]duyguakyol@ktu.edu.tr **(**Responsible Author)

Tuğçe YAZICI [2]

ORCID 2: 000-0003-3653-4170
[2] PhD Student, Karadeniz Technical University, Faculty of Foresty, Department of Landscape Architecture, Trabzon, Türkiye.
tugceyazici.pem@gmail.com

Abstract

Rural resilience is defined as the capacity of rural areas to survive, adapt, and, when necessary, transform in the face of environmental, economic, and social shocks. The concept emerged from the theoretical framework developed in the 1970s on the resilience of ecological systems and has evolved over time into a multidimensional structure with a socio-ecological systems perspective. Today, rural resilience studies are based on a holistic approach that considers interrelated factors such as climate change, natural disasters, economic fluctuations, migration movements, and cultural transformations.

This paper first examines the historical development of the concept of rural resilience in the literature and its definitions across different disciplines, focusing on three main dimensions: ecological resilience economic resilience and social resilience. In the second part of the study, the Trabzon/Akçaabat district, located in the coastal-rural transition zone of the Black Sea Region, is examined as a case study. Akçaabat offers a suitable platform for multidimensional resilience discussions, with factors such as agricultural production systems (especially hazelnuts and tea) vulnerable to climate change, urbanization pressures, youth migration, and the fragility of coastal ecosystems. The theoretical framework found in the literature is linked to Akçaabat's local dynamics, and recommendations are developed to enhance resilience capacity.

Keywords: Rural resilience, rural planning, landscape planning, rural development, Akçaabat

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Machine Learning-Driven Model to Predict Urban Outdoor Thermal Comfort

Hüseyin ÖGÇE [1*]

ORCID 1: 0000-0001-9051-4272
[1] Research Assistant, Istanbul Technical University, Faculty of Architecture, Department of Landscape Architecture, Istanbul-Türkiye
ogce20@itu.edu.tr *(Responsible Author)

Meltem ERDEM KAYA [2]

ORCID 2: 0000-0002-3272-3049
[2] Prof. Dr., Istanbul Technical University, Faculty of Architecture, Department of Landscape Architecture, Istanbul-Türkiye

Abstract

Climate change has been significantly altering both natural and built environments, leading to more frequent extreme weather events, droughts, microclimate shifts, and associated outdoor thermal comfort (OTC) challenges in urban areas. Predicting the magnitude and extent of these changes is essential for climate-responsive landscape design. However, microclimate models such as ENVI-met, while highly detailed, require substantial computational power and long simulation times, limiting their accessibility in practical decision-making.

*This study develops a machine learning (ML)-based model to predict the OTC in open and semi-open urban areas in the Tuzla district of Istanbul for the year 2100, using climate projections under the RCP8.5 scenario. ENVI-met simulations were performed for 24 grid-based urban configurations (100*100 cells, 2*2 m resolution), incorporating diverse surface covers and vegetation types. Microclimatic variables - including air temperature, mean radiant temperature, wind speed, relative humidity, shortwave radiation, and Physiological Equivalent Temperature (PET) - were collected at pedestrian height (1.4 m).*

After data cleaning, balancing, and augmentation, the final dataset comprised over 200000 cell-level records. A Random Forest Regressor was trained separately for tree shade and open conditions, using surface and tree types as primary predictors. Currently, model performance showed high prediction performance when it compares with ENVI-Met results (R^2 >= 0.8) for PET estimation. A user-friendly graphical interface enables rapid scenario evaluation without the need to operate complex simulation tools, allowing landscape architects and urban planners to assess the impact of surface and vegetation configurations on OTC under future climate conditions.

Keywords: Artificial intelligence, climate change, outdoor thermal comfort, ENVI-Met, landscape design

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Strategic Approaches to Climate Change Adaptation and Mitigation

İzel MERAL [1*]

ORCID 1: 0000-0001-7788-7672
[1]KTO Karatay University, Faculty of Fine Arts and Design, Department of Architecture, Konya-Türkiye
izelmeral@gmail.com ***(**Responsible Author)

Abstract

Climate change is one of the major issues of the 21st century, directly or indirectly affecting the lives of all living beings. When the 2021 IPCC (Intergovernmental Panel on Climate Change) reports are evaluated alongside previous IPCC reports, it is evident that the effects of climate change are becoming more pronounced (IPCC, 2021, IPCC, 2014, and IPCC, 2007). This study examines the factors causing climate change and the possible consequences associated with these factors. Since climate change is a complex and multidimensional problem, developing effective and sustainable solutions will be of great benefit on a global scale. The attitudes and approaches of different countries towards making cities more resilient in the fight against climate change have been examined. Based on current emissions, the latest data shows that China, the US, Russia, and EU countries are responsible for 50% of global emissions. In this context, countries such as the US, the Netherlands, Japan, Austria, Denmark, China, the UK, and Scotland, which contribute significantly to the increase in global emissions related to climate change, were selected. The use of permeable materials on Chicago streets allows rainwater to seep into the ground, improving drainage. In Rotterdam, rainwater is collected in basins and used to water plants in the square. A hotel in Vienna stores rainwater to irrigate its gardens and flush its toilets. Green parking lots in Copenhagen help prevent flooding. Green roofs in Shanghai improve air quality while reducing flood risk. The selected examples examine methods for mitigating the effects of climate change and strategies for adapting to climate change. Some of the recommendations for Türkiye include strengthening infrastructure systems, creating rainwater collection areas, increasing the use of renewable energy sources, reducing roof snow loads, using permeable materials on streets, and creating climate change action plans specific to cities. By following international developments in light of these recommendations, the negative effects of climate change can be mitigated.

Keywords: Climate change, urban resilience, climate change adaptation, and mitigation

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Sustainable Development Allegory: *Entelköy Efeköy'e Karşı and SDGs*

Pınar ZEĞEREK ALTUNBEY[1*]

ORCID 1: 0000-0002-5855-1484
[1]Research Assistant Dr., Niğde Omer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, Niğde-Türkiye
pzegerek@ohu.edu.tr***(**Responsible Author)

Abstract

Yüksel Aksu's 2011 film Entelköy Efeköy'e Karşı humorously engages with environmental sustainability themes, which remain underexplored in Turkish cinema. This study examines the film through the lens of the United Nations Sustainable Development Goals (SDGs), aiming to understand how popular culture reflects sustainability concerns. The story of a small Aegean village resisting a proposed thermal power plant provides a compelling backdrop for exploring these issues.

Through a qualitative film analysis, the study interrogates the film's social, economic, and environmental dimensions in relation to specific SDGs. Socially, the interactions between urban environmental activists and villagers reveal both conflicts and moments of solidarity, connected to SDG 10 (Reduced Inequalities) and SDG 16 (Peace, Justice, and Strong Institutions). Economically, the film highlights the tension between short-term promises of industrial development and the long-term sustainability of traditional agriculture, relating to SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production). Environmentally, the narrative emphasizes the importance of protecting natural resources and addressing climate change, corresponding to SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 15 (Life on Land).

Overall, this study illustrates how Entelköy Efeköy'e Karşı not only entertains but also communicates complex sustainability principles. By weaving together social justice, environmental stewardship, and economic considerations, the film exemplifies the interconnected nature of the SDGs. The analysis presented here reflects the unique contribution of cinematic narratives to fostering awareness and critical reflection on sustainability challenges.

Keywords: Environmental sustainability, environmental films, eco-criticism, political cinema, sustainable development goals (SDGs)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Development of Hospital Garden Design

Melike SAĞLAM [1]

ORCID 1: 0009-0007-5133-4499
[1]Research Assistant, Inonu University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya- Türkiye

Sima POUYA [2*]

ORCID 2: 0009-0007-5133-4499
[2]Prof. Dr., Inonu University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya-Türkiye
sima.pouya@inonu.edu.tr *(Responsible Author)

Abstract

Some clinical findings have been obtained regarding the effect of natural areas, which appear as hospital gardens, on the psychological well-being of patients. In the literature, the reasons for the positive contributions of being with nature to the daily lives of patients have been investigated and patients have been shown to benefit from nature internally, mentally and physically. In Türkiye, there are very limited institutions that individuals, especially those with cancer, who need hospital gardens can go to. For this reason, families and patients with cancer are helpless, hopeless, unhappy and in a difficult situation. Natural environments, such as hospital gardens, are known to positively impact patients' psychological well-being. However, these therapeutic spaces are scarce in Türkiye, causing distress for cancer patients and their families. To address this issue, this study aimed to create a design proposal for an interior garden at İnönü University's Oncology Hospital. The design's core goal was to reduce patient stress, enhance motivation, and provide a calm, welcoming space distinct from the typical hospital setting. The research methodology involved four stages: a literature review, an on-site survey, a needs assessment based on interviews and surveys with patients and doctors, and the development of a final design proposal using digital software. The study successfully identified key landscaping elements and provided concrete suggestions for designing effective therapeutic gardens for oncology patients.

Keywords: Cancer patients, hospital garden design, therapeutic landscape, healthcare architecture, patient well-being, healing environment, hospital stay

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Assessing Soundscape Quality in Urban Open and Green Spaces

Gizem DELİKAN [1]

ORCID 1: 0000-0002-4248-3990
[1]Research Assistant, Inonu University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya- Türkiye

Sima POUYA [2*]

ORCID 2: 0000-0001-6419-1756
[2]Prof. Dr., Inonu University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya-Türkiye
*sima.pouya@inonu.edu.tr **(**Responsible Author)

Abstract

Due to rapid urban growth and unplanned development driven by technological advancements, cities have become excessively dense. This has increased the importance of open and green spaces where individuals can meet their social, cultural, and physiological needs. However, the presence of uncontrolled environmental sounds in these areas negatively impacts the user experience and reduces spatial comfort. In this context, the primary goal of this study is to move beyond the "quiet/calm areas" approach in urban open and green spaces. The aim is to explain the design principles of "soundscape," a more comprehensive, human-centered, and perceptual concept, and to raise awareness about its significance. The research also aims to determine the auditory preferences of user profiles, a topic not yet comprehensively defined in Türkiye. The study takes a human-centric approach to evaluating the phenomenon of sound in the landscape design process. To this end, soundscape analyses were conducted in four different urban open and green spaces in the city of Malatya, using both objective measurements and subjective evaluations. Based on the collected data, sound and noise maps were created. Through surveys and observations, the "symbol sounds," "background sounds," and "foreground sounds" that define the auditory identity of the study areas were identified. The findings provided a foundation for developing design and planning recommendations to improve the quality of soundscapes in urban open and green spaces.

Keywords: Soundscape, soundwalk, noise, acoustic comfort

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Adaptive Reuse of Dead Malls into Healthcare Facilities

Dilara BERK COŞKUN [1*]

ORCID 1: 0000-0001-8397-0130
[1] Ph.D. Candidate., Yildiz Technical University, Building Research and Planning Ph.D. Program, Istanbul-Türkiye
dilara.coskun@std.yildiz.edu.tr*(Responsible Author)

Kunter MANİSA [2]

ORCID 2: 0000-0002-8209-0905
[2] Assoc. Prof., Yildiz Technical University, Faculty of Architecture, Department of Architecture, Istanbul-Türkiye
kunter.manisa@yildiz.edu.tr

Abstract

Shopping malls have long been conceived as major urban focal points and became spaces frequently preferred by users, leading to the development of numerous projects across different regions. However, over time, many malls failed to attract the expected interest. While some with qualified design and favourable locations achieved their user targets, others were forced to operate with low occupancy rates due to poor site selection, functional shortcomings, and architectural deficiencies. Declining occupancy reduced visitor numbers, and vacant areas not only caused economic losses but also contributed to the overall obsolescence of the building.

In recent years, the acceleration of digitalization, the rise of online shopping, shifting consumption habits, and economic fluctuations have further intensified this decline, rendering many shopping malls obsolete. This phenomenon has generated challenges beyond economics, extending to social and environmental impacts. Rather than demolition, adaptive reuse and reintegration of such underutilized structures into the urban fabric present more rational solutions in terms of cost, time, and sustainability.

This study examines the causes of functional decline in shopping malls and reviews transformation examples from both global and Turkish contexts. The analyzed cases highlight malls that have been reintegrated into urban life through functions such as education, healthcare, culture, commerce, and religion. Building on these precedents, the study discusses the potential of obsolete shopping malls to be converted into healthcare facilities, particularly regarding accessibility, infrastructural capacities, opportunities linked to urban memory, sustainability, enhancement of urban life quality, and contributions to health sector.

Keywords: Dead malls, adaptive reuse, medical mall, healthcare facilities

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Cappadocia of Traces: Temporary and Permanent Layers

Emine AKCAN ŞİRİN [1*]

ORCID 1: 0000-0003-1540-2427
[1]Assistant Professor, İstanbul Ticaret University, Faculty of Architecture and Design, Department of Architecture, Istanbul-Türkiye
easirin@ticaret.edu.tr *(Responsible Author)

Abstract

Cappadocia is a multi-layered spatiality produced at the intersection of nature and culture. By its very nature, it is a geography where both temporary and permanent traces coexist. On the one hand, the constant change created by weather conditions lends the space a sense of temporariness, while on the other hand, thousands of years of human settlements, both above and below ground, give the region a sense of permanence. Re-thinking this multi-layered spatiality in Cappadocia through the concept of "trace" in the context of both transience and permanence relates the "trace" to both its physical and cultural dimensions. The trace is a sign of both presence and absence. Traces that persist on the soil, landscape, and geography can be read not only as concrete reflections of natural processes but also as abstract counterparts of social memory, identity construction, and a sense of spatial belonging.

This study examines the dilemma between the temporary and permanent layers of traces in the rock-carved spaces of Cappadocia. Traces formed by nature and human hands reveal the layers of time and space; however, today, tourism pressure, spatial transformations, and lack of legal regulation leave these traces in a state of tension between erasure and preservation. In this context, traces produce a resistance against forgetting and disappearance, and traces at high risk of disappearing keep social memory and spatial continuity alive. The traces of Cappadocia reveal a plane extending from transience to permanence, allowing for questioning of the continuity between natural and cultural layers.

Keywords: Cappadocia, trace, temporary, permanent

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sick Building Syndrome and Toxicological Assessment of Construction Materials Among Workers and Residents in Dutse Metropolis, Jigawa State, Nigeria

Bate Garba BARDE [1*]

[1]Department of Environmental Sciences, Federal University Dutse, Jigawa State, Nigeria
bategarba@yahoo.com *(Responsible Author)

Abstract

The type and quality of construction materials determine to a large extent the prevalence of sick building syndrome (SBS) which puts the occupants' lives at risk. This study was conducted to assess the prevalence and risk factors of SBS stemming from construction materials among workers and residents in the study area. A total of 1765 study subjects were involved using a structured questionnaire and observational checklists in a multistage random sampling technique, covering homes, offices, classrooms and business premises. SBS symptoms were assessed using their confirmation criteria and their risk factors were determined using adjusted odds ratio (AOR) with logistic regression analysis at 95% confidence interval (CI). Results showed the general prevalence of SBS to be 58.02% while that of skin symptoms was 5.47% and mucosal symptoms was 93.46%. The most commonly reported symptoms include rhinitis (69.92%) and headache (24.02%) which were mostly observed in the construction workers (76.37%) and residents (23.63%). Type of construction materials were significantly related to SBS symptoms as risk factors which include paint (AOR=1.93, CI=0.48 to 7.77), cement (AOR=1.67, CI=0.26 to 10.06), plastic/rubber (AOR=1.38, CI=0.05 to 3.42) and iron (AOR=0.81, CI=0.17 to 3.92). It is suggested that construction materials in the study area should be standardized and regulated, the workers be provided with personal protective equipments and residents should be properly guided on how to care for themselves while occupying such structures.

Key words: Construction; sick building syndrome; adjusted odds ratio; prevalence; building materials.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Informal Interactive Space in A Design of Faculty of Architecture

A. A. MUHAMMED [1] *

[1] Department of Architecture, Federal University of Technology Minna
ojobee9@gmail.com *(Responsible Author)

D. O. ALONGE [1]

[1] Department of Architecture, Federal University of Technology Minna

J. A. YUSUF [1]

[1] Department of Architecture, Federal University of Technology Minna

Abstract

The integration of informal interactive spaces within the design of a Faculty of Architecture represents a strategic approach to fostering creativity, collaboration, and knowledge exchange among students and faculty members. Unlike traditional classroom and studio environments, informal interaction zones provide flexible, student-centered platforms for spontaneous dialogue, peer learning, and interdisciplinary engagement, which are essential in architectural education. This study explores the significance of incorporating such spaces into faculty building designs, highlighting their role in enhancing communication, social cohesion, and academic performance. Through a review of literature, case studies, and analysis of spatial qualities to identify key design parameters. Descriptive research design with a qualitative and quantitative approach was adopted as it allows for systematic exploration of existing informal interactive spaces within faculties of architecture while capturing user perceptions and spatial characteristics. The findings shows that many faculty are design with little or no consideration for user centric design idea which is the bedrock of informal interaction among users and also aligns with existing literature on the importance of informal spaces in educational environments. The study concludes that integrating informal interactive space in the design of faculty of architecture significantly shapes the students social and academic performance. It also suggests to the architects, designer and relevant authority to prioritizes its inclusion during the design stages.

Keywords: Student centered learning, informal space, interaction, architecture.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Societal Acceptance of Thermal Storage Wall in Buildings in Mediterranean Region

Soad ABOKHAMIS MOUSAVI [1*]

ORCID 1: 0000-0002-5710-6565
[1]Assoc.Prof. Dr., Arkin University of Creative Arts and Design, Faculty of Design, Department of Architecture, Northern Cyprus-Türkiye
soad.mousavi@arucad.edu.tr **(**Responsible Author)

Abstract

The Thermal Storage wall, an ancient passive solar technique, continues to be recognized for its effectiveness in enhancing passive solar systems. However, its practical implementation in contemporary architecture is hindered due to concerns regarding the visual impact of Thermal Storage wall on building facades. This study aims to address two primary objectives: (1) to investigate the reasons behind the limited adoption of Thermal Storage wall in Mediterranean region buildings, and (2) to propose potential solutions to foster societal acceptance of Thermal Storage wall in architectural designs. To accomplish these objectives, the present research endeavors to develop and design alternative Thermal Storage Wall configurations using different materials and facade treatments. A qualitative research methodology was employed, utilizing a combination of observation and questionnaires administered to diverse clients and expert architects within the targeted region. The findings reveal that through innovative designs, the incorporation of Thermal Storage wall on building facades can be accomplished without compromising aesthetic appeal.

Keywords: Thermal Storage wall, passive solar system, architectural design, Societal Acceptance, Building, Energy efficacy.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Local Material Use in Interior Architecture for Thermal Comfort in Arid Climates: A Case Study of Ouarzazate, Morocco

Chaimae KRAOUCH [1]

[1] Graduate Student, Final International University, Faculty of Architecture and Fine Arts, Institute of Graduate studies, Girne - Türkiye

Soad ABOKHAMIS MOUSAVI [2*]

ORCID 1: 0000-0002-5710-6565
[2]Assoc.Prof. Dr., Arkin University of Creative Arts and Design, Faculty of Design, Department of Architecture, Girne-Türkiye
soad.mousavi@arucad.edu.tr * **(**Responsible Author)

Abstract

This research investigates the role of local materials in achieving thermal comfort through sustainable interior architecture in arid climate housing, with a case study focused on Ouarzazate, Morocco. As climate resilience becomes increasingly urgent, there is a growing need to integrate passive design principles with regionally appropriate materials that respond to environmental challenges and cultural contexts. The study aims to explore how locally sourced materials such as adobe, rammed earth, and natural stone, can enhance indoor thermal performance while supporting ecological and economic sustainability.Due to logistical constraints, the research adopts a qualitative, desk-based methodology relying on secondary data, including climate analyses, architectural documentation, and literature on passive and sustainable design. Emphasis is placed on examining how material selection, spatial configuration, and surface treatments in interior spaces contribute to indoor comfort without mechanical systems. Findings indicate that the use of high thermal mass local materials significantly reduces indoor temperature fluctuations in arid zones. The study concludes that integrating these materials into contemporary interior architecture can provide an effective, culturally grounded strategy for sustainable housing in hot, dry climates like that of Ouarzazate.

Keywords: Thermal Comfort, Local Materials, Sustainable Interior Architecture, Passive Design, Arid Climate Housing

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Voicenote: Mobile App for Taking Voice and Written Notes

Ceydanur DUMAN [1]

ORCID 1: 0009-0003-0941-7523
[1]Student., Düzce University, Faculty of Engineering, Department of Computer Engineering, Düzce, Türkiye
ceydanurduman6@gmail.com

Büşra TAKGİL [2*]

ORCID 2: 0000-0002-7927-0083
[2] Asst. Prof., Düzce University, Faculty of Engineering, Department of Computer Engineering, Düzce, Türkiye
busratakgil@duzce.edu.tr ***(**Responsible Author)

Abstract

Today, the integration of mobile devices into every aspect of life and the proliferation of AI-powered voice interaction technologies enable individuals to access information more quickly and easily. The VoiceNote application offers users a note-taking experience using both voice input and voice output, an alternative to traditional text-based note-taking methods. This application is a two-way interactive mobile application that allows users to take notes in either voice or written format and listen back to them. Designed with Flutter, the application's front-end interface offers multi-platform support, while the back-end supports voice interaction using the Whisper (ASR) and Coqui TTS (TTS) models, running under the Python-based FastAPI framework. Authentication and real-time data management are provided using the Firebase infrastructure. The application has a flexible structure for offline scenarios. VoiceNote offers a user-friendly and sustainable digital note-taking solution that aims to increase accessibility, particularly for individuals with physical disabilities, the elderly, and users who lack the ability to write on the go. This system, developed as part of the project, offers a unique and functional contribution thanks to its open-source technology-supported structure and its suitability for multiple use cases. The results demonstrate that VoiceNote offers a unique and functional contribution thanks to its accessibility, multiple use cases, and open-source technology-based architecture.

Keywords: Artificial intelligence, automatic speech recognition (asr), Text-to-Speech Generation (TTS), flutter.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Evaluation of Room Acoustics in Auditoriums in the Context of Speech Intelligibility: An Examination of A University Auditorium

Okan ŞİMŞEK [1*]

ORCID 1: 0000-0003-3500-9438
[1] Research Assistant Dr., Adana Alparslan Türkeş Science and Technology University, Faculty of Architecture and Design, Department of Architecture, Adana-Türkiye
osimsek@atu.edu.tr ***(**Responsible Author)

Abstract

Auditoriums are spaces used for conferences, seminars, ceremonies, and educational purposes within university campuses, where ensuring a high level of speech intelligibility is of critical importance. The acoustic performance of such enclosed spaces depends on many physical variables, including volume, geometric proportions, stage design, source–listener relationship, surface material properties, and ceiling design. In this study, the auditorium of Adana Alparslan Türkeş Science and Technology University was comprehensively examined in terms of room acoustics, the current situation was analyzed, and improvement proposals were developed.

In the research process, the volume values, proportions, stage layout, and all surface materials of the space were examined in detail. Based on these data, the room acoustic parameters of reverberation time (RT), strength (G), and bass ratio (BR) were calculated. The calculated parameters were evaluated within the framework of national and international standards, and the obtained results were assessed in the context of the speech-oriented use of the space.

In the subsequent stage, design interventions were developed to improve acoustic performance. In particular, the ceiling design was reconsidered, solutions for achieving a more balanced distribution of reflections were proposed, and alternative usage scenarios for surface materials were discussed. In this context, the possible effects of different materials on absorbing, reflecting, or diffusing sound were evaluated.

The study emphasizes the necessity of providing acoustic conditions suitable for the functional uses of auditoriums in educational institutions and presents a guiding framework for the evaluation and design processes of similar spaces.

Keywords: Room acoustics, auditorium design, speech intelligibility

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Multi-Layered Spatial Development of Konya: A Topological Analysis of The Basin at Two Scales

Merve ALICI AKA[1*]

ORCID 1: 0002-8260-7767
[1] Research Assistant, Kocaeli University, Faculty of Architecture and Design, Department of Interior Architecture, Kocaeli-Türkiye
merve.alici@kocaeli.edu.tr *(Responsible Author)

Elif Yeşim KÖSTEN[2]

ORCID 2: 0003-3070-6015
[2]Assoc. Prof. Dr., Kocaeli University, Faculty of Architecture and Design, Department of Architecture, Kocaeli-Türkiye

Gülşah ÜNER[3]

ORCID 3: 0001-8039-3024
[3]Research Assistant, Kocaeli University, Faculty of Architecture and Design, Department of Architecture, Kocaeli-Türkiye

Abstract

Throughout history, Anatolia has been located at the intersection of east-west and north-south roads, hosted many civilizations; thus, a rich cultural heritage accumulated in its cities. Yet modernization and rapid urbanization have diminished its visibility in today's urban fabric and caused the fading of historical identity. Konya, in central Anatolia, is not only a transit point at the crossroads of historical routes but also a hub where cultural accumulations and socio-economic relations converge. Situated on the Royal Road, Silk Road and Pilgrimage Road, the city demonstrates a multi-layered spatial development.

This paper aims to read the historical development of Konya through transportation axes and to evaluate the layered structure of the city using the topological analysis method. This study adopts a two-scale approach: at the Anatolian scale, the physical geography of the basin and its surroundings, successive settlements/civilizations, and the historical road network shaped by geography are examined to reveal regional interactions; at the basin scale, the emergence of the first settlements following the retreat of the Ancient Lake Konya and the temporal connections of the ancient road network are assessed through the maps produced. In this context, the analysis process not only traces the historical continuity; it also focuses on identifying the cultural and spatial values that can guide future planning and design decisions for the city. Thus, it is aimed to shed light on today's urban interventions by considering the unique morphology created by transportation networks, together with urban memory and layered texture.

Keywords: Topology, Konya, route structure, urban morphology.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Transformation of the Rami Barracks into a Library: An Evaluation Within the Context of Adaptive Reuse

Miskine AKAR [1*]

ORCID 1: 0000-0002-9743-9401
[1] Research Assistant Dr., Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
miskine.akar@erdogan.edu.tr **(**Responsible Author)

Derya SU [2]

ORCID 2: 0000-0002-0908-8374
[2] Assistant Professor Dr., Fatih Sultan Mehmet University, Vocational School - Architectural Restoration Program, İstanbul-Türkiye
deryasu@fsm.edu.tr

Abstract

The reuse of buildings, also referred to as adaptive reuse, has emerged as a key design and planning strategy in contemporary architecture, combining sustainability principles with the preservation of cultural heritage. Located in Istanbul's Eyüpsultan district, the Rami Barracks was constructed in the second half of the 18th century and is one of the largest examples of Ottoman military architecture. After losing its military function in the 20th century, the complex served for decades as a storage facility and gradually fell into disuse. In 2023, following an extensive restoration and adaptive reuse project, it was reopened to the public as Türkiye's largest library.

The transformation of the Rami Barracks represents a significant example of adaptive reuse, in which the original spatial organisation, façade composition, and material character of the historic structure were preserved, while a "minimum intervention" principle guided the design. In parallel, contemporary functions such as reading halls, a children's library, exhibition spaces, event areas, and social amenities were carefully integrated into the building. The redesign of the courtyards and landscape aimed to create a public realm that harmonises with the library's new function.

This study examines the transformation of the Rami Barracks through the lenses of architectural conservation, public space production, and cultural memory. It discusses how the project goes beyond physical restoration, facilitating a symbolic shift in the urban memory from a site associated with military and commercial uses to a cultural and educational hub. The findings suggest that historic buildings can be both preserved and revitalised through adaptive reuse, thereby contributing meaningfully to the creation of high-quality public spaces.

Keywords: Adaptive reuse, architectural conservation, Rami Barracks, public space transformation, sustainable architecture, cultural heritage, reuse/repurposing.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

IoT And Mobile Application Based Smart Environment Monitoring and Drug Deterioration Prediction System Design

Bedirhan KORKMAZ [1]

ORCID 1: 0009-0004-2381-5795
[1]Student., Düzce University, Faculty of Engineering, Department of Computer Engineering, Düzce, Türkiye

Büşra TAKGİL [2 *]

ORCID 2: 0000-0002-7927-0083
[2] Asst. Prof., Düzce University, Faculty of Engineering, Department of Computer Engineering, Düzce, Türkiye
busratakgil@duzce.edu.tr *(Responsible Author)

Abstract

Storing medicines under optimal conditions is critical throughout the production and delivery process. Various environmental conditions, such as temperature and humidity, significantly impact the shelf life of medicines. This study develops an IoT-based mobile application system that continuously monitors the environmental conditions where medicines are stored, alerts users of out-of-threshold conditions, and also uses artificial intelligence to predict spoilage risk. The primary objective of the study is to instantly monitor environmental variables such as temperature, humidity, and gases, notify users of critical situations via mobile devices, and calculate the probability of spoilage based on environmental risk for drugs entered by the user using artificial intelligence. This system aims to detect improper drug storage conditions, prevent health risks, and minimize economic losses. The system transfers data obtained from DHT11 and MQ2 sensors to the Firebase database via ESP8266 and presents it to the user instantly in the mobile application interface. If the specified thresholds are exceeded, the system notifies the user with a push notification and lists critical situations within the application. The application also stores historical data and offers data export in PDF format. Users can enter medication information into the system and receive AI-powered spoilage predictions based on environmental conditions. This system offers an effective, reliable, and user-friendly solution, particularly for monitoring temperature- and humidity-sensitive medications. All functions operate in real time, and the system operates seamlessly within an integrated structure. The developed application is expected to offer an innovative and practical approach to environmental monitoring and health technologies and contribute to the foundation of more advanced systems in the future.

Keywords: Artificial Intelligence, IoT, mobile application.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sinan & Zaha: Shaping the Urban Skyline Through the "Art of Structure & Geometry"

Ürün BİÇER [1]

ORCID 1: 0000-0002-2436-9844
[1]Assist. Prof. Dr., İstanbul Beykent University, Faculty of Engineering and Architecture, Department of Interior Architecture, İstanbul-Türkiye
urunbicer@beykent.edu.tr

Serkan Yaşar ERDİNÇ [2*]

ORCID 2: 0000-0002-0970-3453
[2]Assist. Prof. Dr., İstanbul Beykent University, Faculty of Engineering and Architecture, Department of Architecture, İstanbul-Türkiye
yasarerdinc@beykent.edu.tr *(Responsible Author)

Abstract

In architecture, structure and geometry play important role in shaping of artefact, safety, durability and aesthetic value of structures. Architecture cannot be fully understood without discovering the dialectical relationship between structure and geometry. Mimar Sinan and Zaha Hadid interpreted this relationship in different eras and cultural contexts, reshaping the dimensions of architecture and silhouettes of cities.

Mimar Sinan, by blending the innovative geometric order and structural knowledge that brought to Ottoman Architecture, prioritized structural integrity and aesthetics in addition to functionality in his structures. On the other hand, Zaha Hadid's bold use of fluid geometric forms has not only ensured that the structures offer a visual feast, but also provided a futuristic image and structural strength. The works of these two great architects reveal the impact of the interaction between structure and geometry on architectural design and urban image, while providing examples of how these elements can be brought together in architectural practice.

In this context, the aim of the study is to analyze the geometric and structural elements in the designs of Mimar Sinan and contemporary architect Zaha Hadid from a holistic perspective. In the study, a qualitative research approach is adopted. Using a qualitative research and comparative analysis method, their design philosophies, aesthetic preferences and their effects on urban space will be systematically addressed. The iconic structures of Sinan and the geometric and structural innovations in Zaha Hadid's contemporary structures will be focused on with case studies, and the effects of the structures on the urban silhouette will be analyzed. The study will reveal how architecture evolved over time by bringing together the architectural understanding and geometric aesthetics of two different periods in a historical and cultural context and evaluating the works of two great architects.

Keywords: Mimar Sinan & Zaha Hadid, architectural geometry, structure & materiality, futuristic vision & innovation, city image

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Smart Design Solutions for University Housing: A Waste-Optimized Architectural Solution for Postgraduate Accommodation at Futminna

OKONNAH SAMUEL David [1*]

[1] Department of Architecture, Federal University of Technology, Minna
samuelokonnah@gmail.com *(Responsible Author)

Abstract

Solid waste management in university hostels is essential for environmental sustainability and public health. Inefficient systems in postgraduate hostels can lead to littering, poor sanitation, and operational challenges, highlighting the need for optimized management practices.

This study aims to optimise waste management systems in the design of postgraduate hostels, improving efficiency, reducing environmental impact, and promoting sustainable waste disposal behaviours among residents.

A qualitative approach was be employed, using unstructured interviews and non-participant observations. Participants from the interview included hostel managers, cleaners, waste collection contractors, and student residents. For the non-participant observation, purposive sampling with maximum variation was used to ensure diversity across hostels. The observations focused on three overarching themes; behavioural strategies in place, student participation behaviours, and effective indicators. The interviews explored participants' knowledge, attitudes, and perceptions of existing practices. Observational data was analysed using content analysis with deductive themes, while interview data was analysed using thematic analysis.

The study revealed that student participation in waste segregation was moderate, with higher compliance in hostels where bins were clearly labelled, awareness materials were visible, and waste collection was timely. Gaps were noted in areas with irregular collection and inconsistent behavioural strategies, like irregular waste segregation, delayed collection schedules, poor adherence to disposal guidelines, inconsistent monitoring and enforcement and limited community education indicating opportunities for improving operational efficiency and resident engagement.

Findings provided recommendations for integrating efficient waste management system into hostel design and operations, fostering sustainable practices and informing higher education environmental strategies.

Keywords: Behavioural strategies, observation, postgraduate hostels, solid waste management, thematic analysis, waste optimisation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Effect of Material Suitability and Availability on Residents' Building Preferences in Nupe Land, Kwara State

KOLO, Vincent Mana[1*]

[1]Department of Architecture, Faculty of Environment Sciences, University of Ilorin, Kwara, Nigeria

OLAKANBI BOLAJI Abdulraheem[2]

[2]Department of Architecture, Faculty of Environment Sciences, University of Abuja, FCT, Abuja, Nigeria
abdelrahim.bola@gmail.com *(Responsible Author)

Abstract

The increasing shift toward modern construction materials has led to the gradual neglect of indigenous materials traditionally used in rural Nigerian architecture, particularly in Nupe Land, Kwara State. This study examined the effect of material suitability and availability on residents' building preferences in the Nupe-speaking region of Edu Local Government Area. The primary aim was to evaluate how perceptions of indigenous materials influence construction choices and to identify factors that sustain or hinder their continued use. Specifically, the objectives were to assess community awareness of indigenous materials, determine their perceived suitability and availability, and explore challenges, opportunities, and cost implications associated with their use.

A mixed-methods approach was adopted. Quantitative data were collected through questionnaires administered to a sample of 330 respondents, drawn from an adult population of 2,257 residents across the villages of Bokungi, Yana, and Patidzuru. A total of 280 valid responses (86.4%) were analyzed using descriptive statistics such as frequencies, percentages, and means. Qualitative insights were obtained through interviews with local architects, builders, and artisans experienced in the use of indigenous materials.

Findings revealed a high level of awareness (80%) of indigenous materials among residents, with Earth, Laterite, and Timber rated highest in both suitability and availability. Over 70% of respondents perceived indigenous materials as more cost-effective than modern alternatives. However, the study identified growing neglect and decline in traditional knowledge, even though communities recognized the environmental, cultural, and aesthetic benefits of indigenous construction practices.

The study concludes that enhancing local production, technical training, and policy support can revitalize the use of indigenous materials, promoting sustainability and cultural preservation. It contributes to knowledge by linking material suitability and availability to user preference in rural housing development. It is recommended that government agencies, NGOs, and educational institutions promote hybrid building models integrating indigenous and modern materials to achieve affordable, climate-responsive architecture in nupe land, kwara state.

Keywords: indigenous materials, vernacular architecture, Nupe land, suitability, stability, sustainable construction, hybrid architecture, earthen construction, cultural heritage, Nigeria

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Influence of Lighting Quality on Emotional and Cognitive Responses to Artworks: A Comparative Study of Prominent Art Galleries in Lagos State, Nigeria

SA'AD Muhammad Abolakale[1]

[1]Department of Architecture, Faculty of Environment Sciences, University of Ilorin, Kwara Nigeria

OLAKANBI BOLAJI Abdulraheem[2]

[2]Department of Architecture, Faculty of Environment Sciences, University of Abuja, FCT, Abuja, Nigeria
abdelrahim.bola@gmail.com *(Responsible Author)

Abstract

Poor lighting design in art galleries can distort visual perception, reduce emotional engagement, and impair visitors' cognitive appreciation of artworks. In tropical contexts like Lagos State, Nigeria, where natural and artificial lighting conditions vary significantly, achieving optimal visual comfort remains a challenge. This study therefore examines the influence of lighting quality on emotional and cognitive responses to artworks across four prominent art galleries—Nike Art Gallery (Lekki), Red Door Gallery (Victoria Island), Mydrim Gallery (Ikoyi), and Thought Pyramid Art Gallery (Ikoyi). The study aimed to determine how lighting adequacy, visibility, comfort level, and shading effectiveness affect visitors' satisfaction and perceptual experiences.

A quantitative survey research design was adopted, using structured questionnaires administered to 382 visitor respondents, determined through Cochran's finite population correction method from an estimated 50,000 gallery visitors. Data were analyzed using the Satisfaction Index (SI), Mean Adequacy Score (MAS), and inferential statistical methods including Pearson correlation and multiple regression analysis to measure the relationships between lighting quality variables and visitors' emotional and cognitive responses.

Findings revealed that lighting quality significantly influenced both emotional and cognitive engagement. The overall MAS of 4.2969 indicated general satisfaction with lighting adequacy across all galleries. Comfort level (MAS = 4.4) and visibility of artworks (MAS = 4.375) ranked above the mean, confirming their positive impact on visitor experience, while shading effectiveness (MAS = 4.1875) scored slightly lower, suggesting minor improvement needs. Regression results further showed that lighting parameters collectively explained over 60% of the variance in visitors' emotional and cognitive satisfaction.

The study concludes that optimal lighting design enhances visitors' emotional connection, comfort, and interpretive depth within gallery environments. It contributes to knowledge by providing a quantitative framework for evaluating perceptual adequacy in art spaces. The study recommends that Lagos art galleries adopt adaptive daylight and artificial lighting systems, improved shading devices, and regular lighting audits to sustain visual comfort and enhance overall visitor experience.

Keywords: Lighting quality, emotional responses, cognitive responses, artworks, art galleries and Lagos State.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Holistic Conceptual Framework for Biophilic Design in Healthcare Environments: Enhancing Elderly Well-Being Through Environmental Integration

Aylar RANJBARIAN[1]

[1] Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran

Mehrdad KARIMIMOSHAVER[2]

ORCID 1: 0000-0001-5536-2138
[2] Professor of Architecture, Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran,
mkmoshaver@basu.ac.ir*(Responsible Author)

Abstract

Biophilic design, which integrates natural elements into built environments, offers significant potential for supporting human well-being, particularly among elderly populations who are vulnerable to environmental stressors in healthcare settings. Despite growing research, a critical gap persists: the absence of comprehensive, multisensory frameworks specifically tailored to healthcare environments for older adults. Existing studies often focus on isolated design elements, overlooking the complex interactions between environmental factors and the well-being of the elderly .This paper proposes a holistic conceptual framework that systematically integrates biophilic design principles into healthcare environments to enhance the well-being of the elderly through environmental integration. A systematic review and synthesis of interdisciplinary literature—including architecture, environmental psychology, gerontology, and healthcare design—identifies key biophilic elements and their theoretical applications in geriatric care .The framework encompasses five core dimensions: optimization of natural light to support circadian rhythms, integration of therapeutic greenery to reduce stress, incorporation of water features for visual and auditory comfort, enhancement of natural ventilation for air quality, and application of multisensory stimuli, including tactile, olfactory, and acoustic natural elements. Each dimension is analyzed with consideration of elderly-specific physiological and cognitive needs .This novel conceptual model provides guidance for architects and healthcare designers, identifies research gaps for future empirical studies, and establishes a theoretical basis for systematic implementation of biophilic principles in healthcare environments. By offering the first comprehensive, multisensory framework for elderly-focused spaces, this study advances biophilic design theory and promotes restorative, supportive healthcare settings for older adults.

Keywords: Biophilic design, elderly well-being, healthcare environments, environmental integration, conceptual framework

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Building Envelope Strategies for Enhancing Urban Thermal Comfort: A Climate-Sensitive Perspective

Alireza GERAMI[1]

[1] Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran

Mehrdad KARIMIMOSHAVER[2]

ORCID 1: 0000-0001-5536-2138
[2] Professor of Architecture, Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran
mkmoshaver@basu.ac.ir*(Responsible Author)

Abstract

Rapid urbanization and climate change have intensified the challenge of outdoor thermal discomfort in many cities. Among the factors that shape this condition, building envelopes and façade materials can play an important role. This study discusses how envelope materials, surface finishes, and vegetation applied to façades and roofs can mitigate outdoor overheating and contribute to more sustainable urban spaces. Insights from climate-responsive design approaches in different Iranian contexts suggest that smooth and light-colored materials are more beneficial in dry climates, while vegetation enhances outdoor livability across multiple regions, although its effectiveness is moderated by humidity. This highlights the importance of considering not only air temperature but also humidity, wind, and solar exposure when assessing the environmental impact of façades. Overall, building envelopes should be seen not just as physical boundaries but as environmental tools. By choosing materials and greening strategies suited to local conditions, designers can reduce heat stress in cities and support sustainable urban development.

Keywords: Building envelope, façade materials, outdoor comfort, vegetation, climate-responsive design

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Morphology and Natural Ventilation: Evaluation of Different Textures in Hot and Dry Climate Cities (Case Study: Kashan City)

Mostafa AZAD [1*]

[1] Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran

mkmoshaver@basu.ac.ir*(Responsible Author)

Mehrdad KARIMIMOSHAVER [2]

ORCID 1: 0000-0001-5536-2138

[2] Professor of Architecture, Department of Architecture, Faculty of Art and Architecture, Bu-Ali Sina University, Hamedan, Iran

mkmoshaver@basu.ac.ir*(Responsible Author)

Abstract

Urban passages constitute essential public spaces within cities, accommodating a wide range of daily activities. When endowed with adequate environmental quality, these spaces support not only movement and necessary functions but also extended use and diverse social interactions, thereby reinforcing social sustainability.

Thermal comfort represents a critical dimension of environmental quality, particularly in hot and arid climates, where it strongly influences outdoor engagement. Within this climatic context, wind flow emerges as a decisive factor in shaping thermal comfort. Accordingly, this study investigates the role of urban texture in modulating natural wind flow, with the city of Kashan serving as the case study.

The research focuses on a comparative assessment of different urban textures—traditional, new, semi-traditional, regular, and irregular. By analyzing the geometric configurations of buildings and open spaces, the study elucidates how various urban forms affect wind behaviour. The findings provide insights into the effectiveness of different morphological components and offer guidance for identifying optimal urban textures capable of enhancing natural ventilation and improving outdoor thermal comfort.

Keywords: Urban morphology, Natural wind flow, Urban open space, Hot and dry climate, thermal comfort.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Density, Morphology, And Soundscapes: Architectural Strategies For Sustainable Design

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper will examine the complex connection between morphology, soundscapes, and urban density and the ways in which the design strategies of architecture can be used to counteract noise pollution and promote sustainable urban living. The study uses a qualitative and quantitative methodology, which entails the use of sound levels data, urban design models, and surveys of residents who evaluate perceptions of noise and landscape quality. The results show substantial relationships between urban shape and soundscapes, where an effectively designed urban environment is able to properly reduce the impact of noise and improve the well-being of urban residents. In particular, the paper shows that the strategic changes in the location of buildings, choice of materials, and integration of green spaces help to reduce the level of ambient noise and enhance the auditory perception. These lessons highlight the need to view soundscapes within urban planning as a vital consideration of health in the urban population since stress reduction, improved cognitive abilities, and improved health outcomes are linked to reduced noise pollution. The wider implications of this study are given to urban planners and architects and it proposes that soundscape considerations must be incorporated into the sustainable design practice to enhance the quality of life in highly populated regions to promote healthier communities. The article is an important addition to the discussion on urban health that highlights the importance of interdisciplinary treatment of urban living complexities.

Keywords: Urban density; acoustic environment; resilient urban form; sustainable design; noise management.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Interplay of Sound and Space in Vernacular Desert Housing: Toward Sustainable Futures

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

The paper explores acoustic dynamics and the physical form of vernacular desert housing with the view to inform sustainable architecture in response to the critical necessity to comprehend how acoustic qualities relate with environmental flexibility in arid environments. This study, based on a thorough qualitative study, involving case studies, acoustic measurements, and occupant experiences, demonstrates, though, that well-designed sound control and space could contribute greatly to the liveability and sustainability of desert homes. Among the major results, the finding that soundscape-friendly structures enhance comfort, along with decreasing the use of mechanical cooling systems, which, in turn, decreases the consumption of energy and leads to increased resource efficiency. The applications of the findings are not restricted to the field of architecture since it is important to note that acoustic environments play a significant role in the healthcare setting, and sound can influence patient health and recovery. This study helps to fill a wider discussion on sustainable living by showing the importance of sound dynamics in designing future housing and encouraging architects and policymakers to put the importance of acoustic design first and foremost. Finally, the research recommends the combined approach that recognizes the synergistic association among sound, space and sustainability leading to the emergence of novel architectural solutions that meet environmental and human health issues in desert areas.

Keywords: Vernacular desert housing; spatial configuration; traditional building techniques; environmental adaptation; cultural sustainability.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Soundscapes and Human Experience: Architecture for the Ear in Urban Futures

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

The paper examines the complexity of the urban soundscapes and their effects on human experience with the aim of bridging the significant gap in architectural design with regard to auditory elements in well-being in urban settings. Through the mixed-method approach, qualitative and quantitative data in the form of surveys and acoustic measurements are analyzed, to examine the impact that various soundscapes have on perceptions and emotional reactions to build spaces. The important research results are that certain acoustic features, including sound variety and volume, largely contribute to user satisfaction and comfort whereas discordant sounds reduce the overall city experiences. These findings have been highlighted as important in the healthcare setting, as auditory environment has been shown to reduce stress and better mental health outcomes among urban populations in the context of improved auditory environment. Moreover, the study has implications in the sphere of healthcare because the study supports a more holistic approach to urban planning and architectural design, where sound is an essential factor in creating healthier urban experiences. This study helps shape solutions to the challenges of providing acoustic well-being in the environment, contributing to the evolution of solutions that would serve to improve community health and the overall quality of life in more urbanized communities, which eventually suggests that sound-aware design ethos will become a key factor in the future of urban design.

Keywords: Soundscapes; sensory architecture; environmental acoustics; architecture for the ear; soundscapes.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Smart Soundscapes: Acoustic Technologies for Sustainable Architectural Environments

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper will examine the complex connection between morphology, soundscapes, and urban density and the ways in which the design strategies of architecture can be used to counteract noise pollution and promote sustainable urban living. The study uses a qualitative and quantitative methodology, which entails the use of sound levels data, urban design models, and surveys of residents who evaluate perceptions of noise and landscape quality. The results show substantial relationships between urban shape and soundscapes, where an effectively designed urban environment is able to properly reduce the impact of noise and improve the well-being of urban residents. In particular, the paper shows that the strategic changes in the location of buildings, choice of materials, and integration of green spaces help to reduce the level of ambient noise and enhance the auditory perception. These lessons highlight the need to view soundscapes within urban planning as a vital consideration of health in the urban population since stress reduction, improved cognitive abilities, and improved health outcomes are linked to reduced noise pollution. The wider implications of this study are given to urban planners and architects and it proposes that soundscape considerations must be incorporated into the sustainable design practice to enhance the quality of life in highly populated regions to promote healthier communities. The article is an important addition to the discussion on urban health that highlights the importance of interdisciplinary treatment of urban living complexities.

Keywords: Smart soundscapes; sustainable architectural environments; intelligent building systems; psychoacoustics; urban acoustic planning.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Performance Driven Generative Design Workflow for Optimizing Building Facades for Daylight and Energy Efficiency in a Mediterranean Climate

Fahim Yar BAIG [1*]

[1] Architect
fahimyarbaig@gmail.com *(Responsible Author)

Samira MEHRAFZA [2]

[2] Assistant Professor Dr., Ahlul Bayt International University, Tehran, Iran

Abstract

The design of building facades in Mediterranean climates presents a critical challenge: reconciling the competing objectives of maximizing natural daylight ingress and minimizing solar heat gain to reduce cooling energy consumption. Traditional design methods often fail to systematically explore the vast solution space for this multi-objective problem. This research aims to develop and test a generative design workflow that leverages computational optimization to identify facade configurations that optimally balance Daylight Autonomy (DA) with Cooling Energy Use Intensity (EUI).

A parametric model of a standard office space was developed in Rhino3D. A generative algorithm was constructed using Grasshopper, incorporating variable parameters for Window-to-Wall Ratio (WWR) and horizontal shading device properties. The Ladybug and Honeybee plugins were used to conduct iterative environmental simulations, evaluating each design variant for spatial Daylight Autonomy (sDA) and annual Cooling Energy Use Intensity. The Octopus solver was employed for multi objective optimization to identify Pareto-optimal solutions.

The workflow successfully generated a Pareto front of non-dominated solutions, quantitatively illustrating the trade-off between daylight availability and energy performance. Specific optimal configurations were identified, ranging from a high-performance solution with a WWR of 45%, a shading depth of 1.0m, and a tilt of 25° (achieving an sDA of 58% and an EUI of 28 kWh/m²/yr) to a daylight-focused solution with a WWR of 60% (sDA 72%, EUI 38 kWh/m²/yr).

The study demonstrates the efficacy of a performance-driven generative workflow as a robust decision-support tool for architects. It facilitates the data-informed design of high-performance building envelopes early in the design process, significantly contributing to energy-efficient and occupant-centric sustainable architecture in Mediterranean regions.

Keywords: Generative design, building performance simulation, facade optimization, daylight autonomy, energy efficiency, parametric design, multi-objective optimization.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Building Climate Resilience Rural Settlement Design for Agricultural Communities

Most MOKARROMA [1]

ORCID 1: 0009-0001-8350-0670
[1] Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh
s2112169103@ru.ac.bd *(Responsible Author)

Esita GHOSH [2]

ORCID 2: 0009-0003-7933-2314
[2] Department: Economics, University of Rajshahi, Rajshahi, Bangladesh

Abstract

Rising temperatures, erratic rainfall, and degrading soils are not only reducing crop yields but also testing the resilience of traditional settlements. This study explores how thoughtful design and planning can help farming communities adapt linking the spaces where people live with the systems that sustain their crops. Based on surveys of 80 farming households in the Rajshahi region, convenience sampling was applied and the data were analyzed using SPSS. Results showed that 43.2% of farmers were experienced very high climate impacts on their crops, driven mainly by pest outbreaks (56%), rising input costs (43%), and increasing irrigation demands (19%). Yet, adaptation was visible in action: many farmers rely on resilient crop varieties such as BR-32 and BARI Gom-33 for wheat, and experiment with maize hybrids like C.P-988 and BARI maize. Regarding actions taken to address the climate crisis, most respondents reported focusing on improving food security (24.00%), reducing fertilizer use (21.00%), and ensuring adequate water supplies for crops (18.00%). Architectural responses mirror this resilience. Traditional building forms, shaded courtyards, and rainwater harvesting systems—combined with modern environmental design—reduce heat stress, improve water use, and support productive land use. The study argues that real climate resilience lies not in isolated interventions but in designing entire rural environments that sustain both people and their livelihoods. By blending indigenous wisdom with practical innovation, this research offers a grounded, low-cost framework for climate-sensitive rural development—one that honors the deep link between shelter, soil, and survival.

Keywords: Climate resilience, rural architecture, agricultural adaptation, sustainable settlement design, agro eco-system planning

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Dynamics of Funeral Practices Among The Haussa Muslims of the City of Zinder

SOUMANA Abdoul-Wahab [1*]

[1]Dr., Lecturer at the Department of Sociology-Anthropology of Université André Salifou, Zinder-Niger Republic
soumsant@gmail.com *(Responsible Author)

KASSOU Maman [2]

[2]Dr., at the Department of History and Strategic Studies of Université André Salifou, Zinder-Niger Republic

LAWALI Maman Toukour [3]

[3]Dr., Lecturer at the English Department of Université André Salifou, Zinder-Niger Republic

Abstract

Funerals are essential sociocultural events in all societies. This study investigates the dynamics of funeral practices Hausa Muslims of Zinder. To do so, the paper attempts to answer the research question how can changes occur in funeral practices among the Hausa Muslims of the city of Zinder. In conducting this research, a qualitative approach is used, with 50 people being interviewed as well as participant observation sessions during the funerals. The investigations led to several results. Funerals are not only an expression of mourning, but also fulfill sociocultural, religious, and symbolic functions in the Hausa Muslim societies of the city of Zinder. These results made it possible to understand that these rites strengthen family and community ties, cultural identity, and active solidarity. The results also show that significant socio-cultural, religious and economic changes, with multiple and varied factors, are observed in funeral rites.

Keywords: Zinder, funeral practice, dynamics, Hausa of Muslim faith, mutation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Spaces That Enhance Well-Being in Türkiye, Ireland, Netherlands, Portugal, Spain, and United States: Designing for Health as a Holistic Approach Where Human Resources Can Thrive

Habil. Cristina Raluca Gh. POPESCU[1]

ORCID 1: 0000-0002-5876-0550

[1] Full-Professor PhD., University of Bucharest, Bucharest, Romania and The Bucharest University of Economic Studies, Bucharest, Romania.
popescu_cr@yahoo.com *(Responsible Author)

Abstract

Nowadays the Sustainable Development Goals have a profound impact on all domains, including on the architectural, engineering and cultural studies, environmental studies, urban studies which have to adapt in order to create spaces that enhance users' well-being. The current research has the objective of highlighting the characteristics of the spaces that promote and enhance well-being, while creating valuable connections with the social, environmental, and economic fields. The paper argues that by incorporating nature, providing ample natural light and fresh air spaces are expected to become functional and comfortable, offering, in turn, significant opportunities for social connection or quiet retreat. Also, by including biophilic design with key elements such as plants and water features, clear air, diverse and adaptable layouts intended to meet different needs, and access to communal and private areas, individuals can thrive, feel happier, and work with more dedication. The study starts with a literature review on this important topic, where the accent is positioned on the importance and role of incorporating nature. Additionally, valuable explanations and examples are provided so that a better understanding of the following elements is facilitated: promoting mental and emotional health; encouraging social well-being; and, fostering physical well-being. The benefits and opportunities of inclusivity in space design in the form described by the European Environment Agency (EEA) initiatives are presented together with several case studies from countries such as Türkiye, Ireland, Netherlands, Portugal, Spain, and United States. The current work demonstrates that designing for health is essential in developing a holistic approach where human resources can thrive. In essence, those spaces that promote and enhance well-being incorporate successfully biophilic design, natural light, and ventilation so that mental and physical health are considered accordingly.

Keywords: Sustainable development goals; architectural studies; engineering and cultural studies; environmental studies; urban studies; employee experience; change management; biophilic design; green and blue spaces; indoor elements; functionality; comfort.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Acoustic Planning Policies: Shaping Sustainable Urban and Architectural Environments

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper analyses how acoustic planning policies can help achieve sustainable urban and architectural environments, especially how noise pollution can be managed and its effects on the sustainability of the urban environment. This study uses a mixed-method design that combines qualitative and quantitative data and examines the case studies of existing acoustic policy, urban noise level measurements and resident satisfaction survey in terms of auditory comfort. Results show that there is a strong relationship between positive acoustic planning and optimized resident well-being and that lower noise levels may result in better healthcare outcomes such as lower stress and anxiety. These findings indicate the importance of sound management in the larger framework of urban health and that cities with effective acoustic policies are in a better position to support programs in the enhancement of the public health and to improve the living conditions of the citizenry. This research has added value to the discipline of healthcare by illustrating the importance of considering the auditory setting within the urban planning systems and this is why this research proposes an interdisciplinary methodology that has to integrate environmental sustainability with promoting health. This study has implications on policymakers, urban planners, and professionals working in healthcare and therefore there is a necessity to embrace sound as an important element of sustainable urban development policies, and it is possible that future policies on these areas and create healthier cities.

Keywords: Acoustic planning; sustainable urban environments; soundscape assessment; noise management policies; urban design strategies.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Biomechanically Informed and Sustainable Architectural Design in Sports Facilities: Enhancing Athlete Performance and Spectator Experience

Shiv KUMAR [1]*

ORCID 1: 0009-0009-6196-2063
[1]Lecturer Physical Education, SBV Vikas Puri, India

shiv.kmr1986@gmail.com *(Responsible Author)

Abstract

The architecture of sports facilities is evolving into a multidisciplinary field that integrates human performance science, environmental sustainability, and smart technology. This study examines how advanced architectural strategies—such as parametric design, computational fluid dynamics (CFD)-optimized airflow, and adaptive day lighting—improve athletic performance, recovery, and spectator comfort across multiple sports. By incorporating evidence from biomechanical analyses and environmental simulations, the research highlights the critical role of spatial geometry, thermal comfort, and acoustics in influencing athlete efficiency and psychological well-being. Case studies of next-generation multi-sport complexes and LEED-certified stadiums demonstrate how green roofs, passive ventilation, high-albedo surfaces, and renewable energy systems can reduce operational energy demands by up to 35% while maintaining high-performance standards. Additionally, the paper explores the use of AI-driven crowd management, digital twin modelling, and modular designs for adaptable, cost-effective, and inclusive sports infrastructures. The findings underscore that athlete-centric and eco-responsive architectural innovations foster not only superior sports performance but also resilient, community-oriented urban development.

Keywords: Sports architecture, sustainable design, biomechanics, adaptive facilities, smart infrastructure, environmental innovation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Climate-Responsive Architectural Strategies for Lahore: A Bioclimatic Approach Toward Sustainable Design

Farhana NAZ [1*]

ORCID 1: 0009-0000-9495-5489

[1]Assistant Professor, Lahore College for Women University, Faculty of Arts and Social Sciences, Interior Design Department, Lahore, Pakistan
farhana.naz@lcwu.edu.pk *(Responsible Author)

Abstract

This study examines Lahore's climatic conditions to derive a comprehensive framework of design strategies that can significantly reduce reliance on artificial systems and promote thermal comfort through passive, climate-responsive architecture. By analyzing interrelated climatic parameters (temperature, humidity, solar radiation, daylight levels, and wind velocity), the research establishes a bioclimatic design approach tailored to Lahore's hot semi-arid climate with monsoon influence.

The results reveal that Lahore experiences substantial temperature extremes, ranging from low winter temperatures below comfort levels to summer peaks exceeding 40°C. Consequently, winter design strategies emphasize compact layouts, south-facing openings for solar gain, thermal insulation, and controlled wind exposure to retain heat. In contrast, summer conditions necessitate intensive passive cooling through cross-ventilation, evaporative cooling systems, shaded courtyards, reflective materials, and vegetative buffers to mitigate solar gain. Spring and Autumn, being naturally comfortable periods, allow for open, flexible, and naturally ventilated spaces requiring minimal mechanical intervention.

Solar radiation analysis confirms Lahore's strong year-round solar potential, advocating dual use, passive solar heating in winter and photovoltaic integration for energy generation in summer. The daylight availability (averaging 6,000–8,500 footcandles annually) supports the use of daylight harvesting systems, light shelves, and adjustable shading to balance illumination with thermal comfort. Wind analysis indicates low average speeds (5–6 mph), limiting wind energy utilization but emphasizing architectural ventilation strategies through orientation and spatial permeability. Temperature–humidity correlation highlights the need for hybrid HVAC systems that can adapt to dry summers and humid monsoon months while maintaining indoor air quality and moisture control.

In conclusion, the study establishes a dual-seasonal, bioclimatic design model for Lahore, promoting energy efficiency through contextual strategies, integrating insulation, shading, orientation, ventilation, and renewable energy systems, to ensure sustainable, adaptive, and human-centered built environments.

Keywords: Climate-responsive design, bioclimatic architecture, passive cooling and heating, thermal comfort, sustainable building strategies

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Echoes of The Desert: Acoustic and Spatial Responses in Vernacular Sustainable Architecture

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This study examines the interactions between acoustic attributes and spatial designs in vernacular sustainable architecture in desert settings in order to optimize architectural designs to increase the acoustic comfort and ecological stability. The results of the thorough analysis based on the synthesis of the qualitative information obtained through acoustic measurements, spatial reviews, and interviews with users show that certain architectural qualities, including the choice of materials, design, and orientation, have a strong impact on the auditory experience and affect the emotional condition of the residents. It is worth noting that buildings constructed using natural sound management systems do not only support a healthier acoustic surrounding but also social interactions and cohesion of the community, which underlines the importance of these designs in improving the general standard of life. The implications of the findings to healthcare are that stress can be alleviated and mental health outcomes are improved through environments that support acoustic comfort, and this may provide new avenues to integrate architecture with the wellness-oriented healthcare practices. The general implication of this research is the promotion of acoustic and spatial concerns as part of sustainable architecture as a support towards better health and environmental performance in desert environments that may influence future building policies and standards towards enhancing holistic health in such environmental settings.

Keywords: Vernacular architecture; acoustic environment; desert architecture; traditional building techniques; cultural sustainability.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Multiculturality of Lviv/Lemberg/Lwów, The Centre of West Ukraine, as Reflected in the Architectural History of The City

Sándor FÖLDVÁRI [1*]

ORCID 1: 0000-0002-7825-0531
[1]Debrecen University, Faculty of Humanities, Baltic Program, Debrecen, Hungary; Emeritus.
alexfoldvari@gmail.com *(Responsible Author)

Abstract

Lviv's architectural legacy is a fusion of various styles that reflect the city's rich history. These include Gothic, Renaissance, Baroque, Classical, Art Nouveau and Modernist features. A notable example is the Hutsul Art Nouveau style, which attempts to create a distinct Ukrainian design by combining folk motifs with Art Nouveau elements. This style is characterised by its decorative features and is a unique Ukrainian style that combines elements of the Viennese Secession with local folk architecture. It is characterised by the use of bold colours and geometric patterns, particularly the prominent sun motif.

Lviv was an important centre for the Hutsul Secession movement, where architects like Ivan Levynsky incorporated local folk elements into the broader Secessionist trend. The historic centre of Lviv, designated as a UNESCO World Heritage Site, showcases a diverse range of European and local architectural styles through its narrow streets. These elements combine to create a unique and distinctive look that represents Lviv's rich cultural heritage and history. This paper focuses on Hutsul art as a significant Ukrainian cultural phenomenon, providing an overview of the various peoples who have inhabited the region over the centuries.

Keywords: Lviv, Ukraine, Polish-Lithuanian commonwealth, hutsul_architecture, cultural_heritage.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Potential And Constraints of Beekeeping Development in Sri Lanka: A Review on Socioeconomic, Technological, and Environmental Perspectives

Mahamarakkalage NETHMI AYODYA PERERA [1*]

[1]Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna
ayodyanethmi99@gmail.com *(Responsible Author)

Abstract

Beekeeping, or apiculture, represents an increasingly important component of sustainable agricultural development and rural livelihoods in Sri Lanka. As a tropical and high bio diversified country, Sri Lanka also has very good climatic conditions and environmental conditions for beekeeping. This review explores the potential and constraints of beekeeping development from socioeconomic, technological, and environmental perspectives. Beekeeping provides a viable income-generating opportunity, particularly for unemployed and low-income rural populations, while contributing to crop pollination and biodiversity conservation. The native species Apis cerana indica remains the primary honeybee used for commercial honey production, supported by Sri Lanka's diverse floral resources. However, the national honey yield and consumption remain relatively low compared to global averages, indicating underutilized potential. Adoption of precision apiculture technologies offers opportunities to enhance productivity, quality assurance, and colony management efficiency. How ever, challenges such as inadequate training, limited access to modern equipment, high initial costs, and low youth engagement limit the progress. Environmental constraints, including pesticide exposure, drought, deforestation, and bee diseases, further limit colony survival and honey yield. The review also identifies positive market prospects through value addition, including the use of wax, propolis, royal jelly, and venom, which can improve profitability and export potential. Strengthening institutional support, expanding training and extension programs, and integrating technology into apiculture practices are essential for realizing the industry's full potential. Therefore, beekeeping in Sri Lanka constitutes a viable pathway for enhancing rural livelihoods, food security and contribute to environmental sustainability despite existing challenges.

Keywords; Apiculture, rural livelihoods, environmental sustainability

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Valuing the Intangible: An Integrated Economic Framework for Assessing the Cultural Capital of Heritage Architecture in Urban Regeneration

Mohsen Mohammadi KHYAREH [1*]

[1]Gonbad Kavous university, Gonbad Kavous, Iran
m.mohamadi@gonbad.ac.ir *(Responsible Author)

Mohadeseh NEZHADIPOUR [2]

[2]BA in Economics, Gonbad Kavous university, Gonbad Kavous, Iran
m.nejadipour@gmail.com

Abstract

This paper addresses the central challenge of quantifying the economic value of cultural capital embedded in heritage architecture within urban regeneration projects. Urban development often prioritizes new structures due to the perceived intangible nature of cultural assets, resulting in a loss of historical heritage and undermined sustainable economic growth. The core research question is: How can the economic value of cultural capital from heritage architecture be quantified, and how can these assessments influence urban policy? To answer this, we propose an integrated, mixed-methods approach combining the Hedonic Pricing Model (HPM), the Contingent Valuation Method (CVM), and the Social Return on Investment (SROI) framework to capture both market and non-market values. Through case study analysis, the framework is demonstrated to robustly quantify cultural capital via indicators such as a heritage premium on property values and tourism multipliers. Expected results, supported by empirical models, suggest that preservation can yield a 10-20% increase in adjacent property values and significant social returns. The findings advocate for the inclusion of standardized, measurable metrics in cost-benefit analyses, ensuring that cultural preservation is effectively integrated as an economic asset in urban planning and policy decisions.

Keywords: Heritage architecture; urban regeneration; cultural capital; economic valuation; urban policy

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Entrepreneurial City: Exploring The Impact of Zoning Regulations and Building Codes on Startup Ecosystems and Innovation Districts

Mohsen Mohammadi KHYAREH [1*]

[1]Gonbad Kavous university, Gonbad Kavous, Iran
m.mohamadi@gonbad.ac.ir *(Responsible Author)

Mohadeseh NEZHADIPOUR [2]

[2]BA in Econmics, Gonbad Kavous university, Gonbad Kavous, Iran
m.nejadipour@gmail.com

Abstract

This paper examines the critical role of urban regulatory frameworks—specifically zoning regulations and building codes—in shaping the development and success of startup ecosystems and innovation districts. In an era where cities increasingly compete to become hubs of economic innovation, understanding the impact of land-use and building policies is paramount. Drawing on theories from urban economics and entrepreneurship, we argue that flexible zoning, such as mixed-use designations and density bonuses, and adaptive building codes that accommodate modern work styles are critical enablers of innovation. This study employs a mixed-methods approach, combining a comparative case study analysis of San Francisco, Berlin, and Singapore with regression modelling of startup and regulatory data. Our key findings reveal that cities with more permissive and adaptable regulatory environments exhibit significantly higher startup density and venture capital investment. Conversely, restrictive and outdated regulations are found to stifle the clustering, collaboration, and scalability essential for entrepreneurial growth. The paper concludes with a proposed policy toolkit for cities aiming to cultivate robust entrepreneurial hubs by strategically reforming their foundational land-use and building policies.

Keywords: Zoning; Startup Ecosystems; Building Codes; Innovation Districts; Urban Policy

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Enhanced Adsorptive Performance of Modified Clay for Efficient Dye Removal from Wastewater

Soumaya MATCHI [1]*

ORCID 1: 0009-0003-8903-9672
[1]Mohammed V University, Faculty of Sciences, Department of Chemistry, Rabat, Morocco
soumayamatchi@gmail.com *(Responsible Author)

Adil El YADINI [2]

ORCID 2: 0000-0003-0885-3588
[2]Mohammed V University, Faculty of Sciences, Department of Chemistry, Rabat, Morocco.

Hanae OUADDARI [3,4]

ORCID 3: 0000-0001-6716-2985
[3] Chemistry Platform, UATRS, National Center for Scientific and Technical Research (CNRST), Rabat, Morocco.
[4] Ibn Tofail University, Faculty of Sciences, Department of Chemistry, Kenitra, Morocco.

Abdelkbir BELLAOUCHOU[5]

ORCID 4: 0000-0003-2328-2015
[5]Mohammed V University, Faculty of Sciences, Department of Chemistry, Rabat, Morocco.

Abstract

The release of synthetic dyes into aquatic environments poses serious environmental and health challenges due to their toxicity, high chemical stability, and resistance to biodegradation. Widely used in various industrial sectors such as textiles, plastics, paper production, and pharmaceuticals, these dyes persist in wastewater and contribute significantly to surface and groundwater contamination. Developing effective, low-cost, and sustainable materials for their efficient removal is therefore of critical importance to protect ecosystems and human health.

In this study, a naturally abundant clay was chemically modified to enhance its adsorption performance toward dye pollutants in aqueous media. The modification process aimed to improve the clay's surface functionality, porosity, and overall interaction with organic molecules responsible for coloration in wastewater.

Structural and morphological characterization of both raw and modified clays was carried out using Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). These analyses confirmed significant structural transformations and improved surface properties following the modification process.

Batch adsorption experiments were conducted to evaluate the effect of key operational parameters, including pH, initial dye concentration, adsorbent dosage, and contact time. The modified clay exhibited a significantly enhanced adsorption capacity and faster kinetics compared to the unmodified raw clay.

Overall, the results highlight the potential of the modified clay as a cost-effective, eco-friendly, and efficient adsorbent for the treatment of dye-contaminated wastewater. This study contributes valuable knowledge to the development of advanced clay-based materials for environmental remediation and industrial wastewater management.

Keywords: Modified clay, synthetic dyes, adsorption, environmental remediation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Achievements in the Temple to Moon God Nanna Built By Kıng Ur Engur in 3 100 Bce in Ur in Mesopotamıa

Natela Borisovna POPKHADZE [1*]

ORCID 1: 0000-0003-1552-7860

[1] Dr., Head of Scholarly Information Center at Academy of Phasis in Tiflis in Gurcistan//Georgia Republic//Sakartvelo
Aiakolkhetikardugeorgia@gmail.com *(Responsible Author)

Abstract

My aim is to talk about the architectural achievement of ancient kings of Sumer//Khaldaea. I have used the method of learning the ancient languages made in cuneiform script, searching as much publications in Sumerian and modern languages Kartuli//Georgian, English, Italian, Latin, Graek, Russian , French, Turkish and Gearman as I could find in libraries in various towns and on the Internet websites. I have noticed that several authors made geographical names changed with words that were not in the texts and I am against tose changes because they distort the true geography and history of ethnicities. liI shall overview a brief history of the building of the Great Ziggurat of Ur built by king Ur-Engur. After his death he was succeeded by his son that was called Tungy by schollars a century ago, but is called now Shulgy. Shulgy continued building the ziggurat of Nanna. It was a religious, cultural, political and economic center. The corners were directed to North , South, East and West. The staircase in front of the building was directed towards the summer solstice sunrise direction. King Nabonidus of Khaldea made restoration of this building in 650 BCE and his son that became king of Khaldea after his death continued the rebuilding and restauration of this building. This king of Khaldea was called Nabu-Kudurru-Uzzur II. His namesake king Nabu-Kudurru-Uzzur I was king in 1100 BCE. Both were very patriotic caring for their kingdom and their compatriots the Khaldaeans. Nabu-Kudurru-Uzzur II was a very handsome person as revealed by his portrait embroidered on the cloth of his clothes when he was a young man of 17. Both kings are praised very much by ancient authors and our contemporary authors and researchers. Nabu-Kudduru-Uzzur II had a political friendship with the king of Media called Cyaksar and even married his daughter to strengthen their friendship. The bride was very sad about the landscape defence with the area from where she arrived to Ur in Khaldaea and she liked it very much when her husband arranged the garden of trees and flowers on the terraces of their palace where they lived in Ur.It was considered to be a marvel and called the Hanging Gardens.

A bit later Enheduana was the Great Priestess of god Nanna and she became the first female poetess in the woorld. The text is signed by her as Enheduana. She was the king's daughter. Her father was the king of Khaldaea. I have learned ancient languages written in the cuneiform Sumerian and cuneiform Akkadyan shrift with professors in my home town Tiflis at the Ivane Javakhishvili University a decade ago and I enjoyed this teaching and learning process very much. It enabled me to notice several facts in the ancient history that my professors did not notice. One of the facts that I noticed was that the king Ur Engur was later mentioned by professors by the different name Ur-Namu. I am against the change.

I think it is important that I have noticed that the song to god Nanna is preserved in my Sakartvelo//Gurcistan//Georgia among my ethnicity that is called Kardu/Katveli/Gurci/Georgians and it is still very popular nowadays in 21th century. I shall demonstrate videos of persons singing this hymn/song to Nanna.

Keywords: God Nanna, a temple, a hymn to God Nanna, Khaldaea.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Evaluation of Biophilic Design Principles in the Design Proposal of 5-Star Hotel

Safiya Bello ABDULLAHI [1*]

[1]Department of Architecture, Federal University of Technology Minna
safiyabello100@gmail.com *(Responsible Author)

Abstract

The growing concern for sustainability and occupant well-being has increased the adoption of biophilic design plans in hospitality architecture. The innovative practice of biophilic design incorporates natural features like plants, water, and natural lighting into constructed spaces to highlight the relationship between humans and the natural world. This study evaluates the integration of the biophilic principles (Terrapin 14 Patterns) into the design proposal of a 5-star hotel in Minna, Niger State, Nigeria, with the aim of identifying patterns suitable for the region's tropical savannah climate. Data were collected from case studies of hotels in Abuja and Minna, and questionnaires administered to architects, hotel managers, and users. Findings show that patterns such as Visual Connection with Nature, Thermal & Airflow Variability, Natural Materials, Prospect & Refuge, and Diffuse & Dynamic Light align strongly with Minna's climate, while Presence of Water and Risk/Peril is less proper and right due to water shortage and cultural restrictions. The study concludes that biophilic design can enhance guest comfort, environmental performance, and cultural identity in luxury hotels if modified to local climate and resources.

Keywords: Biophilic design; hospitality architecture; terrapin 14 Patterns; environmental sustainability; climate-responsive design.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Artificial Intelligence And 3d Printing Technology in Construction: A Review

N.G. Kalyani REDDY [1*]

ORCID 1: 0000-0003-1651-6696
Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College
kalyani.ce@gprec.ac.in *(Responsible Author)

Chayaraju BALASAI [2]

Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College

K. THARANI[3]

Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College

Abstract

Artificial Intelligence (AI) has become an essential element in technological innovation across various sectors in the United States, Europe, and Asia. This research explores the evolving role of AI in 3D printing technology within the construction industry. Findings indicate that a 3D digital model forms the foundation of every 3D printing process, while Building Information Modelling (BIM) integrated with AI enables automation and precision in construction activities. The incorporation of AI-driven 3D printing improves efficiency, accuracy, and productivity while reducing costs and reliance on manual labor. Nevertheless, this integration also raises ethical and technical challenges, including unemployment, data security, intellectual property disputes, AI bias, and cybersecurity concerns.

Keywords: Artificial intelligence, 3D printing, BIM, Construction automation, ethics

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Perceived Effects of Fuelwood Energy Exploitation on Livelihood of Farming Households in Bauchi And Gombe States, Nigeria

Sani Madi YAKUBU [1*]

[1]Department of Agricultural Extension and Management, Federal College of Horticulture Dadin Kowa, Gombe State
Sanimadiyakubu2015@gmail.com *(Responsible Author)

Hannatu Ohunene YUSUF[2]

[2]Department of Agricultural Extension and Rural Development, Ahmadu Bello University Zaria, Kaduna State

Fadlullah Olayiwola ISSA[3]

[3]National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria

Omadachi Ogbodo UGBABE[4]

[4]Department of Agricultural Economics, Ahmadu Bello University Zaria, Kaduna State.

Abstract

The study examined the perceived effects of fuelwood energy exploitation on livelihood of farming households in Bauchi and Gombe States, Nigeria. Primary data were collected using structured questionnaire and interview scheduled among 400 respondents. Percentage and factor analysis were used in analysing the data. The result showed that, there is higher reliance on non-sustainable fuelwood energy exploitation practices, this led to directly felling of green tree, this account for 77.80% of the respondents and the use of chainsaw in cutting down trees accounted for 62% of the respondents in the study area. The result of Principal Component Analysis (PCA) shows the perception items rated on a 5-point Likert scale with mean response varying from 4.34 to 4.81, signifying a very high level of respondent's consensus that fuelwood energy exploitation has negative effects on farming household's livelihood in different ways. The respondents strongly agreed that, fuelwood exploitation lowers food crop output with a mean value of 4.81 and lowers livestock feed availability with a mean value of 4.67. These high mean scores with very low standard deviations of (0.555) for low food crops and (0.528) for livestock feeds availability suggest that, households share a very strong agreement concerning fuelwood energy exploitation activities and its effects on the productivity of farming households. There is need for Government to intensify awareness campaigns on the negative environmental and health effects of unsustainable fuelwood energy exploitation and it use, and also the need for Government and community leaders to collaborate to enforce stringent rules and penalties for illegal green tree cutting especially using chain saw. Inconclusion, there is need for Government to introduce and promote community-based forest guard with improved surveillance equipment and law enforceability. Finally, the need for extension agents to collaborate with local leaders to educate community on sustainable practices and the use of climate smart alternative energy technologies.

Keywords: Fuelwood energy exploitation, livelihood, farming households.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Comparative Analysis of The Role of Rock-Cut Architecture in The Life Cycle of Rural Tourism: A Case Study of Kandovan, Iran, and Göreme, Türkiye

Kazem GOLIZADEH [1*]

ORCID 1: 0000-0002-0381-2667
[1]Department of Architecture and Urban Planning, National University of Skills, Tehran, Iran
K-gholizadeh@nus.ac.ir *(Responsible Author)

Abstract

Rock-cut architecture, as one of the most authentic manifestations of vernacular architecture, plays a crucial role in shaping cultural identity and attracting tourists. This study aims to provide a comparative analysis of the tourism life cycle in two rock-cut settlements—Kandovan in Iran and Göreme in Türkiye—using Butler's Tourism Area Life Cycle (TALC) model. It analyzes the role of rock-cut architecture in sustaining or eroding tourism in these regions. Kandovan, as one of the few living rock-cut settlements in the world, remains in the early stages of tourism development despite its physical and cultural richness. In contrast, Göreme, benefiting from UNESCO World Heritage registration, infrastructural diversity, and cultural branding, has reached a consolidation phase and is recognized as a prominent destination in cultural and experiential tourism. Using a descriptive–analytical approach and Butler's model, this study examines the current status of these two destinations from physical, managerial, and community participation perspectives, and employs the SWOT matrix to propose strategies for Kandovan's transition toward sustainable development. Findings indicate that rock-cut architecture, beyond its visual appeal, serves as a foundation for a cultural ecosystem and, if properly managed, can act as a driver for balanced development. In this regard, physical restoration, prevention of unprincipled interventions, architecture-centered branding, and local community education for the wise use of this heritage are essential steps toward achieving sustainable tourism in Kandovan

Keywords: Rock-cut architecture; butler model; rural tourism; Kandovan; Göreme; sustainable development

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Threads of Escape: Adaptive Reuse of Trains

Hira ZAINAB[1]

[1]Interior Designer
hirazainab2003@gmail.com *(Responsible Author)

Rimsha IMRAN[2]

[2]Ph.D. Architecture (Scholar) University of Engineering & Technology, Lahore, Pakistan
Faculty of Interior Design Department, Lahore College for Women University, Lahore, Pakistan.

Maha TARIQ[3]

ORCID 1: 0009-0008-0917-6981

[3]Masters In interior design National College of Arts, Lahore, Pakistan
Faculty of Interior Design Department, Lahore College for Women University, Lahore, Pakistan.

Abstract

Old train carriages are often left to rust and decay, even though they're built to last and could be repurposed in creative ways. This project repurposes these forgotten carriages into immersive escape rooms, creating interactive environments that engage visitors both intellectually and physically. By building on the existing structure, the design reduces environmental impact and revives forgotten infrastructure with a fresh purpose. The "Threads of Escape" concept links several carriages into one seamless journey, creating a stronger sense of exploration and keeping the experience engaging throughout. Preserving the original form of the trains, the project blends history with innovation, offering a unique recreational attraction that local tourism and public engagement. It demonstrates how adaptive reuse can turn outdated spaces into vibrant, experience-focused destinations, reimagining abandonment as a chance for creativity and innovation.

Keywords: Abandoned trains, adaptive use, adventure, escape, environments, experiential design, interactive space.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Greasing The Gears of Innovation: The Role of Petroleum Chemistry in Architectural Design And Engineering

Ibrahim Khalil ADAMU[1*]

[1]Department of Petroleum Chemistry, American University of Nigeria Yola, Nigeria.
Department of Chemistry, Federal College of Education Gidan Madi Sokoto, Nigeria.
ibrahimkhaliladamu@yahoo.com *(Responsible Author)

Abdullahi ALIYU[2]

[2]Department of Pure and Industrial Chemistry, Federal University, Birnin Kebbi, Nigeria.

Abstract

Petroleum chemistry is a branch of chemistry concerned with the transformation of crude oil and natural gas into valuable products. It plays a fundamental role in the development of materials and technologies used in engineering, construction, design and modern architectural development. The petrochemical industry provides essential building blocks for plastics, resins, adhesives, insulation materials, paints, synthetic rubbers etc. which are integral to modern construction, design, infrastructure and architectural development projects. As architecture and engineering increasingly emphasize efficiency, durability, and sustainability, the relationship between petroleum-derived materials and design innovation becomes more compound and critical. Petroleum chemistry has been a foundational asset behind the contemporary built environment, it influenced both the engineering and architectural realms. While it has aided outstanding improvements in materials science and construction techniques, the environmental cost is substantial particularly the greenhouse gases, oil spills and marine degradation. The future lies in complementing functionality and sustainability through innovation, circular economy models, and integration of greener alternatives for effective service delivery.

Keywords: Petroleum chemistry, architectural design and engineering

.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Architecture, Environmental Externalities, And Economic Policy for Sustainable Cities

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper explores the complex correlation of architectural practices, environmental externalities and economic policy in urban environments which center around the critical role of sustainable urban development. It fills a gap that is very important on current research because it presents empirical information that links architectural strategies to their environmental effects and financial results by gathering and analyzing case studies, thorough statistical data about urban environmental indicators, and analysis of contemporary economic policies. The results indicate that particular design options and construction materials have a considerable impact on urban thermal trapping, air quality, and resource use, and the evaluation of the economic policies indicates the flaws in the incentivization of eco-friendly architectural innovation. The study highlights the importance of combining architectural decision-making with environmental health factors, which might imply that better architectural work could result in a dramatic increase in urban public health conditions, including the number of respiratory diseases solved and the quality of life. Also, the implications go beyond personal health gains; by educating policy-makers and city planners, the study proposes a synergist action plan that creates an equilibrium between the architectural design solution and the environmental sustainability and economic benefits, which will generate the resiliency in the healthcare systems of the city. The findings highlight why the interdisciplinary work of the architects, environmental scientists, and economists is needed to facilitate one holistic approach to urban development that would lead to the long-term sustainability and the benefits of urban development to the population.

Keywords: Environmental externalities; economic policy; sustainable cities; urban sustainability governance; green building design.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Trade-Off Between Economic Growth and Environmental Architecture in Developing Regions

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper examines the compound relationship between economic growth and environmental architecture in the developing world with main emphasis on the frantic conflict between the fast rate of economic growth and the need to follow sustainable environmental practices. The study involves qualitative and quantitative approaches and includes an in-depth examination of economic indicators, environmental impact evaluation, and multiple case-studies of development initiatives in a number of geographic settings. Important findings include the fact that economic growth is a necessary process that improves the standards of living, but it tends to compromise the environmental integrity, which translates to increased pollution and degradation of natural resources. Notably, the research study finds a strong relationship between sustainable architecture and better public health outcomes, which suggests that areas that consider the environmental factor in their developmental policies have improved healthcare profiles, including a lower rate of respiratory diseases and an overall increase in the well-being of the communities. The implications of these results are not limited to the context of urban planning and population health but are vital in policy-making and stakeholders in the healthcare industry, who need to take into consideration the need to ensure that environmental sustainability is part of the economic planning to enhance a holistic development. Finally, the study can be described as part of a more sophisticated perception of the trade-offs inherent in the practice of development, which is why the need to promote the adoption of policies that will encourage economic growth and the preservation of the environmental health are justified, which is also directly connected to the main goal of ensuring that the healthcare systems of emerging economies become more sustainable.

Keywords: Economic growth; environmental architecture; green building design; socio-economic trade-offs; sustainability challenges.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

From Farm to Cup: The Interplay of Sustainability and Governance in Ethiopia's Coffee Value Chain for Sustainable Development

Sintayehu Assefa YIRGA

[1] Ph.D., Hawassa University, Department of Management
sintayehuassefa58@yahoo.com * (Responsible Author)

Abstract

Coffee, Ethiopia's leading export and the livelihood of millions of smallholder farmers, faces mounting challenges from volatile prices, environmental stress, and social inequities. This study explores how economic, social, and environmental sustainability, alongside governance, influence development outcomes in the Sidama coffee value chain. Using survey data from farmers analyzed through Partial Least Squares Structural Equation Modelling (PLS-SEM), the findings reveal that all three sustainability dimensions significantly foster development, with social sustainability exerting the strongest influence, followed by environmental and economic aspects. Governance not only directly drives development but also strengthens the impact of sustainability practices, especially social sustainability, on developmental outcomes. These results underscore that long-term resilience in Ethiopia's coffee sector requires more than economic viability it depends on socially inclusive practices, ecological stewardship, and effective governance frameworks. By grounding the analysis in Sustainable Development Theory and Institutional Theory, this study offers fresh empirical evidence on how governance amplifies sustainability's role in advancing development within Ethiopia's coffee sector.

Keywords: Coffee value chain, sustainability, governance, development, Sidama, Ethiopia, institutional theory, sustainable development theory

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Artificial Intelligence Revolutions and Breakthroughs for Architecture, Engineering, Cultural Studies, and Environmental Disciplines

Vinod Kumar VERMA [1*]

[1]Assiatnat Professor. Dr., Sant Longowal Institute of Engineering and Technology, Deemed to be University, Longowal – India
vinod5881@gmail.com *(Responsible Author)

Klimis NTALINIS [2]

[2]Professor, Dr., University of West Attica, Athens - Greece

Chao-Tung YANG[3]

[3]Professor, Dr., Tunghaı University, Taichung City - Taiwan

Carlos MORENO [4]

[4]Professor, Dr., Central University of Venezuela, Carscus – Venezuela

Eric GAMESS [5]

[5]Associate Professor, Dr., Jacksonville State University, Jacksonville, Alabama - USA

Monica Karel HUERTA[6]

[6]Professor, Dr., Universidad Politécnica Salesiana, Cuenca- Ecuador

Vimal Rau APPROW[7]

[7]Associate Professor, Dr., Taylors University, Selangor - Malaysia

Abstract

Artificial Intelligence (AI) is gaining remarkable momentum in the modern era, influencing nearly every domain—from automated design systems to intelligent urban planning and sustainable environmental solutions. Its impact and adaptability are particularly critical in architecture and engineering, where AI-driven tools directly influence human living environments, structural safety, and ecological balance. The AI revolution has introduced new dimensions in addressing complex design challenges, optimizing building performance, and preserving cultural heritage through intelligent data analysis and predictive modelling.

Recent advancements have shown how AI algorithms can simulate structural behavior, predict material degradation, and even reconstruct historical sites with unprecedented precision, thereby transforming both design and conservation practices. The growing complexity of global environmental challenges poses a major test for urban planners and architects, demanding innovative, data-driven, and interdisciplinary approaches. Researchers and professionals are now integrating AI not only as a computational aid but also as a creative partner capable of generating sustainable and culturally sensitive design solutions.

The Information technology-based era further demonstrated the transformative potential of AI and digital collaboration tools in maintaining continuity of architectural research, design education, and project coordination. Platforms powered by AI enhanced virtual modelling, simulation, and cultural documentation processes, bridging physical gaps across disciplines. Overall, the integration of AI across architecture, engineering, cultural studies, and environmental sciences is redefining the way humanity conceives, designs, and sustains its built and natural environments—fostering innovation while supporting economic and ecological resilience.

Keywords: Artificial intelligence, information technology, architecture, engineering, culture, environment,

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Smart and Ecological Cities: Pathways to Climate-Resilient and Sustainable Urban Futures

K. R. PADMA [1*]

ORCID 1: 0000-0002-6783-3248
[1]Assistant Professor, Department of Biotechnology, Sri Padmavati Mahila Visvavidyalayam (Women's University), Tirupati, AP.
thulasipadi@gmail.com *(Responsible Author)

Abstract

Smart and Ecological Cities is the vision of a new way of building cities, which combines the innovative technology with the environmentally-friendly policy. Due to the rapidly increasing urbanization of the world, cities are increasingly challenged by the lack of resources, pollution, climate change, and social inequality. The idea of smart and ecological cities is suggested to overcome these problems using the digital innovations, green infrastructure, and data-driven governance in order to make living in cities more liveable and resilient. The core idea here is the convergence of information and communication technologies (ICT) and urban systems in order to maximize the consumption of energy, transportation, waste management, and services to the population. Meanwhile, the principles of the ecological design focus on renewable energy, protection of biodiversity, efficient use of water resources, and development of green areas that help people live better and maintain the natural state. A combination of clever technologies and environmentally friendly planning will allow cities to reduce the ecological footprint, but also support economic development and social integration. As case studies in different countries show, such cities do not only contribute to the quality of the environment, but also to the quality of life of citizens, due to participatory form of governance and feedback of data in real-time. The shift to smart and ecological cities needs the cooperation of policymakers and technologists, urban planners, and citizens to guarantee equity and sustainability in the long run. The future studies in the field should be aimed at creating quantifiable sustainability indicators, how citizens use digital ecosystems, and how technology innovation can be consistent with ecological and ethical norms. Finally, smart and ecological cities represent a comprehensive view of the expected urban environment in the future- efficient, adaptable and friendly to the environment.

Keywords: Smart cities, Ecological cities, sustainable development, urban planning, green infrastructure, renewable energy, internet of things (IoT), artificial intelligence (AI), climate resilience, circular economy.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sustainable Urban Planning and Development

S. SHAKTHI SREE[1*]

[1]Bharath Institute of Higher Education and Research, Selaiyur, Chennai-73.
shreesshakthi@gmail.com *(Responsible Author)

Abstract

Sustainable urban planning and development aim to create cities that balance environmental protection, economic growth, and social equity while ensuring long-term resilience. As rapid urbanization accelerates worldwide, cities face growing challenges such as resource depletion, pollution, inadequate housing, and climate change. Sustainable planning provides a strategic approach to address these issues by integrating land use, transportation, housing, and infrastructure in a manner that minimizes environmental impact and promotes efficient resource utilization. Key principles include compact city design, green infrastructure, renewable energy adoption, waste reduction, and participatory governance. Innovative models such as smart cities, transit-oriented development, and eco-friendly urban systems demonstrate how technology and policy can work together for sustainable outcomes. Case studies from cities like Copenhagen, Singapore, and Curitiba highlight the effectiveness of sustainable practices in enhancing liveability, resilience, and economic vitality. However, achieving sustainability requires inclusive policies, community engagement, and strong institutional support. Overall, sustainable urban planning and development are essential for building resilient, equitable, and environmentally responsible urban futures.

Keywords: Urban planning, urbanization, resource depletion, pollution, inadequate housing, climate change.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Urban Landscape of Western Europe: Impact of the Decline of the Western Roman Empire on Urbanization from AD 400 to the 17th Century

Ananda MAJUMDAR[1*]

ORCID 1: 0000-0003-3045-0056
[1]Ananda Majumdar - Harvard University
anandamajumdar2@gmail.com *(Responsible Author)

Abstract

This study looks at how the decline of the Western Roman Empire affected urban development in Western Europe. It focuses on the social and economic changes that occurred from AD 400 to the 17th century. The main goal is to understand why urban life stagnated during the medieval period and how cities eventually started to recover. The study uses historical analysis, reviewing existing literature and archaeological findings to explore changes in city layouts, population shifts, and the impact of invasions by Germanic tribes and Norsemen. It identifies three types of urban forms during this time: rectangular layouts, spontaneous irregular designs, and planned towns, each representing different historical backgrounds and environmental factors. The findings show that urbanization nearly stopped after the fall of the Roman Empire due to isolation, declining agriculture, and the dominance of farming societies. Trade disruptions, particularly during the rise of Islam and Norse raids, worsened city life in Europe. However, the 10th century marked a turning point, leading to a gradual revival of commerce with the reopening of trade routes and the growth of fortified settlements, signalling the beginning of urban renewal. In conclusion, the research highlights how various factors shaped the medieval urban landscape, leading to limited city growth characterized by small populations and a lack of large urban centers. This study offers valuable insights into the political, economic, and social changes during a key period in European history, emphasizing the importance of understanding urban development in a broader context.

Keywords: Decline, isolation, cities, revival.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sustainable Urban Farming in India: Pathways to Achıevıng the Sustainable Development Goals (Sdgs)

Hari Prasad AGARWAL[1*]
[1]Dr., Royal School of Architecture, The Assam Royal Global University, Guwahati
hari_architect94@yahoo.com *(Responsible Author)

Abstract

In areas that are rapidly urbanizing, Urban farming (UF) is becoming a crucial tactic for improving social justice, environmental sustainability, and food security. In the context of Indian cities, where urban expansion, resource scarcity, and socioeconomic inequality pose issues, incorporating UF into the built environment provides a holistic approach that is consistent with the United Nations Sustainable Development Goals. This study investigates the spatial and architectural aspects of sustainable Urban farming in India, looking at how community involvement, land-use regulations, and design interventions may turn underutilized urban areas into resilient, productive ecosystems.

The paper emphasizes key success factors and challenges in implementing UF on a scale through a review of the literature, investigating urban farming projects in cities like Bengaluru, Hyderabad, Delhi, and Mumbai, Kolkata, Bhubaneswar, Guwahati, Jaipur, Udaipur, and case studies of rooftop farms, vertical gardens, and community plots. To promote local food systems and achieve SDG targets like Zero Hunger (SDG 2), Sustainable Cities and Communities (SDG 11), and Climate Action (SDG 13), the study highlights the role that architects and urban designers play to establish inclusive, climate-responsive contexts.

According to key findings, UF may enhance ecological balance and urban resilience when integrated into architectural frameworks such modular farming systems, mixed-use zoning, and green roof typologies. To find ways to incorporate sustainable agriculture into urban planning practices, the investigation proposes a variety of design concepts and regulatory recommendations. This study positions urban farming as an essential tool in India's sustainable urban development by emphasizing the importance that the built environment contributes to establishing food systems.

Keywords: Urban farming, sustainable development goals (SDGs), architectural integration, urban resilience, food security

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Digital Technologies in Landscape Design: Physics-Based Models and Technological Innovations in Agricultural Landscapes

Ali Jan SHARIFI

[1]International Islamic University, Pakistan
sharifialijan32@gmail.com *(Responsible Author)

Ahmad Farid QASEMI

[1]International Islamic University, Pakistan

Mohammad Bashir ASHRAFI

[1]International Islamic University, Pakistan

Hamed MOHAMMADI

[1]International Islamic University, Pakistan

Mohammad Yasin REZAEI [1]

[1]International Islamic University, Pakistan

Abstract

The integration of digital technologies in landscape design is transforming the way agricultural and ecological systems are managed, modelled, and optimized. This chapter explores the intersection of physics-based models, technological innovations, and agricultural landscapes, highlighting how emerging tools can address the pressing challenges of sustainability, climate change, and resource management. Using principles from physics, such as energy balance, fluid dynamics, and soil-water interactions, advanced computational models can simulate environmental processes with greater accuracy, enabling designers and planners to make data-driven decisions in landscape architecture. At the same time, technologies such as Geographic Information Systems (GIS), remote sensing, drones, Internet of Things (IoT) sensors, and virtual reality (VR) applications are providing new dimensions for monitoring, visualization, and design.

This chapter discusses how digital tools contribute to sustainable agriculture through precision farming, smart irrigation, and climate-resilient landscape planning. Furthermore, it emphasizes the role of digital simulations in predicting the impacts of climate change on agricultural and ecological landscapes, and how these predictions can be integrated into adaptive design strategies. Case studies from recent applications in precision agriculture and ecological restoration illustrate the potential for combining traditional landscape knowledge with technological innovation.

By bridging agriculture, physics, and technology, this work contributes to a deeper understanding of how interdisciplinary approaches can transform landscape design into a more resilient, efficient, and sustainable practice. Ultimately, the chapter argues that the integration of physics-based models with digital technologies is not only advancing landscape architecture but also reshaping agricultural systems to meet the global demands of food security, sustainability, and climate adaptation.

Keywords: Digital technologies, landscape design, agriculture systems, sustainable agriculture, remote sensing, resource management.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Capitalizing on Local Knowledge of Tetraclinis articulata in Morocco's Central Plateau: Challenges for Conservation of an Endangered Medicinal Heritage

Jaayefar FATIMA-EZZAHRA[1*]

[1] Ibn Tofail University, Laboratory of Plant, Animal Productions and Agro-Industry, Kenitra, Morocco
Fatima-ezzahra.jaayefar@uit.ac.ma*(Responsible Author)

et Dahmani JAMILA [2]

[2] Ibn Tofail University, Laboratory of Plant, Animal Productions and Agro-Industry, Kenitra, Morocco

Abstract

Tetraclinis articulata also known as Barbary Thuya or Aarar, is a conifer native to North Africa and belongs to the Cupressaceae family. This well-known conifer of Mediterranean landscape is mainly distributed in Morocco, Algeria, and Tunisia with relict populations in Spain and Malta. Morocco is home to the largest sites, and the species occurs particularly in the valleys of the Central Plateau. This study is aimed at gathering and synthesizing recent scientific research regarding this important plant resource. Data was derived from scientific databases (pubmed, science direct, web of science) primarily dealing with phytochemicals and pharmacology. The Barbary Thuya is a thermophilic and xerophilic species common in semi-arid bioclimatic stage (300-500mm in annual rain). This species has high edaphic plasticity, and grows in well-drained calcareous, siliceous, or gypsum soils. It forms pure populations, or it can co-inhabit with Aleppo Pine, Holm Oak or different matorral species. Its role in the ecosystem is highlighted by its importance in soil protection against erosion and in its admirable abilities in regeneration via stump sprouting after fires. Its socio-economic role is multifaceted: its precious wood (notably the burl) is exploited for marquetry or fine cabinet work, service wood, sandarac gum and the production of a honey classified as premium quality. The leaves and the twigs have been used in traditional medicine, particularly for their diuretic, anti-rheumatic effects or against respiratory conditions. Yet, although it is resilient, over the past decades the Barbary Thuya has been facing strident anthropogenic pressures (fires, over-exploitation, and over-grazing), resulting in an alarming regression of its stands. Thus, the conservation and valorisation through an adapted silviculture is required for the Barbary Thuya, and the development of the rural territories of the Maghreb.

Keywords: Tetraclinis articulata, barbary thuya, central plateau, biodiversity, ecology, valorisation, Morocco

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Contribution of Rural Infrastructure Development Fund (RIDF) in rural prosperity in India

Bhawana PAL [1*]

[1] Dr., Faculty Member, Bankers Institute of Rural Development, Kolkata
bhawana.banjare@nabard.org *(Responsible Author)

Abstract

The Rural Infrastructure Development Fund (RIDF) was established by NABARD in 1996 to provide financing to state governments and state-owned corporations for infrastructure development in sectors such as irrigation, rural roads and bridges, health, education, and agriculture-related infrastructure. Through targeted investments, the RIDF plays a crucial role in strengthening rural resilience, promoting inclusive growth, advancing rural development, and improving the quality of life in underserved areas.

Rural infrastructure development is a critical driver of inclusive and sustainable growth in rural areas. This entails mobilising and allocating financial resources for the creation and maintenance of essential physical and social infrastructure such as roads, irrigation systems, bridges, drinking water supply and sanitation, power supply, health facilities, and digital connectivity. Adequate and timely investment in rural infrastructure not only stimulates economic activity by improving access to markets and services but also plays a pivotal role in narrowing the urban–rural divide.

Through the provision of low-cost loans to state governments and local bodies, NABARD facilitates the creation of durable infrastructure assets that improve agricultural productivity, enhance connectivity, and expand market access. This support aims to bridge the rural infrastructure gap, thereby strengthening the resilience and long-term development potential of rural communities. As on FY2025, cumulative sanctions under infrastructure financing from NABARD stood at ₹8.9 lakh crore, with disbursements amounting to ₹6.8 lakh crore. For rural produce to reach market connectivity is of vital importance.

Keywords: RIDF, NABARD, agricultural productivity and digital connectivity.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integrating Spatial and Environmental Needs in Architectural Education Design

A. J. SIMON [1]

[1]Department of Architecture, School of Architectural Technology, Federal University of Technology, Minna, Nigeria
andrewjsmte221@st.futminna.edu.ng *(Responsible Author)

D. O ALONGE[2]

[2]Department of Architecture, School of Architectural Technology, Federal University of Technology, Minna, Nigeria

E. UDOKO [3]

[3]Department of Architecture, School of Architectural Technology, Federal University of Technology, Minna, Nigeria

Abstract

The trajectory of sustainable urban development in Nigeria is intrinsically linked to the quality of its architectural education. However, existing educational facilities often lack the environmental and spatial qualities necessary to train future architects in sustainable design, hindering progress toward resilient urban futures. This study addresses this critical gap by exploring the intersection of environmental studies, cultural relevance, and architectural design within an educational framework. It puts forward a new design proposal for the School of Architectural Technology at the Federal University of Technology, Minna (FUT Minna), that serves as a model for green and sustainable infrastructure. The proposal is grounded in evidence-based principles to foster a learning environment that enhances productivity, well-being, and ecological consciousness.

Employing a mixed-methods case study, the research integrates a comprehensive review of biophilic design, environmental psychology, and sustainable architectural pedagogy with an analysis of existing architectural faculties. This is complemented by qualitative surveys and interviews with students to ensure the design is culturally and contextually responsive.

The findings reveal a significant disconnect between current facilities and the needs of a modern, environmentally focused curriculum, identifying issues such as sub-optimal lighting, inadequate ventilation, and a lack of adaptable, collaborative spaces. In response, our proposed design champions flexible, technology-rich, and biophilic learning environments that are climate-responsive and utilize local, sustainable materials.

This work contributes a contextually grounded model for transforming architectural education infrastructure in Nigeria and beyond. It offers a blueprint for purpose-built facilities that not only enhance student learning but also function as pedagogical tools for sustainable urbanism, construction innovation, and environmental stewardship.

Keywords: Architectural education, biophilic design, Nigeria, spatial needs, sustainable infrastructure.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Pekalongan City Culture and its Nickname as the City of Batik

M. Fathrezza IMANI [1]

ORCID 1: 0000-0001-6071-2390

[1]Magister of Islamic Economics of UIN KH. Abdurrahman Wahid Pekalongan
rezaimani82@gmail.com *(Responsible Author)

Abstract

Pekalongan City is a city that borders the Java Sea in the north, Pekalongan Regency in the south and west and Batang Regency in the east. Since tens and hundreds of years ago until now, most of the production process of Pekalongan batik is done at home. As a result, Pekalongan batik is closely integrated with the life of the Pekalongan people. Batik has become the lifeblood of the Pekalongan people and is proven to still exist and not give up on the times, as well as show the tenacity and flexibility of its people to adopt new ideas. Finally, in 2011, Pekalongan City was dubbed the "World City of Batik" which was carried by Pekalongan City because of the branding that Pekalongan City launched itself. This research was conducted to explain the origin of the nickname Pekalongan city as the world city of batik. The method in this research is an empirical study of phenomenology in the form of library research using a qualitative approach. This study used secondary data obtained from previous studies and other literature with similar research topics. The results of the study explain that in 2011, Pekalongan City was dubbed the "World City of Batik" which was carried by Pekalongan City because of the branding that Pekalongan City launched itself, in order to welcome the city's 105th anniversary. And Batik is designated by UNESCO as a Humanitarian Heritage for Oral and Intangible Culture on October 2, 2009. Since then, every October 2 is always celebrated as National Batik Day.

Keywords: Pekalongan city, motif, and batik.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Cybersecurity Risks in Smart Building Infrastructure

Moses Adeolu AGOI[1*]

ORCID 1: 0000-0002-8910-2876
[1]Lagos State University of Education, Lagos Nigeria
agoi4moses@gmail.com *(Responsible Author)

Samuel Olayiwola AJAGA[2]

[2]Lagos State University of Education, Lagos Nigeria.

David Oladimeji AJIBODE[3]

[3]Lagos State University of Education, Lagos Nigeria.

Oluwanifemi Opeyemi AGOI[4]

[4]Obafemi Awolowo University, Osun Nigeria.

Abstract

Smart buildings integrate networked sensors, building automation systems (BAS), IoT devices, and cloud-based analytics to deliver energy efficiency, occupant comfort, and operational cost savings. However, the IT-OT convergence that enables such benefits also expands the cyberattack surface: unencrypted IoT endpoints, legacy building controllers, and sub segmented networks create routes for attackers to insert physical disruption or exfiltrate sensitive data. This study investigates cybersecurity risks in smart building infrastructure using a mixed-methods design. The key findings illustrate runaway growth of IoT endpoints (tens of billions globally), high and rising percentage of devices with critical vulnerabilities (industry sources report substantial year-over-year increases), and common architectural vulnerabilities such as flat network topologies, default passwords, and unpatched firmware that persist across deployments. From data-driven risk metrics that draw on NIST guidance and industry threat intelligence reports, we show that 10–100 networked BAS/IOT devices in building infrastructure can create numerous high-severity vulnerabilities if proper practices are not being practiced and that attacks can disable HVAC, access control and energy systems with real physical and economic impact. We bring together robust mitigations segmentation, device lifecycle and inventory management, zero trust principles, secure procurement and recommend a research agenda that includes federated intrusion detection for building automation systems and standardized security certification for IoT building infrastructure.

Keyword: Smart buildings, BAS, IoT, cybersecurity, NIST, vulnerability metrics.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Historic Monument Buildings – European Union Perspectives on Their Protection

Voroneanu-Popa Rareș-VASILE[1*]

[1]Grigore T. Popa University of Medicine and Pharmacy of Iași
raresvoroneanu95@gmail.com *(Responsible Author)

Richard CONSTANTINESCU[2]

[2]Grigore T. Popa University of Medicine and Pharmacy of Iași

Abstract

In principle, buildings that are part of the cultural sphere are designated as monuments. In most national legislations, they benefit from a special legal status. Lawmakers have understood that their protection must be ensured through specific legal instruments that set out how such buildings are to be preserved, restored, and maintained.

State authorities have shaped their legislation in ways that highlight and enhance historic buildings. These structures not only demonstrate the historical importance of nations but also preserve the architectural style of their times—an aspect that influences how cities are maintained and developed.

The protection of cultural heritage is primarily the responsibility of national authorities; however, the European Union provides significant support in this area. The most common actions take the form of funding, recommendations, and policy initiatives, though additional strategies are needed to further encourage member states to conserve historical buildings.

Keywords: Culture, historic monument buildings, european union

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Socio-Economic Dynamics and Urban Transformation in Algerian Desert Cities: An Analytical Approach to the Case of Biskra

MOKHNANE Tarek [1*]

1 Scientific and Technical Research Center on Arid Regions CRSTRA
Tarekamin07@yahoo.com * (Responsible Author)

KHIARI Reguia[2]

2 Scientific and Technical Research Center on Arid Regions CRSTRA

ADJLANE Sabah [3]

[3] Scientific and Technical Research Center on Arid Regions CRSTRA

Abstract

Algerian desert cities, particularly Biskra, are experiencing rapid socio-economic and urban transformations driven by agricultural expansion, tourism development, and demographic change. These dynamics are reshaping traditional spatial organization and architectural identity, resulting in both opportunities and challenges for sustainable urban planning.

This paper explores the interaction between socio-economic change and urban morphology in Biskra, focusing on how agricultural investment and social mobility influence housing patterns and architectural forms. Using a socio-economic analytical approach, field observations, and statistical data, the study highlights the mismatch between official urban policies and local practices.

Findings reveal that the accelerated urbanization process often neglects the social and cultural specificities of desert environments, leading to spatial fragmentation and environmental stress. The paper concludes by recommending the integration of socio-cultural dimensions into urban planning and architectural design, promoting inclusive and sustainable development for desert cities.

Keywords: Biskra, socio-economic transformation, urban change, desert architecture, sustainable development.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Eco-Friendly Foreign Investment: The Role of Green FDI in Sustainable Development

Laura DİACONU (MAXIM)[1*]

ORCID 1: 0000-0001-5745-3850
[1]Prof. Dr., "Alexandru Ioan Cuza" University of Iasi, Faculty of Economics and Business Administration, Department of Economics and International Relations, Iasi, Romania
lauradiaconu_07@yahoo.com * (Responsible Author)

Mihai-Bogdan PETRISOR[2]

ORCID 2: 0000-0002-5821-3004
[2] Prof. Dr., "Alexandru Ioan Cuza" University of Iasi, Faculty of Economics and Business Administration, Department of Finance, Money and Public Administration, Iasi, Romania

Abstract

Various theoretical and empirical studies tried to underline that the current rate of economic expansion is unsustainable due to the major environmental issues it causes. In the light of these environmental problems, many policy-makers looked for strategies aimed to enhance sustainable development. Thus, in 2012, GreenInvest was established at the G20 Leaders' Summit, in order to accelerate the investment in green priorities in developing countries. In this context, foreign investors became more tempted to contribute to the environmentally sustainable projects. These investments, named Green FDI, are made especially in sectors such as renewable energy, clean technology and sustainable infrastructure. Taking into account all these aspects, the purpose of the present paper is to analyse the role of eco-friendly foreign investment in promoting sustainable development in developing and emerging economies that face the dual challenge of fostering economic growth while mitigating the environmental degradation. Our results indicate a statistically significant and negative correlation between Green FDI and CO_2 emissions, suggesting that higher Green FDI inflows are associated with improved environmental outcomes. Moreover, we noticed that countries with targeted green investment policies, such as feed-in tariffs, green bonds and tax incentives, have seen stronger positive impacts on renewable energy adoption and green employment rates.

Keywords: Green FDI, sustainable development, developing countries, CO_2 emissions, environment

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Analytical Study of AI-Enabled Tourism and Global Integration

Deepanjali MISHRA[1*]

[1]Associate Professor, School of Liberal Studies, KIIT University, India
deepanjalimishra2008@gmail.com * (Responsible Author)

Abstract

Tourism is one of the major industries which was affected the most during the COVID-19 lockdown. It was in the month of December 2019 when the world came to a catastrophe halt in one of the most devastating pandemic, Covid -19. Looking into the urgence of the situation the governments of all the countries imposed a nationwide lockdown due to which it was impossible for people to go out of their homes except a few hours relaxation to get their necessary daily needs for survival. Tourism, which was one of those sectors that yielded maximum revenues for a country, started to decline at an alarming rate as people were left confined to their homes and aircrafts, trains and other mode of transportation didn't ply from one place to another. However, after 2021, when the situation improved and normalcy returned, people started to travel and aircrafts also took off carrying tourists on board. Tourism has been one of the most developed sectors and technology plays a major impact on it. The basic objective of this paper is to bring out a narrative on the role of Artificial Intelligence in connecting the world through tourism.

Keywords: Tourism, artificial intelligence, culture, technology, internet

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Energy Affordability Crisis: Fuel Price Shocks, Urban-Rural Disparities, and the Climate Mitigation Paradox in Northern Nigeria

Sabiu Bello YUSUF [1*]

[1]Department of Technical Education, Federal College of Education, Gidan Madi
sabelloyusuf@gmail.com *(Responsible Author)

Ashiru BELLO[2]

[2]Urban and Regional Planning, Ahmadu Bello University, Zaria

Umar SHAMSUDEEN[3]

[3]Umaru Ali Shinkafi Polytechnic, Sokoto[3]

Abstract

This research examines the critical conflict between climate mitigation goals and socio-economic reality in Northern Nigeria, focusing on the impact of recent fuel and electricity price hikes. Building on longitudinal data from Sokoto, we analyse the limited success of national energy policies like the National Gas Policy. Our findings reveal a severe energy affordability crisis: low-income urban households spend over 12% of their income on electricity under conservative estimates, tripling the World Bank's affordability threshold. The recent removal of the petrol subsidy and increased electricity tariffs have intensified this crisis, forcing a regression to polluting biomass fuels like firewood and charcoal despite growing LPG infrastructure. This creates a critical climate mitigation paradox; well-intentioned policies designed to create sustainable energy markets effectively price out the population, thereby perpetuating reliance on GHG-intensive energy sources. Analysis of household energy choices shows that availability, not cost, remains the primary driver, underscoring profound infrastructural deficits. The crisis manifests differently across settlements: urban households face crippling costs, while rural communities, largely off grid, experience deepened energy poverty and accelerated deforestation. The study concludes that without integrated pro-poor energy strategies, targeted subsidies, and decentralized renewable systems, climate policies will continue to undermine their own objectives. The findings offer crucial insights for sustainable architecture and urban planning, emphasizing the need for housing designs and settlement strategies that integrate passive environmental controls and affordable clean energy systems. This will help to build resilience against both energy poverty and climate change.

Keywords: Energy poverty, climate mitigation, fuel pricing, urban-rural disparities, Nigeria, sustainable housing.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Legal Implications of Building Collapse in Nigeria: A Case Study Approach

Samuel Akpadiagha ETUK, Esq[1*]

[1]Department of Paralegal Studies , Akwa Ibom State Polytechnic, Ikot Osurua
harrieslawpartners@gmail.com *(Responsible Author)

Udeme E. ETTENTUK, Esq[2]

[2]Faculty of Law, University of Uyo

Abstract

The frequent occurrence of building collapses in Nigeria has raised serious legal, ethical, and professional concerns within the construction and architectural sectors. This study examines the legal implications of building collapse in Nigeria through a case study approach, focusing on the interplay between negligence, regulatory failures, and enforcement gaps in the nation's building and construction industry. Using notable incidents such as the Synagogue Church of All Nations (SCOAN) building collapse and the Ikoyi high-rise tragedy as case references, the paper analyses the extent of legal accountability borne by architects, engineers, builders, and regulatory agencies. It explores relevant statutory frameworks including the Building Code of Nigeria, the Architects Registration Council of Nigeria (ARCON) Act, and tort principles of duty of care, breach, and liability for professional negligence. The study also highlights the challenges of weak institutional oversight, corruption, and non-compliance with approved standards, which collectively undermine public safety. Furthermore, it evaluates judicial responses to building collapse cases and the limitations of existing legal remedies in providing justice for victims. By adopting a doctrinal and empirical analysis, the paper underscores the urgent need for stricter enforcement of building regulations, professional accountability, and legal reform to deter future occurrences. Ultimately, the research advocates for a more robust integration of law, architecture, and engineering ethics as a foundation for sustainable and safe urban development in Nigeria.

Keywords: Building collapse, legal liability, architecture, negligence, regulation, Nigeria.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Architectural Philosophy of Southern Albania (15th Century – Early 20th Century)

Vivian MUKLI[1*]

[1]Universiteti POLIS, Tirana, Albania
vivian_mukli@universitetipolis.edu.al *(Responsible Author)

Abstract

The traditional architecture of southern Albania (Labëria, Vlora) is characterized by a functional and defensive approach, deeply connected to the natural environment. Vernacular architecture represents regional identity, founded not only on family and social customs but also on the internal functional organization of the dwelling. Houses typically include a courtyard, multiple stories, and gender-based divisions of space. Within the same clan, family houses were built close to each other, forming compact residential clusters. The buildings were generally two-story structures: the ground floor was used for storing work tools and sheltering animals, while the upper floor served as the living space. Each house possessed its own oven. Researcher E. Riza, who has extensively studied the settlements and vernacular constructions of Labëria, emphasizes: "The inhabited centers of this region, mostly villages, are located on the western slopes of the highlands that stretch almost parallel to the Ionian coast, at an altitude of 300–600 meters. The settlements along the coastal zone are built on rugged rocky terrain, never directly by the seaside." A key feature of southern Albanian architecture is the use of local materials—stone, wood, and roof tiles. The stone houses have thick walls, simple floor plans, and high defensive functionality. Traditional dwellings express self-sufficiency, safety, and harmony with nature. The architecture possesses an organic character, as every element is interrelated with the terrain and the lifestyle of the inhabitants.

Keywords: Traditional architecture, architectural philosophy, settlements.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sustainable Concrete Design Using Low-Volume Fly Ash: Experimental Evaluation of Strength and Durability

Marjuka MEHJABIN[1*]

[1]Department of Civil Engineering, Hajee Mohammad Danesh Science & Technology University, Dinajpur, Bangladesh
marjukamehjabin.ce@gmail.com *(Responsible Author)

Abstract

Concrete is used extensively in modern building; however, sustainability issues are raised by the high carbon footprint of cement manufacturing. Since concrete cannot be made without cement, it is imperative for us to find alternatives that will minimize environmental damage. One such alternative could be fly ash, which is a byproduct of coal-fired power plants, as it can sustainably replace a portion of cement. This research experimentally studies the mechanical as well as durability properties of concrete containing Class C fly ash at replacement levels of 10%, 20%, 30%, 40%, and 50%, comparing it to a control mix without fly ash. Superplasticizer gave early-age strength and workability; therefore, it was added into the water cement ratio of 1:2.1:2.4, with a constant water cement ratio of 0.48. At 7, 14, and 28 days, 72 cylindrical specimens measuring 100 x 200 mm were prepared and tested for water absorption, splitting tensile strength, and compressive strength. The specimens' mechanical strength decreased as the amount of fly ash increased. However, workability and durability improved and water absorption was reduced. The results indicate that low-volume fly ash can successfully produce concrete that is both environmentally friendly and meets strength performance requirements while having improved durability. By reducing the quantity of cement used and the amount of waste generated by industries, this method helps to create more sustainable construction practices.

Keywords: Low-volume fly ash, sustainable concrete, mechanical properties, durability properties

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Development of Smart Biosensors for Real-Time Glucose Monitoring

DAVID. G.[1*]

[1]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India
*(Responsible Author)

DEEPAK. S.[2]

[2]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India

PALANISAMY. A.[3]

[3]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India

RAVI. C.[4]

[4]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India

N. JAYARAMAKANI[5]

[5]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India

R. SRINIVASAN[6]

[6]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai 600073, India

Abstract

Diabetes mellitus is one of the most prevalent metabolic disorders globally, requiring continuous monitoring of blood glucose levels. Traditional glucose measurement techniques often involve invasive sampling and delayed results. The emergence of smart biosensors has revolutionized glucose monitoring by enabling non-invasive, real-time detection. These biosensors integrate nanotechnology, biocompatible materials, and microelectronics to detect glucose concentrations with high sensitivity and specificity. Enzyme-based biosensors using glucose oxidase (GOx) have demonstrated reliable electrochemical performance, while novel approaches involving graphene-based nanomaterials and wearable technologies have enhanced signal transduction efficiency and patient comfort. Recent advancements include flexible, skin-mounted biosensors capable of transmitting data to mobile applications for continuous tracking and predictive analytics. These systems not only improve patient adherence but also support precision medicine through personalized treatment plans. Despite progress, challenges such as calibration accuracy, sensor stability, and biofouling remain significant. Future developments in biosensor technology are expected to focus on multi-analyte detection and full integration with artificial intelligence for predictive health management.

Keywords: Smart biosensors, glucose monitoring, nanotechnology, wearable devices, biomedical engineering

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Islamic Economic Principles in Eco-Mosque Architecture: A Path to Sustainability

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Abstract

This paper explores the introduction of Islamic economic values to eco-mosque buildings to help develop sustainability to meet the urgent intersection of religious practice and environmental care. The study using a mixed-methods approach includes both qualitative data (case studies of currently existing eco-mosques), interviews with architects and community leaders, and the examination of a quantitative data on the environmental effects of these buildings. The results demonstrate that the design of eco-mosques that demonstrates Islamic values helps to decrease carbon footprints and increase community interactions with sustainability programs. Moreover, the structures show how the faith in religious principles can guide the proper management of the resources, thus creating the holistic perspective that would solve the spiritual satisfaction and environmental protection issue. The implications of these results can be conveyed to the healthcare industry as a sustainable environment is associated with better population health results; thus, the introduction of environmentally-friendly construction of mosques may influence a wider change in society towards healthier constructions. Finally, this research has deep implications, proposing that green architecture which incorporates Islamic economic principles not only facilitates environment sustainability but also can serve as an example of establishing health-aware communities, which should trigger a massive reconsideration of how religious environments can be used to the forefront of communal health and environmental robustness.

Keywords: Eco-mosque architecture; Islamic economic principles; sustainable architecture; religious buildings; community-oriented design.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Green Waqf: Financing Eco-Architecture Through Islamic Endowments

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Abstract

This paper examines the plausibility of Green Waqf as a sustainable financing tool to fund eco-architecture by Islamic communities with a particular emphasis on whether the traditional Islamic endowments can be modified to favourably fund environmentally friendly building practices. The study indicates that current Green Waqf practices have the potential to finance eco-architecture projects, thus showing that Waqf can be used to tackle the current environmental issues. The study comes up with essential insights through qualitative data collected in different case studies and interviews with stakeholders in the fields of Islamic finance and architectural realms, which reveal the significance of implementing sustainability in urban development in these societies. The results of the study show the importance of Green Waqf in the creation of health promoting environment and indicate that investment in eco-architecture is not just in line with Islamic, but also leads to the well being of the people by improving the air quality, lessening energy use, and providing habitable spaces. The present study provides meaningful implications to the health field, as it shows that building environmentally friendly infrastructure can bring significant improvement in health outcomes and community resilience. This study, by providing an example of how conventional Waqf can be redefined to serve as a dynamic environmental sustainability tool, can be added to the larger discussion on the intersection of Islamic finance, architecture and community health, indicating avenues of future initiatives that reimburse cultural values to promote sustainable development.

Keywords: Green waqf; eco-architecture; sustainable financing; environmental stewardship; sustainable urban development.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Economic Viability of Vertical Farming in Urban Architecture: A Sustainability Perspective

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper explores the economic feasibility of vertical farming in urban architecture, in terms of how it would contribute to food production sustainability, as well as environmental impact reduction. The research design combines both quantitative analysis of the initial investment expenses, operating costs, yields as well as revenue and qualitative analysis of consumer attitudes and policy frameworks that are in place to influence urban farming projects. Highlighted in the findings include that initial expenses are high, but vertical farming can provide competitive yield benefits and operational efficiency, thus it is a viable alternative to an urban setting with space constraints and food supply issues. Moreover, the work emphasizes an increasing tendency of the consumers towards locally sourced food which is important in terms of urban agricultural policy and the ability to maintain a healthier diet. These findings are important to the healthcare sector because they highlight the importance of sustainable urban food systems in overcoming food insecurity, enhancing both nutritional quality and reducing the population health hazards related to environmental degradation. Finally, the study adds to the discussion of urban sustainability, causing policymakers and urban planners to reconsider how urban agriculture can not only increase the efficiency of food production, but also rebuild the community health outcomes, which can make urban environments more sustainable.

Keywords: Vertical farming; urban architecture; food security; agri-architecture; sustainability assessment.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Embedding Circular Economy Principles in Architectural Design for Sustainable Cities

Khelil SARA[2]

[2] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Melik SAMI [1]*

[1] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.
[2]LACOMOFA Biskra laboratory. Algeria.
sami.melik@univ-biskra.dz *(Responsible Author)

Tallal Abdel Karim BOUZIR[3]

[3] Department of architecture, Mohamed Khider Biskra University, Biskra, Algeria.

Abstract

This paper explores how the concepts of circular economy can be incorporated into architectural design as a measure to improve the sustainability of urban areas in this context; that is, the current challenges of resource depletion and waste generation common in the modern-day architectural design practices. The study, conducted on the basis of a detailed examination of qualitative case studies of the available sustainable buildings and quantitative evaluation of resource utilization and waste reduction indicators, shows that effective implementation of the practice of the circular economy can significantly reduce material waste and make the use of resources in cities more efficient. The main conclusions are that the principle of circles is used not only to ensure the minimum impact on the environment, but also to create a healthier urban habitat due to the positive effect on the air quality and the overall well-being of the community. These results go beyond the profession of architecture since they emphasize the importance of sustainable urban settings on overall population health outcomes indicating that environmentally more sustainable architectural endeavors can achieve an improved health of urban populations. Furthermore, the paper puts forward the possible implication to the healthcare industry, including the need to use the concept of sustainable buildings that may offer a paradigm of healthier environments, lower healthcare-related expenditures in connection with environmental pollution, and enhance the comprehensive perspective on community health. Presenting the architectural design in the framework of the circular economy, the current research study helps to continue the existing discussion of sustainable urban development and its applicability to areas of public health, thus stimulating future investigations and implementation of these principles into different sectors.

Keywords: Circular economy; sustainable architecture; urban sustainability; zero-waste design; resilient urban development.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Logistical Aspects of The Transport System Development in Zakarpattia Region (Ukraine)

Natalia HABCHAK[1*]

ORCID 1: 0000-0002-5549-7793
[1]Assoc. Prof., PhD., Dean of the Faculty of Tourism and International Communications
Uzhhorod National University, Ukraine
natalia.habchak@uzhnu.edu.ua *(Responsible Author)

Svitlana MYSHKO [2]

ORCID 2: 0000-0001-6773-8219

[2]Assoc. Prof., PhD., Head of the Department of Multicultural Education and Translation, Faculty of History and International Relations, Uzhhorod National University, Ukraine

Abstract

Zakarpattia region, despite being one of Ukraine's smallest regions by area (13.0 thousand km²), holds a unique economic and political-geographical position at the intersection of four European Union countries: Hungary, Slovakia, Romania, and Poland. This geographical configuration shapes a specific development vector for the region, focused not only on tourism and recreation but also on logistical integration into European transport and trade networks [1]. The region's economy remains relatively small in the national context, and prior to the full-scale Russian invasion in 2022, Zakarpattia accounted for only 1.5% of the country's Gross Regional Product (GRP) [4]. At the same time, the GRP per capita was approximately 48.9 thousand UAH, which was 52% of the national average. In addition, the GRP's physical volume index demonstrated a stable upward trend, indicating the area's potential for economic development [4]. Zakarpattia is characterized by a high degree of foreign economic dependence. In 2024, the region's goods exports totalled $1,446.2 million, while imports amounted to $1,620.4 million, resulting in a negative trade balance of $174.2 million [2,5]. The scale and direction of this foreign trade underscore that transport and logistics infrastructure are a critical factor in regional development.

A significant socio-economic factor is border traffic, which is regulated by EU Regulation No. 1931/2006 [6]. Thanks to local border traffic agreements (with Hungary in 2007, Slovakia and Poland in 2008, and Romania in 2015), residents of the border zone gained simplified access to crossing the state border, which facilitated the intensification of cross-border connections and the formation of local logistics flows [6].

As of 2025, the number of checkpoints in Zakarpattia Oblast exceeds 19 (including the recently opened Velyka Palad–Nagyhódos crossing) and continues to expand. However, only a few of them have infrastructure that meets modern logistics standards, such as automated customs services, sufficient vehicle lanes, and multimodal connections [3, 7]. A milestone was the opening of the new Velyka Palad–Nagyhódos crossing on the border with Hungary in 2025, which was the first new checkpoint to open in two decades [7]. This partially alleviated congestion at other crossings and optimize cross-border flows. There are also plans to open the Bila Tserkva–Sighetu Marmației crossing on the border with Romania [8], which would significantly strengthen the southern logistics corridor. Overall, low throughput capacity, limited number of traffic lanes, insufficient automation of customs procedures, and the lack of multimodal hubs remain key barriers to the development of the border infrastructure. Despite positive developments, the region's logistics faces several challenges: a low level of road network development, absence of modern logistics hubs, congestion at main crossings, limited development of railway infrastructure, and poor integration into the European TEN-T transport corridors. The key directions for the development of transport logistics in Zakarpattia by 2030 are defined by the following priorities: modernization of the road network; integration into TEN-T; establishment of multimodal logistics centers; increasing the number of border checkpoints and digitizing customs control; development of "green logistics"; and cross-border cooperation within the framework of Interreg NEXT 2021–2027.

Keywords: Logistical integration, logistics infrastructure, foreign economic dependence, multimodal hubs, cross-border cooperation

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Economic Development and Sustainable Development Goals in Africa: Challenges, Opportunities, and Policy Perspectives

Ali Jan Sharifi [1]

[1]International Islamic University, Islamabad, Pakistan
sharifialijan32@gmail.com *(Responsible Author)

Ahmad Farid Qasemi[2]

[2]International Islamic University, Islamabad, Pakistan

Mohammad Bashir Ashrafi [3]

[3]International Islamic University, Islamabad, Pakistan

Hamed Mohammadi[4]

[4] International Islamic University, Islamabad, Pakistan

Mohammad Yasin Rezaei [5]

[5]International Islamic University, Islamabad, Pakistan

Abstract
The Sustainable Development Goals (SDGs) provide a universal framework designed to address interconnected social, economic, and environmental challenges while promoting long-term prosperity. In Africa, the pursuit of these goals is shaped by distinctive demographic dynamics, economic structures, and environmental realities, which present both formidable obstacles and transformative opportunities. Despite progress in selected areas, the continent continues to face persistent poverty, inequality, weak governance systems, limited financing, climate change vulnerabilities, youth unemployment, inadequate infrastructure, regional disparities, public health crises, and data constraints. These challenges hinder the pace of implementation and highlight the urgent need for integrated and context-sensitive approaches. At the same time, Africa holds significant potential to accelerate SDG achievement through technology adoption, renewable energy transitions, regional integration, human capital development, governance reforms, and strengthened multi-stakeholder partnerships. Case studies from Kenya, Rwanda, Ghana, South Africa, Ethiopia, Senegal, Botswana, Nigeria, Tanzania, and Morocco illustrate innovative interventions and successful practices that offer valuable lessons adaptable across the continent. The analysis emphasizes the importance of inclusive governance, innovative financing, and policy coherence in overcoming structural barriers. Ultimately, Africa can leverage its demographic dividend, natural resources, and innovation capacity to achieve sustainable, inclusive, and resilient development by 2030. Meeting the SDGs will not only foster economic prosperity and social equity but also safeguard environmental sustainability for future generations.

Keywords: Sustainable development goals, Africa, governance, inequality, renewable energy, regional integration, inclusive development.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sustainable Irrigation of an Apple Orchard Using a PV Pumping System: A Case Study from Algeria

Aicha BELGACEM[1*]

[1]Dr. Moulay Tahar University of Saida, Algeria, Electrical Engineering Laboratory
aicha.belgacem95@yahoo.com *(Responsible Author)

Fatima BELGACEM[2]

[2]Dr. Moulay Tahar University of Saida, Algeria, Electrical Engineering Laboratory.

Mohamed MOSTEFAI[3]

[3]Pr. Moulay Tahar University of Saida, Algeria, Geometry, Analysis, Control and Applications Laboratory.

Yahia MILOUD[4]

[4]Pr. Moulay Tahar University of Saida, Algeria, Geometry, Analysis, Control and Applications Laboratory.

Abstract

This study focuses on the design of a solar-powered water pumping system for irrigating a 10-hectare apple orchard during the growing season, which extends from March to September. The orchard is irrigated for 8 hours per day and is divided into two equal parts, with each part receiving 4 hours of irrigation between 10 a.m. and 6 p.m. This schedule aligns well with solar availability, enabling the solar pump to operate efficiently during daylight hours. The motor (IM) drives a water pump that extracts water from a well with a depth of 20 meters, delivering it to a drip irrigation system. The water requirement is estimated at 2 m³/h per hectare for land planted with 1000 trees. Therefore, for 5 hectares irrigated at a time, the system must provide 10 m³/h. To accurately simulate the proposed PV pumping system under real climatic conditions, MATLAB and its Simulink environment are utilized to develop a comprehensive simulation model. The suggested system is constructed in such a way that it always performs satisfactorily regardless of the insolation variation. In order to assess whether the proposed PVPS satisfies the orchard's water requirements and to evaluate its dynamic behaviour, a case study based on a typical day of solar irradiance in August is conducted. The corresponding results are presented. The simulation results confirm that the proposed PVPS is sufficient to adequately irrigate the apple trees through direct solar operation without battery storage, demonstrating the soundness of the system's design and the relevance of the proposed concept.

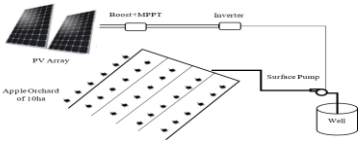


Figure 1. Schematic representation of the PVP system.

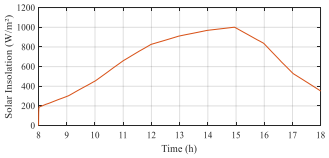


Figure 2. Solar radiation in a day of August

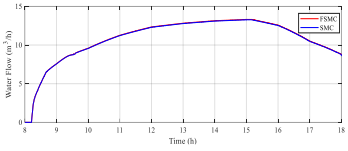


Figure 3. Low rate

Keywords: Photovoltaic pumping, apple orchard, real climatic conditions, irrigation, Matlab.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integrating Climate-Responsive Strategies in Environmental Design for Sustainable Urban Futures

Jibril JAMILU[1]*

[1]Department of Biology, Al-Hudah Schools Sokoto, Nigeria
jamilujibril09@gmail.com *(Responsible Author)

Ibrahim Khalil Adamu[2]

[2]Department of Petroleum Chemistry, American University of Nigeria Yola, Nigeria.

Ibrahim Khalil Adamu[3]

[3]Department of Chemistry, Federal College of Education Gidan Madi Sokoto, Nigeria.

Abstract

As climate variability intensifies across urban regions, the need for climate-responsive design has become a fundamental concern in environmental architecture. This study explores how adaptive design strategies can mitigate the impact of extreme temperatures, enhance thermal comfort, and reduce energy dependency in built environments. The research adopts a mixed-method approach, combining field observation, simulation analysis, and stakeholder interviews within selected urban neighborhoods in semi-arid zones. Findings indicate that integrating passive cooling systems, locally sourced materials, and landscape-based shading significantly improves building performance while maintaining cultural relevance. The study also highlights the gap between design intention and user adaptation, emphasizing the importance of community engagement in the design process. Results suggest that climate-responsive principles are most effective when contextualized within social and environmental realities rather than applied as standardized technical models. The paper concludes that sustainable urban futures depend on locally informed, climate-responsive environmental design capable of bridging ecological efficiency with human comfort.

Keywords: Climate, responsive design, environment and sustainable urban development

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Advanced and Future NDDS Concept

V. HARIHARAN[1]
[1]Bharath Institute of Higher Education and Research
hariharanvelu0624@gmail.com *(Responsible Author)
D. KHAN[2]
[2] Bharath Institute of Higher Education and Research
G. MADHAN PRASADH[3]
[3] Bharath Institute of Higher Education and Research
S. PUNITHAVALLI[4]
[4] Bharath Institute of Higher Education and Research
P. SARANYA[5]
[5] Bharath Institute of Higher Education and Research
A. VIVEK [6]
[6] Bharath Institute of Higher Education and Research
S. MAHAPATRA[7]
[7] Bharath Institute of Higher Education and Research
R. THELSHATH [8]
[8] Bharath Institute of Higher Education and Research

Abstract

Advanced and future concepts in Novel Drug Delivery Systems (NDDS) are revolutionizing the way therapeutic agents are delivered to specific sites in the body, enhancing efficacy and minimizing side effects. Traditional drug delivery methods often suffer from poor bioavailability, systemic toxicity, and lack of target specificity. Emerging NDDS technologies aim to overcome these barriers through intelligent, controlled, and personalized drug delivery approaches. Advanced systems such as nanocarriers, liposomes, dendrimers, micelles, and polymeric nanoparticles are being engineered to provide site-specific and sustained release of drugs. Smart delivery systems responsive to stimuli like pH, temperature, enzymes, or magnetic fields offer precise control over drug release profiles. Furthermore, the integration of biotechnology and nanomedicine has led to the development of gene and peptide-based delivery platforms, opening new horizons for treating chronic and genetic disorders. Future NDDS research is focused on combining artificial intelligence (AI), 3D printing, and biomaterials to design patient-specific drug delivery systems with predictive release patterns. These innovations promise to transform modern therapeutics by improving patient compliance, reducing dosing frequency, and ensuring optimal therapeutic outcomes.

Keywords: Advanced NDDS, targeted drug delivery, nanocarriers, smart drug delivery, controlled release, gene delivery, nanotechnology, personalized medicine, 3D printing, artificial intelligence.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

From Beneficial Modulation to Adverse Toxicity: Dose-Dependent Insights into TBHQ Safety Thresholds

Saha ANIK, Datta NARAYAM, Chowdhury BAPPY [1]

[1] Department of Applied Food Science and Nutrition, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh.
anik.saha.fst@gmail.com *(Responsible Author)

Hossain, Md. TAMIM, Ranjan Acharjee, MAHIMA[2]

[2] Department of Aquaculture, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh.

Prank, Md. RASEL[3]

[3] Department of Anatomy and Histology, Faculty of Veterinary Medicine, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh.

Ahmad, MONSUR[4]

[4] Department of Applied Chemistry and Chemical Technology, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh.

Abstract

The increasing use of synthetic antioxidants such as tert-butylhydroquinone (TBHQ) in food, cosmetics, and pharmaceuticals has raised concern due to dose-dependent toxicological effects on vital organs. Although TBHQ is permitted at low concentrations, evidence of hepatotoxicity, nephrotoxicity, and metabolic disturbances at higher doses underscores the need for experimental validation of its physiological consequences.

This study aimed to evaluate the effects of graded TBHQ supplementation on growth performance, hematological and biochemical indices, lipid profile, glucose regulation, and histopathological changes in Swiss albino mice (Mus musculus).

Forty mice were randomly assigned to one control and four treatment groups (T1–T4), each receiving escalating TBHQ doses for the experimental period. Growth indices, including relative body weight (RBW%), average weekly weight gain (AWWG%), and specific growth rate (SGR%), were monitored. Hematological parameters, serum biochemical markers (SGPT, SGOT, urea, creatinine, uric acid), glucose levels, and lipid fractions (HDL, LDL, TG, TC, VLDL, atherogenic index) were analyzed, alongside histopathological examinations of liver and kidney tissues.

It demonstrated a dose-dependent decline in growth indices, with the most pronounced reduction in T4. Elevated SGPT, SGOT, urea, creatinine, and uric acid indicated progressive hepatic and renal dysfunction. Moderate doses (T2, T3) improved glucose tolerance, while higher supplementation reduced this benefit. Lipid analysis revealed reductions in triglycerides, total cholesterol, VLDL, and atherogenic index, particularly in T3 and T4, suggesting paradoxical lipid-lowering effects. Histopathology confirmed dose-dependent damage, including hepatocyte swelling, fatty degeneration, necrosis, and renal tubular injury.

TBHQ demonstrated dualistic effects, exerting lipid- and glucose-modulating potential at moderate doses but severe hepatotoxic and nephrotoxic outcomes at higher levels. These findings highlight the importance of strict dose regulation in food and pharmaceutical use and call for further research on oxidative stress–mediated mechanisms of toxicity.

Keywords: Tert-Butylhydroquinone (TBHQ), Swiss albino mice, hepatotoxicity, nephrotoxicity, and lipid profile

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Natural Farming a Sustainable Approach for Management of Soil Degradation and Climate Change Mitigation

Ganesh KUMAR[1]*

[1]School of Environment and Sustainable Development
Central University of Gujarat, Kundhela, Vadodara-391107 Gujarat, India
*(Responsible Author)

R.Y Hiranmai, Harshita Marwal, Ajay Neeraj [2]

[2]School of Environment and Sustainable Development

Central University of Gujarat, Kundhela, Vadodara-391107 Gujarat, India

Abstract

Agricultural production is continuously declining due to environmental contamination, groundwater depletion, shrinkage in agricultural land and cost of production. With changing time agricultural practices were practiced using modern technology. This advanced approach of agriculture served many opportunities but also posed several challenges for long term use in crop production. Continuous use of modern chemicals in agricultural system seriously impacted soil health and productivity. Excessive use of synthetic fertilizers polluted soil and water ultimately leading to ecosystem degradation. The agricultural land gets converted into barren land in due course of time as the soil fertility declines. The present study explores the role of natural farming a chemical free crop production strategy as an agroecological approach and excludes the use of chemical fertilizers. Natural farming is a holistic approach integrating the use of available diversity on farm such as livestock, trees, crops. Natural farming have the potential to increase yield and income of farmers, offers various benefits such as restoration of soil quality, mitigates greenhouse gas emission and improves the overall health of environment. Furthermore as a substitute of chemical fertilizers biocultures like Beejamrit, Ghanjeevamrit and Jeevamrit are used to increase floral population in soil. Different farm made pesticides such as Neem Astra, Dashparni Ark, Brahmastra and Agni Astra are applied in fields to control diseases and pest in sustainable manner. Organic matter decomposition by microbes occurs directly on surface of soil and enhances nutrients uptake. Natural farming involves multiple cropping strategy that promotes agricultural system in sustainable manner. Natural farming addresses issues of food insecurity, health problems associated with fertilizers, pesticides, climate change, global warming and other calamities. This strategy of farming blends traditional wisdom with modern science helps in the conservation of biodiversity,reduces greenhouse gases emission and maintains proper balance with nature. Natural farming also plays important role in achieving the targets of sustainable development goals.

Keywords: Natural farming, soil degradation, climate change, sustainability

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Smart İrrigation System for Sustainable Farming

Nithish KUMAR R[1]

[1]Second Year Ece, R.M.K. Engineering College
240830.ec@rmkec.ac.in

S. Udhaya Kumar[2]

[2] Second Year Ece, R.M.K. Engineering College

S. Rakshith[3]

[3] Second Year Ece, R.M.K. Engineering College

Abstract

The growing demand for sustainable farming has led to the creation of smart systems that improve the use of water and fertilizers. This paper presents a Smart Irrigation System that combines a soil moisture sensor and an NPK (Nitrogen, Phosphorus, Potassium) sensor for precise irrigation and nutrient management. The system constantly checks the soil's moisture level and nutrient content using real-time data. A microcontroller, like Arduino or Node MCU, processes these sensor readings and automatically adjusts water and fertilizer pumps based on the soil's needs.

Using Internet of Things (IoT) technology, the system allows for remote monitoring and control through mobile apps or cloud platforms. Data can be viewed, stored, and studied to spot trends and improve irrigation schedules. By tracking both water and nutrient levels, the system ensures crops get enough water and balanced nutrients, which boosts growth efficiency and cuts down on manual work.

Compared to traditional irrigation methods, this system offers significant advantages, including conserving up to 40% of water, improving soil fertility, and increasing crop yield. Its modular design allows it to scale and fit various agricultural settings, from small gardens to large farms. Additionally, solar power operation enhances energy efficiency and supports environmental sustainability.

In summary, the Smart Irrigation System provides a practical and affordable way to embrace modern precision farming. It supports global goals for sustainable agriculture by promoting smart water management, reducing waste, and giving farmers real-time, data-driven decision-making tools.

Keywords: Smart irrigation system; soil moisture sensor; NPK sensor; precision agriculture; IoT-based irrigation; sustainable farming; water conservation; soil nutrient management; automation; embedded systems.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Iranian Art and Architecture

Mehdi Shalchi Tousi[1*]

ORCID 1: 0000-0003-4601-1082
[1] Dr. Engineer, Department of Engineering Faculty of Ahle Beyte International University, Tehran, Iran

Abstract

The art and architecture of Iran stand as a profound testament to centuries of cultural synthesis, innovation, and spiritual expression. From the early vernacular traditions to the sophisticated urban ensembles of the Islamic period, Iranian artistic practice has consistently fused form, function, and symbolism. Architecture in Iran has uniquely integrated climatic adaptation, geometric rigor, and intricate ornamentation, producing spaces that are both meticulously crafted and deeply experiential. The visual language—characterized by domes, iwans, muqarnas, and tilework—reflects a continuous dialogue between secular dynasties and religious authorities, guiding daily life while elevating collective memory. Iranian art transcends regional boundaries, influencing and being influenced by neighbouring civilizations along the Silk Roads, thereby shaping a distinct Mediterranean-Asian continuum. This scholarly inquiry interrogates the epistemologies of Iranian aesthetics, examining how material choices, technological innovations, and patronage networks cohere into a cohesive artistic panorama. By analyzing monuments, furniture, metalwork, and manuscript illumination, we uncover patterns of continuity and rupture that illuminate identity construction over time. The study also engages with contemporary reinterpretations of traditional motifs, assessing how modern architectural practice negotiates heritage, modernity, and sustainability. Ultimately, this article seeks to contribute a nuanced understanding of how Iranian art and architecture articulate space, memory, and meaning within broader regional and global contexts.

Keyword : Art, architecture.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Information And Communication Technology Adoption Behaviour of Farmers in Thanjavur District: A Study

B. MAHADEVAN[1*]

[1]Assistant Professor and Head, PG Department of Library and Information Science, Vellalar College for Women (Autonomous), Thindal (Post), Erode, Tamilnadu, India.

dmaha32@gmail.com ***(**Responsible Author)

Abstract

The study examines the adoption behaviour of Information and Communication Technology (ICT) among farmers in Thanjavur District, Tamil Nadu. It aims to understand the extent of ICT awareness, accessibility, and utilization in agricultural practices. A descriptive survey method was employed, and data were collected from a representative sample of farmers using a structured questionnaire. The findings reveal that most farmers are aware of ICT tools such as mobile phones, the internet, and agricultural information portals. However, the level of adoption varies based on factors such as age, education, farm size, and income. The study highlights that while ICT has significantly improved access to agricultural information, barriers such as inadequate training, poor connectivity, and lack of technical knowledge persist. Recommendations are made to strengthen ICT infrastructure and promote digital literacy among farmers to enhance productivity and sustainable agricultural development.

Keywords: Information and communication technology, ICT adoption, farmers, agricultural information, thanjavur district, digital literacy.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Comparison of the Effectiveness of Silicon and Nanosilicon in Stimulating the Growth of *Lycium Chinense* Mill. Shoot Cultures in Vitro

Marcelina KRUPA-MAŁKIEWICZ[1*]

ORCID 1: 0000-0002-4333-9122

[1]Assoc Prof. Department of Plant Genetics, Breeding and Biotechnology, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland
mkrupa@zut.edu.pl *(Responsible Author)

Ireneusz OCHMIAN[2]

ORCID 2: 0000-0002-3606-1927

[2]Department of Horticulture, West Pomeranian University of Technology Szczecin, Słowackiego 17 Street, 71-434 Szczecin, Poland

Abstract

The aim of this study was to determine the effect of silicon and nanosilicon supplementation on the growth and development of Lycium chinense Mill. shoot cultures under in vitro conditions. This species, commonly known as goji, is valued for its health-promoting properties and has long been used in traditional Asian medicine. Due to its antioxidant, anti-inflammatory, and metabolism-regulating properties, it represents a valuable pharmacological and dietary resource. Stabilized shoot cultures were propagated on Murashige and Skoog (MS) media supplemented with silicon in the form of Actisil (200 mg/L) and nanosilicon (nSi) at concentrations of 200, 400, and 600 mg/L. Key morphological parameters were analysed, including shoot and root length, number of shoots, fresh and dry biomass, and relative water content (RWC).

The obtained results demonstrated that nanosilicon supplementation significantly stimulated vegetative growth. The most favourable effects were observed at 600 mg/L nSi, which increased root length by 47%, fresh biomass by 83%, and dry biomass by 66% compared to the control. The addition of Actisil also promoted growth, though to a lesser extent than nanosilicon.

The results confirm the potential of silicon nanoparticles as effective biostimulators in plant tissue cultures. These findings may serve as a foundation for further research on the use of nanosilicon to optimize micropropagation and enhance plant tolerance to environmental stress.

Keywords: Nanosilicon, actisil, goji berry, biomass, relative water content (RWC)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Conceptual Considerations on the Application of The Precautionary Principle in the Environmental Law Relationship

Mihaela (BEJENARI)[1]

[1] Assistant Professor, Faculty of Law, Administration, Public Order and Security, Stefan cel Mare" Academy of the Ministry of Internal Affairs
mihaela.bejenari26@gmail.com *(Responsible Author)

COJOCARU[2*]

ORCID 1: 0000-0002-3118-1225
[2] PhD student, Doctoral School "Criminal Sciences and Public Law

"Nature is the greatest artist of all time".

Dante Alighieri

Abstract

The principle of prevention in environmental policy provides a conceptual basis for the argument that the best environmental strategy is to prevent pollution and environmental damage of any kind from occurring, rather than trying to remedy its effects. Prevention involves, on the one hand, risk assessment to avoid hazards and, on the other hand, actions based on knowledge of the present situation to avoid environmental degradation.

The purpose of the article is to approach the principle of prevention in a conceptual-applicative way, which aims to study the field, the development of regulation, case law and the difficulties that may arise in its application, as well as the interaction of the principle of prevention with other principles in environmental law. Thus, the article states that the most appropriate and effective environmental strategy is to prevent pollution and environmental damage of any kind, rather than to repair its effects.

Keywords: Precautionary principle, the environmental law report, environmental damage, environmental protection, environmental strategy.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Toxic Tanning: Assessing Environmental Pollution and Occupational Health Risks in the Leather Industry

Seifeslasie ASMAMAW [1*]

[1] Bahir Dar University, Apparel faculty, Department of Leather Product Design and Engineering, Ethiopia
seifeslasie@gmail.com *(Responsible Author)

Esayas SHEGAW [2]

[2] Debre Tabor University, Department of Medical Laboratory, Ethiopia

Abstract

The leather business is an essential part of economic development and the job market; however, it is among the most harmful manufacturing industries in terms of the environment and workplace health and safety. This paper explores the two-fold effects of the leather manufacturing industry on the environment and human health with specific reference to an in-depth examination of the tanning process, which involves the intensive use of toxic substances like chromium salts, sulphides, and acids. The study determines the level of environmental pollution in terms of air emissions, wastewater discharge, and solid waste production, which tend to pollute soil, surface water, and groundwater resources. Moreover, it raises the occupational health hazards for tannery workers, which include respiratory illnesses, skin diseases, and prolonged exposure to carcinogenic substances. The case studies of the developing world indicate that poor treatment of waste, bad ventilation of the working space, and the shortage of protective equipment aggravate these problems. The article goes further to discuss the emerging green options, including vegetable tanning, enzyme processing, and closed-loop water, as the ways forward in the journey of making production sustainable. This paper will focus on the importance of more stringent regulatory implementation, technological development, and worker protection schemes through an integrated environmental and health analysis framework.

Keywords: Occupational health, environmental pollution, tanning chemicals, sustainable production

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Economic Implications of Climate Change on Rice (*Oryza sativa*) Production in Bangladesh

Most. MOKARROMA[1*]

ORCID 1: 0009-0001-8350-0670
[1]Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh
s2112169103@ru.ac.bd *(Responsible Author)

Arifa YEASMIN [2]

ORCID 2: 0009-0009-6363-2738

[2]Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh

Salauddin SOHAN [3]

ORCID 3: 0009-0009-8598-7919

[3]Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh

Sakhawat Hosen SOURAV[4]

[4]Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh

ALSHAHRIA[5]

ORCID 5: 0009-0002-4610-2670

[5]Department: Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh

Sazzadul ISLAM [6]

[6]Department: Crop Science and Technology,University of Rajshahi, Rajshahi, Bangladesh

Mizanur RAHMAN[7]

ORCID 7: 0009-0000-7994-1513

[7]Department: Fisheries, University of Rajshahi, Rajshahi, Bangladesh

Abstract

Rice (Oryza sativa), the global staple food, is increasingly vulnerable to the economic and agronomic pressures of climate change. Rising temperatures, erratic rainfall, and extreme events are reshaping production conditions and farmer livelihoods. This study explores how rice farmers in Rajshahi and Naogaon districts of Bangladesh perceive these changes and adapt their practices, with an emphasis on economic sustainability. Data were collected through convenience sampling and analyzed using SPSS. Farmers reported sharp increases in production costs, water demand, and pest infestations, particularly cutworm and stem borer. Nearly half adopted resistant varieties such as BRRI 11, BRRI 81, and BRRI 71, while about three-quarters depended on motorized irrigation to secure adequate water. Yields ranged from 7–10 tons/ha using 14-21 kg seed inputs, yet rising costs continue to squeeze profit margins. These findings show that climate change not only disrupts agronomy but also reshapes the economic landscape of rice farming. Ensuring sustainability will require integrated approaches that link genetics, agronomic innovation, and socioeconomic strategies. Such measures can strengthen both productivity and resilience, helping farmers maintain their livelihoods in the face of growing climate stress.

Keywords: Rice production, climate change, economic sustainability, adaptation, Bangladesh

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Capacity Analysis of Signalized Intersections in Oran, Algeria: A Probabilistic Model for Left-Turn Movements

Wissem BELKHEIR[1*]

ORCID 1: 0000-0001-6561-2022

[1]University of Sciences and Technology of Oran-Mohamed BOUDIAF, Faculty of Architecture and Civil Engineering, Department of civil engineering. Oran-Algeria
wissem.belkheir@univ-usto.dz *(Responsible Author)

Zahra BOUNOUARA[2]

[2]University of Sciences and Technology of Oran-Mohamed BOUDIAF, Faculty of Architecture and civil engineering, Department of civil engineering. Oran-Algeria

Fatima HADJADJ[3]

[3]University of Sciences and Technology of Oran-Mohamed BOUDIAF, Faculty of Architecture and civil engineering, Department of civil engineering. Oran-Algeria

Wafaa TEBBOUNE[4]

[4]University of Sciences and Technology of Oran-Mohamed BOUDIAF, Faculty of Architecture and civil engineering, Department of civil engineering. Oran-Algeria.

Abstract

Signalized intersections constitute a critical component of urban road networks, and their operational efficiency significantly dictates overall network performance. This study addresses the need for detailed, context-specific analysis by investigating the impact of key operational parameters—specifically left-turn movements—on the capacity of signal-controlled intersections.

Empirical data were gathered from several intersections within the metropolitan area of Oran, Algeria. An initial evaluation, utilizing established international capacity methodologies, revealed notable shortcomings in their applicability to the local traffic environment. Specifically, the estimated flow rates for left-turn movements exhibited statistically significant discrepancies from observed values.

To rectify these inconsistencies, we developed a novel probabilistic model designed to accurately represent the evacuation dynamics of left-turning vehicles from a shared lane. This model was rigorously validated against field data collected under diverse operational regimes, including: varying left-turn storage capacities (1 to 5 vehicles), fixed-time signal control, a wide range of left-turn proportions (9% to 100%), and opposing traffic saturation levels (38% to 99%).

The results demonstrate that the proposed probabilistic model achieves a strong alignment with observed capacities, effectively capturing the complex dynamics of mixed-lane operations under opposing flows. Statistical validation, performed using a paired t-test, confirmed that the residual differences between predicted and observed values were not statistically significant at the 95% confidence level. This supports the model's accuracy and establishes its suitability for enhanced traffic planning and operational analysis within Algerian urban settings.

Keywords: Signalized intersection, capacity, permissive left turn, shared lane, Algeria

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integrating Traditional and Modern Sustainable Architectural Practices for Cost-Efficiency and Climate-Responsive Buildings in Niger State, Nigeria

Muhammad Hassan ISHAQ[1]

[1] Department of Architecture, Ahmadu Bello University Zaria, Nigeria.
muhammadhassanishaq@gmail.com *(Responsible Author)

Bukar Ali KIME[2]

[2] Department of Architecture, University of Maiduguri, Nigeria.

Abstract

Niger State, Nigeria, characterized by its hot-dry and tropical wet-dry climates, faces significant challenges in creating affordable and climate-responsive housing. This study examines how traditional vernacular architectural practices in Niger State, Nigeria, can be integrated with modern sustainable building strategies to deliver cost-efficient, climate-responsive buildings. For generations, traditional architectural techniques—courtyard layouts, thick masonry walls, and systems for natural ventilation—have served efficiently in adapting to the humid tropical climate of the region. Yet, as urbanization accelerates and modern influences grow, many of these methods are being replaced by modern contemporary styles that often fail to accommodate local climatic demands coupled with the urgency to reduce energy consumption, improve indoor thermal comfort and lower construction and lifecycle costs. Through a comparative analysis of vernacular and contemporary case studies in Minna and surrounding areas, the study demonstrates how hybrid approaches can reduce construction costs by up to 40% while enhancing thermal comfort and energy efficiency. Key findings show the importance of integrating both traditional and modern approaches to enhance climate responsiveness and cost efficiency in buildings in Niger state. The paper proposes a hybrid design framework, cost comparisons, and guidelines for integrating vernacular and modern strategies in Niger State, with implications for more sustainable housing policy contributing to Nigeria's sustainable development goals.

Keywords: Niger State, traditional architecture, sustainable design, climate-responsive buildings, cost efficiency.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Public Squares Along Didouche Mourad Street in Skikda: Urban Continuities and Transformations

Boukerma RIMA[1*]

PhD Student in Architecture, Specializing in Urban and Landscape Architectural Heritage. University of Algiers 1 Benyoucef Benkhedda, Faculty of Science, Department of Architecture.
r.boukerma@univ-alger.dz *(Responsible Author)

Mansouri LAMIA[2]

[2] Doctor of Architecture; MCA. University of Algiers 1 Benyoucef Benkhedda, Faculty of Sciences, Department of Architecture.

Bouaroudj RADIA[3]

[3] Doctor of Architecture; MCA. Salah Boubnider Constantine 3 University, Faculty of Architecture and Urban Planning.

Mekki SANA[4]

[4] PhD Student in Architecture. Mohamed Khider University, Biskra, Department of Architecture, LACOMOFA Laboratory.

Azzam ROUFAIDA[5]

[5] PhD Student in Architecture. University of Abu Bekr Belkaid, Tlemcen. Laboratory of Archeological Heritage and its Valorization. Tlemcen, Algeria

Abstract

The public spaces located on Didouche Mourad Street in Skikda are symbolic places where social life, architectural heritage, and significant movements in the city intersect. Formerly named Georges Clemenceau Street, this historic thoroughfare, established during the French colonial period, is an extension of the cardo maximus of the ancient Roman city.

This study examines the evolution of these spaces, initially designed as places of representation, encounter, and transition, in light of urban changes and contemporary practices.

The study is based on a comparative visual approach that contrasts old postcards with recent photographs taken at the same locations. The aim is to highlight, through visual representations, the transitions and discontinuities observed in the development of the structures, uses, and ambiances of urban areas. The analysis is structured around three complementary axes: the first axis concerns morphology (including spatial organization, built environment, and landscaping), the second axis concerns functionality (encompassing uses, mobility, and social interactions), and finally, the third axis concerns perception (including light, sounds, materials, and visual depth).

In addition to its documentary nature, the research questions the function of public spaces as vectors of collective memory and their impact on the urban and sensory identity of the street. The results highlight the coexistence of structures inherited from colonization and the emergence of new social practices that are constantly redefining the quality of the experience of these spaces.

Keywords: Public spaces - urban heritage - visual interpretation - urban ambiance - Didouche Mourad Street (Skikda).

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Choosing a Slope-Stability Method under Groundwater Conditions: A Decision-Oriented Reframing of an Inter-Software Comparison

Hachimi DAHHAOUI [1*]

ORCID 1: 0000-0002-6603-1411
[1]Department of Civil Engineering /EOLE Laboratory, University of Tlemcen, Algeria

Abdeldjalil ZADJAOUI, Mohammed BEKHTI, Naima BELKADI[2]

[2]Department of Civil Engineering /EOLE Laboratory, University of Tlemcen, Algeria

Abstract

Evaluating slope stability in the presence of groundwater is highly sensitive to the chosen calculation method and to modeling assumptions. Building on unchanged analyses performed with GeoStudio and cross-checked against PETAL-LCPC, this paper reframes prior findings into a decision-oriented framework for method selection under hydrological effects. The original results—kept intact—show a marked influence of groundwater on deformation and displacement patterns, shifting the locus of maximum movement toward the slope toe, as well as systematic differences among widely used limit-equilibrium methods (Bishop, Perturbation, Fellenius, Janbu, Sarma). In dry and wet scenarios, several methods yield lower factors of safety by a few percent, with Janbu commonly returning the most conservative values under groundwater; in one comparison, a discrepancy of about 20% is observed for Sarma versus PETAL-LCPC, attributable to methodological assumptions and thus warranting verification rather than dismissal. We translate these discrepancies into actionable rules aligned with design objectives and consequence of failure: (i) state the objective (ULS/ELS) and risk posture; (ii) select a primary method consistent with the hydraulic regime; and (iii) cross-check when inter-method or inter-software deltas exceed preset thresholds (e.g., 5–10% near ULS) or when pore-pressure modelling is critical. A concise checklist—covering boundary conditions, mesh density, slip-surface search, and documentation of assumptions—supports reproducibility. The proposed framework preserves scientific rigor while improving day-to-day decision-making for geotechnical design and slope-risk management under groundwater conditions.

Keywords: Slope stability, groundwater; decision framework; limit-equilibrium methods; inter-software comparison

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Rapid Estimation of Secondary Creep in Soft Clays Using Machine Learning

Hachimi DAHHAOUI [1*]

ORCID 1: 0000-0002-6603-1411
[1]Department of Civil Engineering /EOLE Laboratory, University of Tlemcen, Algeria

Abstract

The long-term performance of embankments and foundations on soft clays is governed by the secondary compression coefficient (Cαε,max), yet measuring this parameter currently demands multi-day creep tests that are rarely scheduled in routine site investigations because of their cost and programme impact. This study investigates whether Cαεmax can be estimated at the end of a conventional oedometer test by exploiting an open dataset comprising 282 Finnish clay and gyttja samples. The input features are restricted to index properties already collected as standard practice: initial void ratio, natural water content, compression index, pre-consolidation stress and over-consolidation ratio, thereby avoiding any additional laboratory effort or expense. Using a non-linear machine-learning workflow with rigorous cross-validation, we obtain predictions with a coefficient of determination R^2 higher than 0.60 and a substantial reduction in error compared with classical empirical correlations. Training and inference are completed in less than one second on a standard laptop, highlighting the method's suitability for rapid decision-making. The talk will describe the data curation, the feature-engineering strategy and the safeguards adopted to prevent over-fitting, before illustrating how the resulting "day-0" estimate can shorten design programmes and support low-carbon construction choices. Finally, we outline how the same framework could be transferred to other regional databases and packaged in an open-source web application for geotechnical practitioners.

Keywords: Soft clays; secondary creep; oedometer; machine learning; predictive modelling; open data

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Circular Memory of Hands: Circularity in the Domestic Wisdom of Peoples

Yasin KHALILOV[1*]

ORCID 1: 0000-0001-6251-7556
[1]Associate Professor, PhD in Technical Sciences, Department of Design, Faculty of Architecture and Construction, Baku Engineering University, Hirdalan, Azerbaijan
*yxalilov@bmu.edu.az **(**Responsible Author)

Abstract

This study examines the universal role of spherical and circular shapes in the daily lives of people worldwide through a multidisciplinary approach. The article systematically analyzes the manifestations of circularity in household utensils, domestic objects, and everyday items across various cultures.

The work demonstrates that circular and spherical shapes are not merely an aesthetic preference but also a result of practical necessity, ergonomic advantage, material efficiency, and profound cultural symbolism. From African basketry to Asian porcelain, from Indigenous American grinding stones to European pottery, and from traditional Azerbaijani and Turkish cauldrons to modern smart home appliances, circularity functions as a universal design language across all cultures.

The article scientifically explains the compatibility of spherical shapes with human anatomy, the optimization of stress distribution, material economy, and production efficiency. It also explores the cultural meanings of circular shapes as symbols of social unity, cosmic harmony, and spiritual perfection. The findings indicate that the principle of circularity has been an integral part of human life from ancient traditions to modern technology and will maintain its importance in future design solutions. This universal form provides both practical functionality and aesthetic harmony, reflecting intercultural understanding and the deep needs of human nature.

Keywords: Circularity, round shapes, household items, domestic tools, cultural anthropology, ergonomics, traditional craftsmanship, universal design, practical aesthetics, cross-cultural research

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Circular Bridge from East to West: The Global Dialogue of Cultures

Yasin KHALILOV[1*]

ORCID 1: 0000-0001-6251-7556
[1]Associate Professor, PhD in Technical Sciences, Department of Design, Faculty of Architecture and Construction, Baku Engineering University, Hirdalan, Azerbaijan
*yxalilov@bmu.edu.az **(**Responsible Author)

Abstract

This study examines the phenomenon of sphericality in music through a multidisciplinary approach, analyzing the manifestations of these principles across various dimensions of the musical art. The article investigates the role of sphericality in music on physical, acoustic, structural, cultural, and psychological levels. The research reveals that spherical and circular forms constitute one of the fundamental building blocks of music. The physical nature of sound propagates in spherical waves, and this principle finds extensive application—from the design of musical instruments to the architecture of concert halls. In nearly all world cultures, circular musical instruments—frame drums, tambourines, gongs, tabla, tar, saz, kamancha, zurna, balaban, and others—rely on this form to achieve optimal acoustic properties. In harmonic theory, fundamental concepts such as the "Circle of Fifths," cyclical structures in musical composition, and loop techniques in minimalist music are abstract expressions of circularity. Circular dances in folk music, ritual ceremonies, and community-unifying practices are universal.

The study concludes that sphericality in music is not merely an aesthetic or technical issue, but a universal principle that plays a significant role in human psychology, social interaction, and the formation of cultural identity. These principles are also expected to play an important role in the development of future technologies such as quantum music, holographic sound, and neuro-musical interfaces.

Keywords: Sphericality, circular forms, musical acoustics, harmonic circles, cyclical structures, musical instruments, interdisciplinary research, cultural symbolism**.**

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Metaphysics of Form: Energy, Geometry, and Sphericity in Nature

Yasin KHALILOV[1*]

ORCID 1: 0000-0001-6251-7556
[1]Associate Professor, PhD in Technical Sciences, Department of Design, Faculty of Architecture and Construction, Baku Engineering University, Hirdalan, Azerbaijan
*yxalilov@bmu.edu.az **(**Responsible Author)

Abstract

This paper analyzes the energy efficiency of various geometric shapes (sphere, cube, and pyramid) under the same volume conditions. The study was conducted based on two main physical models: surface tension energy for liquids and internal elastic energy for solids.

Theoretical calculations and finite element method (FEM) results show that the spherical shape is the most suitable geometric shape in terms of minimizing both surface energy and internal elastic energy. Stress concentration factor (SCF) and internal energy calculations prove that the geometric structures of shapes directly affect stress distribution and total energy consumption.

The research results explain the widespread use of spherical shapes in nature (cells, droplets, planets), engineering (pressure vessels, aerodynamic capsules), architecture and design (domed structures, circular planning, spherical buildings), and also in symbolic and cultural fields using basic laws of physics.

This multidisciplinary approach demonstrates that the form-function relationship is universal at the technical, architectural, design, and symbolic levels. It has been determined that the dominant role of globality in nature, technology, architecture, and culture is guided by the principles of energy optimization.

Keywords: Spherical shape, energy efficiency, surface tension, internal elastic energy, stress concentration (SCF), FEM analysis, form-function relationship, nature and design, engineering geometry, symbolic structures

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Eco-Colonialism or Climate Justice? Reassessing Global Environmental Agreements from the Global South Perspective

Astitva Kumar RAO[1*]

[1]Dr. B.R. Ambedkar National Law University, Sonepat, Haryana, India

Anamika PRASAD[2]

[2]Amity University, Gwalior, Madhya Pradesh, India

Abstract

The discourse on global environmental governance has increasingly highlighted the tensions between climate action and socio-economic equity, giving rise to debates on eco-colonialism and climate justice. Eco-colonialism critiques the imposition of environmental norms and policies by the Global North on the Global South, often disregarding local contexts, developmental imperatives, and historical responsibilities. Climate justice, conversely, emphasizes equity, fairness, and accountability, advocating that nations most responsible for environmental degradation bear the primary burden of mitigation, while vulnerable countries receive support to adapt and sustain development. This paper critically reassesses major global environmental agreements—including the Paris Agreement, Kyoto Protocol, and UN Framework Convention on Climate Change—from the perspective of the Global South. It examines whether these frameworks perpetuate structural inequalities or meaningfully address the disproportionate vulnerabilities faced by developing nations. Drawing upon case studies, policy analyses, and historical data, the study highlights the persistent gap between global commitments and local realities, revealing instances where well-intentioned climate policies inadvertently reinforce economic dependence and technological asymmetry. Furthermore, it explores alternative models of environmental governance, rooted in the principles of sovereignty, equity, and indigenous knowledge systems, that prioritize justice alongside ecological sustainability. By reframing global environmental discourse through the lens of the Global South, this paper argues for a recalibration of climate negotiations, emphasizing inclusive decision-making, differentiated responsibilities, and transnational solidarity. Ultimately, the research contributes to a nuanced understanding of how global environmental agreements can evolve from instruments of hegemonic imposition to platforms of cooperative climate justice, enabling equitable pathways for sustainable development.

Keywords: Eco-colonialism, climate justice, global south, environmental agreements, sustainable development

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Geological Event Modelling and Illustration

Abdelfattah ABOULFARAJ[1]*

[1]Cadi Ayyad University, Faculty of Sciences Semlalia, Department of Geology, 2GRNT Laboratory (Geosciences, Geotourism, Natural Hazards and Remote Sensing). Marrakech, MOROCCO

Abdelhalim TABIT, Ahmed ALGOUTI, Latifa ABOULKASIM[2]

[2]Cadi Ayyad University, Faculty of Sciences Semlalia, Department of Geology, 2GRNT Laboratory (Geosciences, Geotourism, Natural Hazards and Remote Sensing). Marrakech, MOROCCO

Abstract

Understanding, interpreting, and disseminating geoscientific data requires the modelling and representation of geological events. A complementary method that combines scientific accuracy and visual quality is made possible by the integration of digital technologies like ArcGIS, ENVI, and Adobe Illustrator. Geological data management, geographical analysis, and cartographic representation are made easier by the robust geographic information system (GIS) ArcGIS. It makes it possible to create accurate and dynamic thematic maps by superimposing several layers of data (lithology, tectonics, geomorphology, mineral resources, etc.). In contrast, ENVI, which specializes in processing satellite and aerial images, provides sophisticated spectral analysis and classification tools that enable the identification of tectonic structures, changed regions, and geological formations from multispectral or hyperspectral data. In the last stage of formatting and illustration, Adobe Illustrator steps in. It is used to improve the readability, aesthetics, and graphic consistency of maps, geological sections, and interpretive diagrams produced by scientific software in preparation for publishing or presentation. As a consequence, the integration of these three technologies facilitates comprehensive geological modelling: Adobe Illustrator for graphic enhancement and results distribution, ArcGIS for information structure and spatialization, and ENVI for raw data analysis. The scientific and aesthetic value of contemporary geological works is strengthened by this integrated approach.

Keywords: Geological events, modelling, illustration, ArcGIS, ENVI, adobe illustrator

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Eco-Building Mortars Incorporating Sewage Sludge Ash for Sustainable Construction: A Review

BOUSLAH Mahmoud[1*]

ORCID 1: 0009-0007-2645-6160
[1]University of M'sila, Faculty of Technology , Civil Engineering Department, M'sila, Algeria

MAZA Mekki[2]

[2] University of M'sila, Faculty of Technology, Civil Engineering Department, M'sila, Algeria.
[2]https://orcid.org/0000-0002-4742-4711

RAHMOUNI Zine EL Abidine [3]

[3] University of M'sila, Faculty of Technology, Civil Engineering Department M'sila, Algeria.
[3]https://orcid.org/0000-0001-8551-2715

TEBBAL Nadia[4]

[4] University of M'sila, Faculty of Technology, Civil Engineering Department, M'sila, Algeria.

Abstract

The development of eco-building materials has become a key priority in sustainable construction, aiming to reduce environmental impact while maintaining structural performance. This review investigates the potential of sewage sludge ash (SSA), a residue from wastewater treatment plants, as an alternative raw material in mortar production. The incorporation of SSA aligns with circular economy principles by transforming waste into a valuable component for eco-friendly construction.

This paper compiles and analyzes recent research on the physical, chemical, and mechanical properties of mortars containing SSA. Findings reveal that replacing SSA can lead to improved sustainability outcomes, including reduced carbon emissions, resource conservation, and enhanced durability under thermal and chemical exposure. The review also examines microstructural developments that contribute to improved bonding and densification in SSA-based mortars.

However, the variability of SSA composition and the need for standardized processing techniques remain key challenges to large-scale implementation. Overall, this study highlights the promising role of SSA in the production of eco-building mortars, reinforcing its potential to support greener and more resilient infrastructure.

Keywords: Eco-building mortar, sewage sludge ash, sustainability, circular economy, construction.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Thermal Stability of Composite Materials Using a Refined Higher Order Shear Deformation Theory

Tebboune WAFA[1*]

[1]Department of Civil Engineering, Faculty of Architecture and Civil Engineering, University of Sciences and Technology Mohamed Boudiaf, Oran, Algeria

*(Responsible Author)

Belkheir WISSEM, Bounouara ZAHRA, Hadjaj Fatima ZOHRA[2]

[2]LMST Laboratory, Department of Civil Engineering, Faculty of Architecture and Civil Engineering, University of Sciences and Technology Mohamed Boudiaf, Oran, Algeria.

Abstract

In this paper, a sinusoidal shear deformation theory is presented for thermal buckling analysis of composites plates. It is assumed that the plate is in contact with elastic foundation during deformation. This refined plate theory contains only four unknowns. It is assumed that the mechanical and thermal non-homogeneous properties of functionally graded plate vary smoothly by distribution of power law across the plate thickness. Using the non-linear strain-displacement relations, the equilibrium and stability equations of composites plates made of functionally graded materials are derived. The boundary conditions for the plate are assumed to be simply supported on all edges. The elastic foundation is modelled by two-parameters Pasternak model, which is obtained by adding a shear layer to the Winkler model. The effects of thermal loading types and variations of power of functionally graded material, aspect ratio, and thickness ratio on the critical buckling temperature of functionally graded plates are discussed.

Keywords: Refined plate theory; thermal buckling analysis; FGM plates

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design

B. S. Abdur RAHMAN CRESCENT[1*]

[1]Department of EEE, B. S. Abdur Rahman Crescent Institute of Science and Technology, a Private deemed university, Chennai, India

Professor, Institute of Science and Technology, a Private deemed university, Chennai, India

Abstract

The escalating frequency and intensity of global wildfires, exacerbated by climate change and unsustainable land management practices, demand a fundamental paradigm shift in architectural and urban design approaches. This paper introduces Fire-Adaptive Architecture as a transformative framework that reconceptualizes fire from an adversarial force to an ecological partner in regenerative design. Grounded in the ancient Indian philosophy of Panchabhutas, where fire (Agni) represents transformation and renewal, this approach integrates millennia-old Indigenous fire stewardship wisdom with cutting-edge material science and contemporary architectural innovation. Through comprehensive analysis of case studies from Australia, North America, Africa, and the Mediterranean, we demonstrate how spatial configuration, sacrificial design elements, landscape integration, and community-scale planning can create settlements that not only survive but thrive in fire-prone environments. The framework directly contributes to Sustainable Development Goals (SDGs) 11, 13, and 15, offering scalable solutions for climate adaptation and ecosystem regeneration. Our findings reveal that fire-adaptive strategies reduce structural vulnerability by up to 75% while enhancing biodiversity and community resilience, providing a blueprint for sustainable coexistence with natural fire regimes.

Keywords: Fire-adaptive architecture; indigenous fire stewardship; climate resilience; sustainable development; regenerative ecosystems; wildfire mitigation

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Green by Design: The Role of Urban Farming in Achieving Sustainable Cities

Astitva KUMAR RAO[1*]

[1]Dr. B.R. Ambedkar National Law University, Sonepat, Haryana – 131029 (India)

Anamika PRASAD[2]

[2]Amity University, Gwalior, Madhya Pradesh – 474005 (India)

Abstract

The accelerating pace of urbanization has intensified pressure on natural resources, food systems, and urban sustainability. The study explores how integrating agriculture into urban environments can foster ecological balance, social well-being, and economic resilience. Urban farming—ranging from rooftop gardens and vertical farms to community plots and hydroponic systems—represents a transformative approach to rethinking food production and urban planning. By localizing food systems, cities can significantly reduce carbon footprints associated with food transport, minimize waste through circular resource use, and enhance food security for urban populations. Moreover, urban green spaces contribute to improved air quality, biodiversity restoration, and temperature regulation, thereby mitigating the urban heat island effect. Beyond environmental benefits, urban agriculture promotes community engagement, provides livelihood opportunities, and enhances mental health through interaction with nature. This paper analyses global best practices, policy frameworks, and design strategies that facilitate the integration of green farming infrastructures within urban landscapes. It also addresses challenges such as land scarcity, water management, and institutional support, proposing policy-driven solutions to scale sustainable urban farming models. The study concludes that urban farming, when embedded in city planning and governance, is not merely an environmental initiative but a multidimensional tool for achieving the United Nations' Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

Keywords: Urban farming, sustainable cities, green infrastructure, food security, climate resilience

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Synthesis, Characterization, and Evaluation of Biological Activities of M(Ii) Metal Complexes (M=Co, Zn and Cu) Based on a Bidentate Schiff Base Ligand

Ibtissam ELAARAJ, Oumayma OULIDI, Asmae NAKKABI, Noureddine EL MOUALIJ, Mohammed FAHIM[1*]

[1]Laboratory of Innovative Materials and Biotechnology of Natural Resources, Faculty of Sciences, Moulay Ismail University, Kingdom of Morocco

*(Responsible Author)

Filippo GIARRATANA[2]

[2]Department of Veterinary Sciences, University of Messina, Polo Universitario dell'Annunziata, Viale Giovanni Palatucci snc, Messina, Italy.

Riconnexia srls, Department of Veterinary Sciences, University of Messina, Polo Universitario dell'Annunziata, Viale Giovanni Palatucci snc, Messina, Italy.

Abstract

This work focuses on the preparation of Zn(II), Co(II), and Cu(II) complexes from the Schiff base ligand bidentate. The molecular structures of the synthesized compounds were elucidated using various spectroscopic analysis methods such as mass spectroscopy IR, UV-vis, NMR (^{1}H, ^{13}C), and DTA, TGA. In addition, the antibacterial, antifungal, and antioxidant activity of the ligand and their metal complexes were examined in vitro. Results showed that Cu (II) complexes exhibited very strong free radical scavenging activity against the DPPH free radical, while antibacterial activity using the disk diffusion method and the micro-dilution method against Gram-positive and Gram-negative bacteria enabled us to conclude that antibacterial activity varies according to compound structure and strain sensitivity. The results for antifungal activity revealed that transition metal complexes showed good activity against the fungus Candida.

Key words: Schiff base; complexes; antibacterial activity; antioxidant activity; antifungal activity; DPPH.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Use of *Berberis* L. Species in the Creation and Reconstruction of Parks and Squares in the Steppe Dnipro Region

Anatoliy M. KABAR[1*]

ORCID 1: 0000-0002-8231-4745
[1] PhD., Oles Honchar Dnipro National University, Dnipro, Ukraine
*(Responsible Author)

Tetyana Y. LYKHOLAT[2]

ORCID 2: 0000-0002-5076-0572
[2] PhD., Oles Honchar Dnipro National University, Dnipro, Ukraine

Maksim O. KVITKO[3]

ORCID 3: 0000-0002-3713-7620
[3]Lectıre., Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine
Oles Honchar Dnipro National University, Dnipro, Ukraine

Olena A. LYKHOLAT [4]

ORCID 4: 0000-0002-3722-8602
[4]Prof. Dr., University of Customs and Finance, Dnipro, Ukraine

Yuriy V. LYKHOLAT [5]

ORCID 5: 0000-0003-3354-8251
[5]Prof. Dr., Oles Honchar Dnipro National University, Dnipro, Ukraine

Abstract

To expand the range of plants recommended for the creation and reconstruction of parks and squares in the Steppe Dnipro region, we conducted studies on representatives of the genus Berberis L., which are undergoing the process of introduction under the conditions of the Oles Honchar Dnipro National University Botanical Garden. The assessment of plant vitality was determined by the activity levels of antioxidant system enzymes.

Studies were conducted on the activity of catalase, peroxidase, and SOD, which catalyze the two-electron reduction of H_2O_2 to water while using hydrogen peroxide as an electron donor in catalase and various reductants in peroxidase. The highest peroxidase activity was observed in Berberis koreana and B. rotundifolia, while the lowest was in B. lyceum. Catalase activity in all studied species varied depending on changes in climatic conditions. The obtained results regarding SOD indicate that the highest activity was observed in B. koreana, B. lyceum, and B. rotundifolia, while the lowest was in B. canadensis and B. vulgaris.

The analysis of changes in the activity of all studied antioxidant enzymes in the leaves of the introduced species relative to the changes in enzyme activity in the local species B. vulgaris showed a decrease in catalase activity in August, while the activity of other enzymes increased.

A high correlation was established between the activity of antioxidant enzymes in the leaves of introduced species of the genus Berberis compared to the local species B. vulgaris in terms of catalase activity, as one of the key enzymes of the adaptive antioxidant system. The specific changes in the activity of all the studied enzymes indicate the balance of the defense system in the leaves of Berberis species and allow recommending B. koreana for broader introduction in the creation and reconstruction of parks and squares in the steppe Dnipro region, as one of the species most adapted to local conditions.

Keywords: Representatives of the genus *Berberis*, introduction, adaptation, parks and squares, Dnipro steppe region.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Ksour of the Ksour Mountaıns in Algerıa: An Oasian Heritage on the Path to World Recognıtıon

Sana MEKKI[1*]

[1]PhD student in Architecture, LACOMOFA Laboratory, Department of Architecture, Mohamed Khider University, Biskra

Rima BOUKERMA[2]

[2]Phd student in Architecture, Department of Architecture, University of Algiers 1

Leila SRITI[3]

[3]Professor of Architecture, LACOMOFA Laboratory, Department of Architecture, Mohamed Khider University Biskra

Abstract

The ksour of the Ksour Mountains region represent an architectural and cultural heritage of outstanding value. These fortified settlements, built from local materials and seamlessly integrated into their mountainous and oasis environments, demonstrate a remarkable adaptation to arid climatic conditions and to a long-standing communal way of life. Their urban layouts, irrigation systems, and social structures reflect a sustainable balance between human settlement, nature, and architectural design. Despite their exceptional heritage significance, the ksour remain vulnerable due to rural depopulation, material degradation, and the lack of appropriate protection and promotion measures. Their recognition and potential inscription on the UNESCO World Heritage List are key steps toward ensuring their preservation and transmission to future generations.

This paper aims to highlight the outstanding universal value of the ksour of the Ksour Mountains, assess their conservation status, and propose an integrated approach to their management and valorisation. This approach combines scientific documentation, community involvement, and sustainable development strategies to strengthen their visibility and guarantee their long-term protection.

Keywords: Ksour, Ksour Mountains, world heritage, popular architecture, preservation, cultural identity.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Green Spaces: Restoring Mind and Body in Urban Life

Maryam MOSLEHI [1*]

ORCID 1: 0000-0003-2065-5234

[1]Associate Prof, Natural Resources Research Department, Agricultural and Natural Resources Research and Education Center, Hormozgan, I.R. Iran

*(Responsible Author)

Abstract

Modern urban living has distanced humans from nature, increasing stress, anxiety, and chronic health conditions. Research shows that green spaces can serve as a natural remedy for high-stress urban environments. Presence in parks, tree-lined streets, and hospital green areas activates the parasympathetic nervous system while reducing sympathetic activity, lowering stress hormones and psychological tension, and accelerating mental and physical recovery. Observing natural landscapes and engaging in activities such as walking, cycling, and exercise in these spaces improves cardiovascular health and immune function. In hospitals, access to green spaces reduces patient anxiety and pain, decreases the need for pain medication, and shortens recovery time. In urban streets, trees and natural scenery lower environmental stressors, enhance driver focus, and reduce accident rates. Moreover, green spaces foster social interaction, enhance collective well-being, and improve overall urban quality of life. These findings indicate that the development and preservation of green spaces are not only an ethical and economic necessity but also a natural, cost-effective investment for promoting physical, mental, and social health in urban populations.

Keywords: Green spaces, mental health, stress reduction, urban life.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Effects of Organic Mulch and Natural Methods on Soil Moisture Retention and Growth of *Ziziphus spina* Christi Seedlings in Afforestation

Maryam MOSLEHI [1*]

ORCID 1: 0000-0003-2065-5234

[1]Associate Prof, Natural Resources Research Department, Agricultural and Natural Resources Research and Education Center, Hormozgan, I.R. Iran.

Abstract

Proper soil moisture management and the use of natural methods play a key role in the success of seedling planting in afforestation and the restoration of vegetation in dry and semi-arid areas. In this study, 12 Ziziphus spina seedlings were planted in two experimental groups: the first group was mulched with organic material derived from local plant residues, while the second group was left without mulch. Mulch was applied to a depth of 20 cm in the planting holes and 5 cm on the soil surface. Irrigation was provided during the first year and was stopped whenever rainfall occurred. Soil moisture was measured 24 hours after rainfall to assess the effect of mulch on moisture retention under realistic field conditions. After three years, measurements showed that mulched seedlings exhibited significantly greater growth in both height and crown area compared to unmulched seedlings (crown height: 70.2 cm vs. 55.2 cm; crown area: 2032 cm² vs. 1311 cm²). Additionally, annual height growth (73.76 cm vs. 55.23 cm) and soil moisture around mulched seedlings were higher (soil moisture: 23.95% vs. 18.83%). These findings indicate that organic mulch, by conserving moisture, reducing environmental stress, and enhancing root access to nutrients, accelerates growth and improves seedling health. The use of organic mulch and natural methods represents a cost-effective, sustainable, and efficient approach to improving seedling survival and growth in afforestation and ecosystem restoration projects in dry regions.

Keywords: Organic mulch, soil moisture, plant growth, natural methods

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Fire-Adaptive Architecture: Integrating Indigenous Fire Stewardship for Climate-Resilient and Regenerative Design

ARAVINDHAN R.[1*]

[1]Department of EEE, B. S. Abdur Rahman Crescent Institute of Science and Technology, a Private deemed university, Chennai, India

RAMSHIN Rahiman[2]

[2]Associate Professor, B. S. Abdur Rahman Crescent Institute of Science and Technology, a Private deemed university, Chennai, India

SRI HARSHAVARSHINI C.

[3]Department of EEE, B. S. Abdur Rahman Crescent Institute of Science and Technology, a Private deemed university, Chennai, India

Abstract

The escalating frequency and intensity of global wildfires, exacerbated by climate change and unsustainable land management practices, demand a fundamental paradigm shift in architectural and urban design approaches. This paper introduces Fire-Adaptive Architecture as a transformative framework that reconceptualizes fire from an adversarial force to an ecological partner in regenerative design. Grounded in the ancient Indian philosophy of Panchabhutas, where fire (Agni) represents transformation and renewal, this approach integrates millennia-old Indigenous fire stewardship wisdom with cutting-edge material science and contemporary architectural innovation. Through comprehensive analysis of case studies from Australia, North America, Africa, and the Mediterranean, we demonstrate how spatial configuration, sacrificial design elements, landscape integration, and community-scale planning can create settlements that not only survive but thrive in fire-prone environments. The framework directly contributes to Sustainable Development Goals (SDGs) 11, 13, and 15, offering scalable solutions for climate adaptation and ecosystem regeneration. Our findings reveal that fire-adaptive strategies reduce structural vulnerability by up to 75% while enhancing biodiversity and community resilience, providing a blueprint for sustainable coexistence with natural fire regimes.

Keywords: Fire-adaptive architecture; Indigenous fire stewardship; climate resilience; sustainable development; regenerative ecosystems; wildfire mitigation

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Strength Characteristics of M40 Grade Concrete as Partial Replacement of Cement by GGBS and Fine Aggregate by Crusher Dust

Subhashish Dey[1*]

[1]Department of Civil Engineering, Gudlavalleru Engineering College, Andhra Pradesh, India

Abstract

Concrete is the most widely used material in the construction industry. The cement required in the concrete leaves enormous carbon which shows an alarming impact on the global environmental conditions. Hence, there is a requirement of some material which can be effective in supporting cement when added along with it shows similar characteristics. Ground granulated blast furnace slag (GGBS) is found to be one such material which has similar characteristics when mixed with cement. GGBS is a by-product of steel manufacturing industry which is disposed. Quarry dust is a waste from the stone crushing unit. This quarry dust can be used as partial replacement for fine aggregates in concrete. The principle objective is to study the strength properties. Concrete cubes, cylinders and beams for M40 grade are prepared initially by replacing the sand with quarry dust by increasing proportions as 10%, 20%, 30% and so on until an optimum is obtained. After with the optimum percentage of fine aggregate, the cement is replaced with GGBS by 10%, 20%, 30%, and 40%. According to the results, the quarry dust increases the strength for 20% replacement of fine aggregate and GGBS with 30% replacement of cement.

Keywords: Concrete, quarry dust, cement, ground granulated blast furnace slag, M40 grade and global environmental

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Durability of Vegetable Fiber-Reinforced Concrete Under External Sulfate Attack

Imane MIHOUB[1*]

[1] Department of Civil Engineering, Faculty of Science and Technology, University Center of Morsli Abdellah Tipaza, Algeria.

Sif Allah MEGHZILI[2]

[2] Department of Civil Engineering, Faculty of Science and Technology, University Center of Morsli Abdellah Tipaza, Algeria.

Abderraouf ACHOUR[3]

[3] Department of Civil Engineering, Faculty of Science and Technology, University Center of Morsli Abdellah Tipaza, Algeria.

Abstract

The durability of cementitious materials is a major concern in civil engineering, especially when exposed to aggressive environments. This study focuses on the behaviour of concrete reinforced with natural plant fibers under external sulphate attack. The incorporation of vegetable fibers, aims to improve the mechanical performance and sustainability of concrete through enhanced crack control and toughness. However, the interaction between these organic fibers and a sulphate-rich environment raises questions regarding their long-term stability and the microstructural integrity of the cement matrix. Laboratory tests were conducted to evaluate the physical and mechanical properties of fiber-reinforced concretes after exposure to sodium sulphate (Na_2SO_4) solutions over several curing periods.

Results indicate that while fiber addition improves flexural strength and reduces crack propagation at early ages, prolonged sulphate exposure leads to gradual degradation due to ettringite and gypsum formation, which affects both matrix integrity and fiber-matrix adhesion.

Nevertheless, the use of suitable fiber treatments and optimized mix designs can mitigate these effects and extend the service life of sustainable, eco-friendly concrete materials

Keywords: Durability, vegetable fibers, sulphate attack, fiber-reinforced concrete, eco-friendly concrete materials.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Mapping Albania's Cultural Heritage: A Spatial and Typological Analysis of Tangible and Intangible Assets

Mishela RAPO[1*]

ORCID 1: 0009-0000-9263-0146
[1]Assistant Lecturer, PhD Student, Department of Management and Marketing, European University of Tirana

Abstract

This study analyzes the spatial distribution and typological composition of Albania's cultural heritage, drawing on data from the national inventory of tangible and intangible assets. Using a descriptive-analytical approach supported by Excel-based data processing, the research provides a comparative overview of heritage representation across the country. Findings reveal that tangible heritage constitutes the most comprehensively documented component of Albania's cultural landscape. Monuments, archaeological sites, historical architecture, and religious structures collectively account for more than two-thirds of all recorded elements. These assets are widely represented across regions, with the highest concentrations in Gjirokastër, Berat, Vlorë, Tirana, and Korçë, reflecting their enduring historical and architectural significance and their potential for heritage-based tourism development. In contrast, intangible heritage appears significantly underrepresented in the national register. The recorded data include only three regions, Gjirokastër, Korçë, and Shkodër, where traditional crafts, polyphonic music, rituals, and gastronomy are officially recognized as cultural assets. This limited spatial scope highlights major gaps in the systematic documentation and territorial integration of living heritage. The resulting imbalance between tangible and intangible heritage underscores the need for a more comprehensive and geographically inclusive inventorying framework. The study recommends the development of an integrated geo-information system that would enable more accurate mapping, monitoring, and policy coordination of cultural assets. Such an approach would strengthen Albania's capacity to preserve, promote, and manage its diverse heritage, ensuring that both material monuments and living traditions contribute to sustainable regional development and cultural identity preservation.

Keywords: Albania; cultural heritage; cultural categories; spatial distribution; geo-information system; heritage documentation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj

Shahriar Hasan Mridha RATUL [1*]

[1]Department of Architecture, Southeast University (SEU), Dhaka, Bangladesh

Moukuri MOHIM [2]

[2]Department of Architecture, Southeast University (SEU), Dhaka, Bangladesh
mmoukuri@gmail.com *(Responsible Author)

Ahsan REZWAN [3]

[3]Department of Architecture, University of Asia Pacific (UAP)

Abstract

The colonial period in Bengal (1757–1947) profoundly transformed the architectural landscape, introducing hybrid typologies that reflected a dialogue between European grandeur and indigenous spatial sensibilities. This study explores the form, space, and spatial organization of three exemplary colonial-era houses in Narayanganj, a prominent river port and industrial hub during British rule. Through architectural documentation, spatial mapping, and morphological analysis, the paper examines how colonial domestic architecture in this region negotiated climatic adaptation, social hierarchy, and cultural identity. The selected houses—representing distinct socio-economic and stylistic backgrounds—illustrate variations in planning concepts, façade articulation, and functional zoning. While the external expressions reveal neoclassical and Indo-Saracenic influences, the internal arrangements reflect a nuanced response to Bengali lifestyle and environmental demands, such as cross-ventilation, verandah transitions, and courtyard-centric planning. The study identifies a spatial duality—the coexistence of formality and intimacy, where the imported ideals of order and symmetry were localized through vernacular materiality and living patterns. By analyzing these architectural configurations, the paper contributes to understanding the colonial negotiation between power, culture, and space, offering insight into the evolution of domestic architecture in Bengal. The findings not only emphasize the architectural significance of Narayanganj's colonial heritage but also underscore the urgent need for heritage conservation and adaptive reuse to safeguard these endangered cultural assets for future generations.

Keywords: Colonial architecture, Narayanganj, spatial organization, domestic heritage, form and space, Bengal

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Partial Replacement of Coarse Aggregate with Crumb Rubber Chips in Concrete Production

N.G. KALYANI REDDY[1*]

ORCID 1: 0000-0003-1651-6696

[1]Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College, (Autonomous), Kurnool-518002 (A.P)

Chayaraju BALASAI[2]

[2]Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College, (Autonomous), Kurnool-518002 (A.P)

K. THARANI[3]

[3]Assistant Professor in Civil Engineering, G Pulla Reddy Engineering College, (Autonomous), Kurnool-518002 (A.P)

Abstract

This research aims to examine the performance of concrete where a portion of the coarse aggregate is replaced by crumb rubber derived from used tires. Globally, over 270 million discarded tires are generated annually. In India, improper disposal of these non-biodegradable wastes poses major environmental, fire, and health challenges. Beyond their use as tire-derived fuel, recycled rubber finds promising applications in civil engineering, such as artificial reefs, erosion prevention, and as aggregate substitutes in concrete. This study evaluates M30-grade concrete where scrap tire chips are introduced as partial replacements for natural coarse aggregates at 5%, 10%, and 15% substitution levels. Workability and compressive strength tests were conducted to determine the most efficient proportion of crumb rubber that can be incorporated without significantly compromising concrete performance.

Keywords: Coarse aggregate, crumb rubber, tires

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Implications and Environmental Impact of Artisanal Gold Mining on Land use Patterns in Minna Metropolis, Niger State

Abdullahi, M. I.[1]
[1]Department of Geography

Usman, Z. N.[2]
[2]Department of Curriculum and Instruction

Ndako N.[3]
[3]Federal University of Technology, Minna, Nigeria· Department of Biology and Department of Science Education

Abdullahi M. K.[4]
[4]Niger State College of Education[12&34] and Federal University of Technology, Minna, Nigeria

Hussaini, I. [5]
[5]Federal University of Technology, Minna, Nigeria· Department of Biology and Department of Science Education

Abstract

This study examined the environmental impact of artisanal gold mining in Minna Metropolis, Niger State. The study was guided by three research objectives which was translated into three research questions. The study adopted survey research design. The population of this study was 1000 artisan gold miners in mining sites in Minna Metropolis, Niger State. Krejcie and Morgan table was utilized in determining the sample size of the study which was 278. The instrument used in collecting data was a structured questionnaire State College of Education Minna, The data collected was analyzed using simple percentage, frequency table, mean and standard deviation in order provide answers to the research questions. Based on the findings, this research concluded that that activities of artisanal gold miners have significantly alter land use patterns, leading to deforestation, farmland loss, health hazards, and socio-economic challenges for local communities. It was therefore, recommended that Government should develop and implement awareness programmes to educate artisanal miners and local communities about existing laws and regulations related to land use and environmental protection. This should include information on the legal consequences of illegal mining activities and the importance of sustainable practices.

Keywords: Environmental impact, artisanal, gold mining, land use pattern

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Assessment of Aquifer Protective Capacity and Corrosivity Around Solid Waste Dumpsites in Parts of Minna Metropolis, North-Central, Nigeria

BALARABE, J. J., RAFIU, A. A., ADETONA, A., SHEHU, J., SALIHU, Y.L. [1]

[1]Department of Physics, Federal University of Technology Minna, Niger State, Nigeria

Abstract

This study investigates the aquifer protective capacity and soil corrosivity of subsurface layers around solid waste dumpsites in Chanchaga and Maitumbi, Minna metropolis, Niger State, Nigeria, using the Vertical Electrical Sounding (VES) geophysical method with the Wenner configuration. The research aims to delineate subsurface layers, assess aquifer potential, evaluate aquifer protective capacity, determine soil corrosivity, and identify suitable sites for productive boreholes. A total of 60 VES points were surveyed across the two dumpsites, revealing three to four geoelectric layers, including topsoil, weathered/fractured basement, and fresh basement. Results indicate that 77% of the study area has medium groundwater potential, with aquifer thicknesses ranging from 10–25 m and resistivity values between 80–100 Ωm. In Chanchaga, 27% of the area exhibits moderate to good aquifer protective capacity, while 73% shows weak to poor capacity. In Maitumbi, 44% has excellent to very good protective capacity, and 56% is weak to poor. Soil corrosivity analysis shows 7% moderately corrosive, 26% slightly corrosive, 19% very strongly corrosive, and 48% practically non-corrosive areas. The findings highlight vulnerable zones susceptible to contamination and recommend avoiding borehole development in areas with weak protective capacity, using electrical resistivity tomography for further contamination assessment, and preferring plastic pipes in corrosive zones to prevent infrastructure deterioration. This study provides critical insights for groundwater protection, site remediation, and sustainable waste management strategies in Minna metropolis, Niger State.

Keywords: Vertical electrical sounding, aquifer potential, corrosivity, aquifer protective capacity and good/moderate rating.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Artificial Intelligence in Creating Public Value in Local Government: Evidence from Hyderabad City, Pakistan

Liaquat Ali RAHOO[1*]

[1]IT Officer, Mehran University of Engineering and Technology, Jamshoro

Muhammad Nawaz TUNIO[2]

[2]Assistant Professor, University of Sufism and Modern Sciences, Bhitshah

Abstract

Objective: the purpose of this research is evaluating the effects of artificial intelligence on generating public value, with the focus on government employees and citizens in the Hyderabad City, Pakistan. Theoretical framework: This study builds on the theory of digital governance, which argues that digital technologies can transform public administration by improving transparency, efficiency, accountability, and service delivery. This study explores how these technological interventions can promote participatory governance models by facilitating better interactions between citizens and government. Methods: The study uses structural equation modelling (SEM) to explore key aspects of digital governance, including transparency, cost-effectiveness, data-driven policymaking, accountability, and service quality. Results: The analysis shows a strong positive correlation between various elements of digital governance and increased citizen engagement. These findings highlight the power of digitalization in public administration to increase public engagement and trust. The findings suggest a close relationship between the role of AI in local government and the building of public values. This suggests that integrating AI into local governance can deliver significant public benefits, enhancing its importance in policymaking and service delivery. Implications: The study provides important insights for policymakers on the impact of digital initiatives on urban governance. It highlights the importance of continued investment in technological advancement and data security to improve urban governance and increase citizen engagement. Originality: This study makes a unique contribution to the understanding of how digital government initiatives can create public value by enhancing citizen engagement. It critically examines the components of digital governance and their effectiveness in promoting public engagement and trust, and provides valuable recommendations for policymakers concerned with urban governance and digital transformation.

Keywords: Artificial intelligence, local government, public service delivery, citizens, transparency, saves costs, and e-governance.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Mosques and Shrines in the Socio-Political Life of Settlements and Their Influence on Urban Formation

Mahammad BAYRAMOV[1*]

ORCID 1: 0009-0009-2074-58-71
[1]PhD Candidate, Lecturer at the Department of Architecture Nakhchivan State University
*mehemmedbayramli996@gmail.com (Responsible Author)

Abstract

Mosques and shrines have played a fundamental role in the socio-political life of settlements for centuries. The Juma Mosque in the city of Nakhchivan *and the congregational mosque located in the city of Ordubad are among the most prominent examples of such institutions. These structures have not only served as places of religious worship but have also evolved into central hubs for social, cultural, and political processes. Mosques have significantly contributed to the development of urban and rural communities through educational, charitable, and other public activities. Although the structure of society has changed over time, mosques and shrines have preserved their significance, becoming centers that unite people, shape the cultural environment, and influence regional development. In modern times, they also serve as important monuments that offer insights into the historical and social life of societies. Therefore, the study of mosques and shrines provides a deeper understanding of both the historical and contemporary structures of communities, as well as the processes shaping their socio-political life.*

Keywords: Juma Mosque, Shrines, Nakhchivan, urban formation

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Utilizing Recycled Aggregate Concrete

Chayaraju BALA SAI[1*]

ORCID 1: 0009-0003-4055-9773
[1]Assistant Professor Department of Civil Engineering, G. pulla reddy Engineering College (Autonomous), Kurnool, AP, India

Nadagouda KALYANI[2]

[2]Assistant Professor Department of Civil Engineering, G. pulla reddy Engineering College (Autonomous), Kurnool, AP, India

K. THARANI[3]

[3]Assistant Professor Department of Civil Engineering, G. pulla reddy Engineering College (Autonomous), Kurnool, AP, India

Abstract

Concrete that contains recycled aggregate may help protect the environment. The materials of the future are recycled aggregates. Large-scale construction projects in numerous European, American, Russian, and Asian nations have begun to use recycled aggregate. In order to increase the usage of recycled aggregate, many nations are relaxing their infrastructure regulations. The fundamental characteristics of recycled coarse and fine aggregate are described in this work along with a comparison to natural aggregates. The implications of basic changes in all aggregate qualities on concreting work are extensively examined. In a similar manner, recycled aggregate concrete's characteristics are also established. Here are explanations of basic concrete attributes for various combinations, such as workability, flexural strength, and compressive strength. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here.

Keywords: Concrete, recycled aggregate**,**

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Intellectual Property and Design Protection

Aswin M. NAIR[1*]

ORCID 1: 0009-0008-7177-4990
[1]BBALL B student, Sharda School of Law, Sharda University, Greater Noida, India

Payal SHUKLA[2]

ORCID 2: 0009-0001-7074-3374
[2]BALL B student, Sharda School of Law, Sharda University, Greater Noida, India

Abstract

Intellectual Property (IP) plays a pivotal role in safeguarding creativity, innovation, and the commercial value derived from original works. Within this framework, design protection occupies a distinctive space as it bridges the gap between artistic creativity and industrial applicability. Design law ensures that the aesthetic aspects of products such as shape, configuration, pattern, or ornamentation, receive legal recognition and protection from unauthorized reproduction. In architecture and industrial design, where artistic expression meets functional utility, IP protection becomes crucial to preserve the creator's moral and economic rights. This paper examines the legal framework governing design protection, with a special focus on the Designs Act, 2000 in India, and its alignment with international instruments such as the TRIPS Agreement and the Hague System. It explores how intellectual property rights, particularly copyrights, design rights, and patents, interact and sometimes overlap in the domain of design and architecture. Further, the study analyses issues related to plagiarism, infringement, and moral rights, which often arise due to technological advancements and easy replication methods. The research highlights recent judicial interpretations and landmark cases that have shaped the understanding of design protection in India. It also evaluates the challenges faced by designers in enforcing their rights and proposes measures to strengthen the existing legal regime. Ultimately, the paper underscores the need for a balanced approach that encourages innovation while maintaining fair competition in creative industries.

Keywords: Intellectual property rights, design protection, copyright, innovation, architecture, TRIPS Agreement, Designs Act 2000

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Exploring Evidence Based Design Strategies to Foster Healing in the Design of a Paediatric Hospital in Rigasa, Kaduna State

Amira ABDUL-AZEEZ[1*]

Department of Architecture Faculty of environmental Design Ahmadu bello university, Zaria Nigeria

Abstract

Architecture can significantly become part of the healing process through the creation of spaces that foster and provide meaning to those activities utilized to achieve gradual rehabilitation through a therapeutic environment. In recent years, design for health care environments have begun to include proven enhancements in an attempt to reduce stress and anxiety, increase patient satisfaction, and promote health and healing. This concept is referred to as Evidence Based Design. Despite the numerous proven ways in which Evidence-based healthcare design can provide favourable clinical outcomes, few hospitals have incorporated this concept within the Nigerian context. On this account, we embarked on local and international case studies to assess the level of application of the concept in Kaduna State. Local cases were chosen using a criterion that will represent variety of hospital types in the study area. Comparative analyses using visual survey and checklist methods were used during the case-studies. Comparative analyses, using the designated framework helped to explore the design elements that were employed in the hospital designs. Qualitative analyses in the form of semi-structured interviews were conducted among hospital users to gain useful insight on user experience within the hospitals. Findings show that the paediatric hospital cases assessed through visual observations in Kaduna have a very low level of application of evidence-based design approaches with the following indices: environmental factors 30%, patients' sustainability 46.6%, support spaces 43% and wayfinding strategies 40%. This was demonstrated in a design proposal of a paediatric hospital in Rigasa, Kaduna State using evidence-based design strategies to promote healing. This research finally recommends that when designing paediatric hospitals in the North Western region of Nigeria, architects should try to consider Evidence Based Design strategies as they make the hospital achieve optimum functionality.

Keywords: Kaduna, Rigasa, paediatric hospital, foster healing

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Use of Artificial Intelligence in Transport for Rural Development

J. Salai Thillai THILAGAM[1*]

[1]Associate Professor, Dept. of Electronics and Communication Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India

Gorla LALITHA[2]

[2]Student, Dept. of Electronics and Communication Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India

Abstract

This paper explores the role of Artificial Intelligence (AI) in transforming various aspects of the transport sector for rural development. It reviews recent developments in AI applications in traffic management, public transport planning, autonomous vehicles, maintenance, and safety systems. Through a systematic literature review, the paper identifies key methodologies, current results, and gaps in research. It also presents a methodology for evaluating AI-based systems in transport using case studies and simulation experiments. The findings show that AI has significant potential for reducing congestion, improving safety, lowering emissions, and optimizing operations, but challenges related to data quality, ethical issues, interpretability, and deployment remain. The paper concludes with recommendations for future research and policy considerations.

Keywords: Artificial intelligence; transportation; machine learning; traffic management; autonomous vehicles; predictive maintenance; safety; public transport.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Gep- Based on Modeling of Alkaline Activators Effects on Geopolymer Concrete

Chayaraju BALA SAI[1*]

ORCID 1: 0009-0003-4055-9773

[1]Assistant Professor Department of Civil Engineering, G. pullareddy Engineering college (Autonomous), Kurnool, AP, India

Nadagouda KALYANI[2]

[2]Assistant Professor Department of Civil Engineering, G. pullareddy Engineering college (Autonomous), Kurnool, AP, India
kalyani0519@gmIOTl.com

K. THARANI[3]

[3]Assistant Professor Department of Civil Engineering, G. pullareddy Engineering college (Autonomous), Kurnool, AP, India
tharanijawahar@gmIOTl.com

Abstract

This paper reviews how alkaline activators (type, concentration, and silica modulus) and other mix/processing factors influence the mechanical and durability properties of geopolymer concrete (GPC) produced from industrial wastes such as fly ash, GGBS, and rice husk ash. The study also presents a Gene Expression Programming (GEP)-based modelling framework to predict key properties such as compressive strength and chloride penetration resistance. The methodology is aimed at researchers and engineers interested in optimizing activator usage while enhancing waste valorization.

Keywords: Alkaline activator, sodium silicate, geopolymer concrete -, fly ash, GGBS, industial waste

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Forest Carbon Assessment and Modelling in Bangladesh: Pathways for Sustainable Forest Management and Climate Mitigation

Sadid SHAHRIYAR[1*]

[1]Faculty of Agriculture, Sher-e-Bangla Agricultural University

Abstract

Bangladesh's forests are critical carbon sinks, yet they face significant threats from deforestation, degradation, and unsustainable land-use practices. This study synthesizes secondary data from the Food and Agriculture Organization (FAO), Bangladesh Bureau of Statistics (BBS), Intergovernmental Panel on Climate Change (IPCC), and peer-reviewed publications to provide updated estimates of forest carbon stocks and evaluate management scenarios. Remote sensing products (Landsat, MODIS, Sentinel) and biomass models were analyzed to determine

sequestration status. Findings indicate that the Sundarbans (~110–120 Mg C ha−1), Chittagong Hill Tracts (~80–100 Mg C ha−1), and Sal forests (~70–85 Mg C ha−1) store substantial carbon, although annual losses of 0.5–1% persist. Scenario modeling predicts that REDD+ strategies could improve sequestration by 15–20%, while afforestation and community forestry programs could enhance storage by up to

25% compared to Business-as-Usual (BAU). However, limitations in standardized methodologies, national inventories, and institutional frameworks restrict accurate assessments. This study proposes the integration of GIS-based MRV systems, localized allometric equations, and REDD+ financing to strengthen forest carbon management in Bangladesh.

Keywords: Carbon sequestration, forest carbon dynamics, remote sensing, GIS-based modelling, soil and blue carbon, REDD+ mechanisms, climate finance, sustainable forest management, tropical forestry, South Asia

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Experimental Study on Mechanical Properties of Normal Strength Concrete by Partial Replacement of Fine Aggregate with Demolished Brick Waste

Pathangi ESWANTH[1*]

[1]Asst.Professor, Department of Civil Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India

Mahendrakar HEMANTH KUMAR[2]

[2]Asst.Professor, Department of Civil Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India

Ramireddy SUSHMITHA[3]

[3]Asst.Professor, Department of Civil Engineering, G. Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, India

Abstract

Bangladesh's forests are critical carbon sinks, yet they face significant threats from deforestation, degradation, and unsustainable land-use practices. This study synthesizes secondary data from the Food and Agriculture Organization (FAO), Bangladesh Bureau of Statistics (BBS), Intergovernmental Panel on Climate Change (IPCC), and peer-reviewed publications to provide updated estimates of forest carbon stocks and evaluate management scenarios. Remote sensing products (Landsat, MODIS, Sentinel) and biomass models were analyzed to determine

sequestration status. Findings indicate that the Sundarbans (~110–120 Mg C ha−1), Chittagong Hill Tracts (~80–100 Mg C ha−1), and Sal forests (~70–85 Mg C ha−1) store substantial carbon, although annual losses of 0.5–1% persist. Scenario modelling predicts that REDD+ strategies could improve sequestration by 15–20%, while afforestation and community forestry programs could enhance storage by up to

25% compared to Business-as-Usual (BAU). However, limitations in standardized methodologies, national inventories, and institutional frameworks restrict accurate assessments. This study proposes the integration of GIS-based MRV systems, localized allometric equations, and REDD+ financing to strengthen forest carbon management in Bangladesh.

Keywords: Carbon sequestration, forest carbon dynamics, remote sensing, GIS-based modelling, soil and blue carbon, redd+ mechanisms, climate finance, sustainable forest management, tropical forestry, South Asia

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Impact of Green Finance in Sustainable Performance: Mediating the Role of CSR

Aqsa FAROOQ[1*]

[1]Department of Business Administration, Riphah International University Rawalpindi

Rimsha IQBAL

[2]Department of Business Administration, Riphah International University Rawalpindi

Abstract

Purpose: This study aims to examine the impact of Green Finance on sustainable organization performance, assessing how financial sustainability drives environmental and social outcomes. It also explores the mediating role of Corporate Social Responsibility who influence the relationship of both variables. By analyzing financial strategies and CSR practices, the research seeks to identify how businesses balance profitability with sustainable growth.

Design: By using deductive approach, Applying established scale theories to test the relationship between green finance, CSR and sustainable performance. A survey-based methodology is used, incorporating the all three variables scale to measure key constructs. we take data from university students and corporate sectors to capture diverse perspectives specifically in Pakistan. The findings aim to validate theoretical assumptions and provide practical insights into financial sustainability and responsible corporate practices. through questionnaire form using the scale of three variables.

Finding: Our analysis confirms that green finance exerts a significant direct influence on sustainable performance, while also positively driving Corporate Social Responsibility (CSR) initiatives. Correlation and regression analyses reveal robust relationships between these variables—green finance is strongly associated with both CSR ($r = 0.824$; $p < 0.05$) and sustainable performance ($r = 0.588$; $p < 0.05$). Furthermore, CSR markedly mediates the relationship between green finance and sustainable performance (indirect effect $B = 0.2380$ with a 95% confidence interval that excludes zero), underscoring the dual pathway through which financial strategies both directly and indirectly enhance long-term organizational outcomes.

Originality: In my limited knowledge. I haven't found any study that examines the impact of green finance on sustainable performance within this specific population in Pakistan also this research incorporates the mediating role of CSR which the the best of my understanding, has not been widely explored in this context. By addressing this gap, the study provides unique insights

into financial sustainability and responsible business practices in Pakistan's corporate and entrepreneurial landscape.

Keywords: Green finance, CSR, developing countries, decision making, sustainable performance

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Smart Fabrication and Automated Building Technologies

KISHORE. R[1*]

[1]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India -600 073

VAISHNAVI. K[2]

[2]Faculty of Pharmacy, Bharath Institute of Highe Education and Research, Chennai, India -600 073

KEERTHANA. V[3]

[3]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India -600 073

MEENATCHI. S[4]

[4]Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India -600 073

SARAVANAN[5]

[5]Guide: Dr., Faculty of Pharmacy, Bharath Institute of Higher Education and Research, Chennai, India -600 073

Abstract

The evolution of Advanced Fabrication and Construction Technologies is redefining the future of architecture and engineering, enabling faster, smarter, and more sustainable building processes. This emerging field integrates digital design, automation, robotics, and additive manufacturing to enhance precision, efficiency, and environmental performance. Techniques such as 3D printing, robotic assembly, prefabrication, and modular construction are revolutionizing how structures are conceived and realized — reducing material waste, labor intensity, and on-site disruptions. Additionally, parametric modelling and Building Information Modelling (BIM) allow real-time collaboration and optimization across design and construction phases. Innovations in smart materials, including self-healing concrete and responsive composites, further expand the scope of adaptive and resilient structures. These advancements not only streamline complex fabrication but also support circular design principles and energy efficiency goals. Ultimately, advanced fabrication and construction technologies represent a paradigm shift from traditional craftsmanship to data-driven, automated precision — bridging creativity, technology, and sustainability in the built environment.

Keywords: Automated construction, building automation, 3D printing in architecture, digital fabrication, construction robotics

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Photoresponsive Behavior of N-Acylhydrazones: A Study of Solvent-Dependent E/Z Isomerization

Yahya BOUBEKRI[1]*

[1]Laboratoire Chimie-Biologie Appliquées à Environment URL-CNRST 13, Equipe Chimie Moléculaire et Molécules Bioactive. Université Moulay Ismail, Faculté des Sciences –Meknès, Maroc.
yahya.boubekri@edu.umi.ac.ma *(Responsible Author)

Amina AMINE[1]

[1]Laboratoire Chimie-Biologie Appliquées à Environment URL-CNRST 13, Equipe Chimie Moléculaire et Molécules Bioactive. Université Moulay Ismail, Faculté des Sciences –Meknès, Maroc.

Siham SLASSI[1,2]

[1]Laboratoire Chimie-Biologie Appliquées à Environment URL-CNRST 13, Equipe Chimie Moléculaire et Molécules Bioactive. Université Moulay Ismail, Faculté des Sciences –Meknès, Maroc.
[2]Laboratory of Engineering and Materials (LIMAT), Faculty of Sciences Ben M'sick, University Hassan II of Casablanca, Casablanca, Morocco

Mohammed AARJANE[1,3]

[1]Laboratoire Chimie-Biologie Appliquées à l' Environment URL-CNRST 13, Equipe Chimie Moléculaire et Molécules Bioactive. Université Moulay Ismail, Faculté des Sciences –Meknès, Maroc.
[3]Laboratory of Organic Chemistry, Materials, Electrochemistry, and Environment, Faculty of Sciences Ain Chock, Hassan II University, Casablanca, Morocco

Abstract

Acylhydrazones represent a distinctive class of Schiff bases that have attracted considerable attention due to their wide range of applications. These compounds serve as valuable intermediates in organic synthesis and coordination chemistry. Notably, N-acylhydrazones act as key precursors for various heterocyclic frameworks and exhibit strong coordinating abilities with metal cations. Several N-acylhydrazones and their metal complexes have demonstrated remarkable sensitivity and selectivity toward specific metals, as well as significant bioactive properties in medicinal chemistry.
In this study, we report the synthesis and characterization of two N-acylhydrazones prepared through simple and cost-effective methods using salicylic acid as a starting material. The target molecules were obtained via condensation of hydrazide intermediates with different natural and/or synthetic aldehydes, affording the desired products in good yields.
Furthermore, we investigated the photoisomerization behavior of the synthesized N-acylhydrazones under UV irradiation. UV–visible spectral analysis revealed a reversible E/Z isomerization around the C=N bond, whose kinetics were strongly influenced by the solvent polarity. In methanol, the trans-to-cis conversion occurred within approximately 30 minutes, whereas in DMSO it required about 45 minutes. These observations demonstrate the solvent's role in stabilizing the photoinduced transition states and confirm the reversible photoresponsive nature of these compounds, making them promising candidates for use as molecular photoswitches or photoactive materials.

Keywords: N-acylhydrazone; salicylic acid; photoisomerization

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Advanced Building-Integrated Photovoltaic (Bıpv) Systems for Sustainable Architectural Design

Muhammad Mateen AFZAL AWAN

ORCID 1: 0000-0002-7354-5058
Assist. Prof., University of Management and Technology Lahore, Sialkot Campus, Pakistan
mateenafzalawan@gmail.com

Abstract:

The global demand for sustainable and energy-efficient buildings has accelerated the adoption of Building-Integrated Photovoltaic (BIPV) systems that seamlessly merge architectural aesthetics with renewable energy generation. This paper presents an interdisciplinary approach combining architectural design principles with advanced electronics engineering to optimize photovoltaic performance within building structures. The study emphasizes the role of semiconductor materials, power electronics, and maximum power point tracking (MPPT) algorithms in enhancing the efficiency and reliability of BIPV installations. Various integration strategies are analyzed, including façade, rooftop, and window-based PV modules, with a focus on their electrical modeling, energy yield, and thermal management. The work also explores the potential of emerging thin-film and organic PV technologies for flexible and transparent surfaces, enabling novel design possibilities for modern architecture. The proposed framework aims to establish an efficient synergy between aesthetic design and functional energy conversion, contributing toward the development of self-sustaining smart buildings.

Keywords: Building-integrated photovoltaics (BIPV), architectural design, renewable energy, power electronics, MPPT, semiconductor materials, sustainable buildings, energy efficiency

V. International Architectural Sciences Congress

(IArcSC-2025)

https://www.iarcsas.org/

October 29-30-31, 2025 / Demre, Antalya, Türkiye

PROCEEDINGS BOOK

Full Text List

ISBN: 979-8-89695-259-6
DOI: https://doi.org/10.5281/zenodo.17937655

ISSUED: December 15, 2025

TITLE	AUTHORS	Page No
The Role of Design Strategy in Creating Resilient Historic Cities within the Framework of Sustainable Development Goals	• Kağan GÜNÇE	238-249
Spatial Distributions of Land Use/Land Cover (LULC) in the Demre Stream Corridor: Assessment of Current Issue	• Hüseyin Batuhan DÜNDAR • Atila GÜL • Sibel AKTEN	250-258
The Role of Light Shelf Systems in Architectural Design: An Examination in the Context of Visual Comfort and Energy Efficiency	• Sümeyra AKGÜN • Ümit ARPACIOĞLU	259-266
Examining Secondary School Landscape Spaces from a Design Perspective in the Climate Change Adaptation Process	• Sibel AKTEN • Atila GÜL	267-279
Determining Route Selection Criteria for the Creation of a Bicycle Route in the Context of Diversifying Cultural Tourism	• Sibel AKTEN • Atila GÜL • Hüseyin Batuhan DÜNDA	280-296
The Effects of Material on Spatial Atmosphere in Architectural Design Approaches Adopting A Minimalist Attitude	• İremnur MUSLU • Ümit Turgay ARPACIOĞLU	297-305
Principles and Guidelines for Planning Restoration in Forest Fire-Affected Areas	• Ufuk COŞGUN • Sohaib K. M. ABUJAYYAB	306-315
Current Status and Analysis of Demre (Antalya) Urban Green Areas	• Atila GÜL • Sibel AKTEN • Hüseyin Batuhan DÜNDAR • Çağrı YOLUK	316-329
The Assessment of Key Factors Sustainable Smart Cities	• Ahmet FİDAN • Esra BAYIR • Pelin KARAÇAR • Aysun Ferrah GÜNER	330-341
Child-Friendly Street Designs in Urban Areas	• Habibe ATAK • Gülbin ÇETİNKALE DEMİRKAN	342-348
Healing Garden Designs as Supportive Elements in Oncology Hospitals	• İpek İPEKLİ • Gülbin ÇETİNKALE DEMİRKAN	349-359

An Evaluation of the Conservation History, Archaeological Findings, and the "Heritage for the Future" Project of the Church of St. Nicholas	• Ebru Fatma FINDIK	360-373
The Importance of Urban Green Areas in Demre (Antalya) in the Climate Change Adaptation Process, and Strategic Actions	• Atila GÜL	374-391
Classification of Kinetic Building Components in Contemporary Architecture	• Hatice Eda GÜL • Nazire Tuğçe YENİCE • Yenal AKGÜN	392-405
Dwelling-Street Relations in Traditional Urban Fabrics: The Case of Famagusta Walled City	• Hasan DOĞAN	406-420
Reflections of Designer Identity on Architecture: Analyses on Peter Zumthor and Kengo Kuma	• Pınar TASLI • Hare KILIÇASLAN	421-441
Spatial and User-Centered Evaluation of the Main Entrance at Karadeniz Technical University Department of Architecture	• Sevde DİNÇER • Hare KILIÇASLAN	442-454
Transitioning from IFC to Linked Building Data: Semantic Simplification with BOT, PRODUCT, and PROPS Ontologies	• Murat AYDIN	455-466
Conceptual Uncertainties in Semantic BIM: Achieving Definition Clarity through Ontology Engineering	• Murat AYDIN	467-478
Development of Lignin-Modified Phenol-Formaldehyde Resins: Sustainability Effect in the Furniture Industry	• Fatma Pinar SENKON • Busra ŞİMŞEK • Arif AKILLILAR • Franz ZEPPETZAUER • Birgit KAMM	479-488
Public Rest Areas in Shopping Centers: Samsun Piazza Mall	• Hande YILDIRIM • Serap FAİZ BÜYÜKÇAM	489-496
Current Research Trends in Interior Architecture: A Conceptual Mapping	• Serap FAİZ BÜYÜKÇAM • Hande YILDIRIM	497-506
In Search of Thermal Comfort: Forgotten Design and Planning Principles for Cities	• Nursevil YUCA • Feran AŞUR	507-518

Climate-Concerned Urban Furniture in the Urban Landscape	• Feran AŞUR • Nursevil YUCA	519-529
Daylight Utilization in Architectural Structures	• Zübeyde Çiçek • Halil Sevim	530-548
An Examination of Lighting Use in Exhibition Spaces within the Context of Refunctioned Museum Buildings through Sample Studies	• Kübra CİVELEK KALINCA • Menşure Kübra MÜEZZİNOĞLU	549-575
The Impact of the White Cube Paradigm on Interior Design in Contemporary Art Museums: A Comparative Analysis of İstanbul Modern and New York MoMA	• Sena YILMAZ • Menşure Kübra MÜEZZİNOĞLU	576-590
Urban Squares: A Citizen-Centered Assessment of Aliağa Democracy Square in İzmir	• Pelin ÖZDEN	591-599
Comparative Performance of Adaptive Façade Systems in Different Climate Types: An Evaluation of Three Buildings	• Esra Nur ARVAS • Ümit Turgay ARPACIOĞLU	600-609
Technical Contributions of Civil Engineering in the Intervention Processes for the Conservation of Historical and Cultural Heritage and the Comparative Analysis of the Role of Related Courses in Architectural Graduate Programs	• Pınar ARIK • Hayriye Hale KOZLU	610-619
An Experience-Based Mapping of the Samsun City-Center	• Hande ASAR	620-629
A Discussion on the Spatial Atmosphere: The Example of Samsun Süleyman Pasha Madrasah	• Hande ASAR	630-638
Thematic Review of Machine learning techniquess in Landscape Planning Processes	• Aslı İlayda TURGUT • Murat AKTEN	639-650
Enhancing Urban Microclimate through a Digital Twin–Based Approach: The Case Study of Kaymakkapı Square, Isparta	• Aslı İlayda TURGUT • Murat AKTEN	651-661
Mobility as Cultural Heritage: Rethinking Yörük Settlements through Spatial Practices	• Uğur Efe UÇAR • Ethem GÜRER	662-672

From Cognitive Tool to Pedagogical Assistant: Rethinking AI in Interior Design Education through Student Experiences	• Gözde GÖKDEMİR • Hande Zeynep KAYAN	673-683
Landscape Character Analysis Evaluation in Rural Settlements: Erzurum Palandöken Example	• Ahmet KOÇ • Sevgi YILMAZ	684-692
Human-Centered Approaches to Educational Furniture Design: Ergonomic Analysis of Classroom Desks	• Emre ECEVİT • Merve BİLGEN IŞIK	693-701
The Role of Streets and Avenues in The Formation of City Identity; Gaziantep Karagöz Street	• Ebru Begün SAÇIKARA Meltem BARIŞ ARARAT	702-709
Analysis of Perception-Experience-Image-Memory Relationships in the Context of Fictional Spaces in the Film "Room"	• Esra TOKUÇ • Serhat ANIKTAR	710-723
GIS Tools Used in Spatial and Temporal Prediction and Analysis of Land Use/Land Cover Changes: MOLUSCE	• Çağla AYDEMİR • Ömer Kamil ÖRÜCÜ • Seda ÖRÜCÜ	724-735
Interior Architecture Design Suggestions in Traditional Urfa Houses: Re-Functioning	• Ayşe Gül GÜZEL	736-750
Investigating the Effects of Transport Factor on Structural Systems' Life Cycle Environmental Performance	• Neriman Gül ÇELEBİ • Ümit ARPACIOĞLU	751-757
The Role of Green Infrastructure in Improving Air Quality: A Case Study of Kocaeli Darıca Millet Garden	• Kübra HANOGLU • Gülnur KARDAN • Sultan Sevinc KURT KONAKOGLU	758-772
Assessment of Green Infrastructure Systems Based on Ecosystem Services: The Case of Amasya University	• Mustafa Taha KESKİNER • Alper Kaan KALKAN • Sultan Sevinc KURT KONAKOĞLU	773-780
3D Construction Technology for Building Elements	• Berrin ŞAHİN DİRİ	781-810

Comparison of Survey Results on the Use of External Wall Filling Materials and the Usage Trends of These Materials in the Construction Sector in Türkiye	• Berrin ŞAHİN DİRİ • Ahmet Cüneyd DİRİ	811-821
Integration of Eye Tracking Technology into the Urban Green Space Planning	• Murat YEŞİL • Mesut GÜZEL • Rabia Nurefşan AÇIKGÖZ • Eda ŞENTÜRK	822-834
The Effects and Limitations of Safety Standards on Creative Designs in Children's Playgrounds	• Elif SAĞLIK • Efe Arda HASANOĞLU	835-845
Visualizing the Impacts of Modularity and Mobility on Contemporary Urban Design through AI: Inspirations from Archigram	• Elif SAĞLIK • Fatma ERDOĞAN	846-857
Timber Decay in Gaziköy Houses and The Sustainability of The Rural Fabric	• Özlem BOZKURT	858-866
Adaptive Reuse of Historical Buildings as Libraries: Original Function-Based Approaches	• Rümeysa AYDIN • Şebnem ERTAŞ BEŞİR	867-881
Spatial and Functional Suggestions for the Sustainability of Traditional Marketplaces: from Consumption to Production	• Ayşe Seda ÇALIŞKAN • Özge KANDEMİR	882-896
Conceptual Transitions and Reflections from Landscape Performance Assessment to Design Practice	• Mahmut Can AST • Elif SAĞLIK	897-908-
Integration of Virtual Reality (VR)- Augmented Reality (AR) and Mobile Applications in Urban Recreation Areas	• Seyhan SEYHAN • Banu Çiçek KURDOĞLU	909-913
How Do Urban Recreation Areas Contribute to Social Solidarity and Integration?	• Seyhan SEYHAN • Banu Çiçek KURDOĞLU	914-920
Comparative Assessment of Simulation Tools in the Scope of Indoor Air Quality	• Rana KİBAROĞLU KANTARCI • Elif ÖZER YÜKSEL	921-934

3D Topographic and Architectural Documentation of the Multi-Functional Underground Structure at Kaletepe, Miletus	• Özel TERAMAN HEPDNÇLER • Nikolai TECHOW • Haralamibos NIKOLAYIDIS • Özlem KAYA • Hasan Ersin GÜVENDİK • Ece KIZILDAĞ	935-947
An Examination at the Intersection of Cinema and Architecture: The Rings of Power - The Land of Numenor	• Tolgay İNANÇ • Halil SEVİM	948-961
Digitalization of Sustainability in Steel Structure Design Projects	• Esin ŞAHİN • Kerim KOÇ	962-971
An Examination of Post-Disaster Housing Design in the Context of Regional and Climatic Adaptation	• Emine Şeyma ERKAN • Nilay COŞGUN • Elif ÖZER YÜKSEL	972-990
Analysis of the Impact of Urban Design on Social Inequalities and Mental Health: A Case Study of Isfahan, Iran	• Parsa BARAHOUEİ • Çilen ERÇİ	991-1014
Nature-Based Open Space Approaches for Sustainable Campus Life	• Emirhan AKSU • Alper SAĞLIK	1015-1024
The Social Dimension of the Climate Crisis	• Hatice Gözde ÖZKARAKAYA • Murat AKTEN	1025-1044
Applications of HVAC Condensate Water in Landscaping and Its Water–Energy–Carbon Impact	• Buğrahan ÇETİNKAYA • Murat AKTEN	1045-1062
Contributions of the “Placemaking” Approach to the Urban Environment	• Pınar Özge PARLAK • Elif BAYRAMOĞLU	1063-1073
Nature-Based and Digital Solutions for Flood-Resilient Urban Systems	• Pınar Özge PARLAK • Elif BAYRAMOĞLU	1074-1079
A Study on the Use of Parametric Design Tools in Architectural Education	• Berfin YILMAZ • Ümit ARPACIOĞLU	1080-1096
Ecological Compatibility and Accessible Design in Archaeological Sites	• Bilgenur AK • Öner DEMİREL • M. Bihter BİNGÜL BULUT • Tuba Gizem AYDOĞAN	1097-1110

Rainwater Design and Management in Housing Estate Gardens	• Melisa EKEN • Irem KAYA • Ece YILDIZ • Hatice ADA	1111-1116
Expert Opinions and Evaluation within the Scope of Urban Forest Management	• Öner DEMİREL • Bilgenur AK • Meryem Bihter BİNGÜL BULUT	1117-1123
Reducing the Urban Heat Island Effect with Water Surfaces: The Case of Hazar Lake	• Yaşar MENTEŞ • Sevgi YILMAZ	1124-1128
Climate-Sensitive Urban Design Approaches: The Case of Elazığ City	• Yaşar MENTEŞ • Sevgi YILMAZ	1129-1136
Use of Fragrant Plants Growing in Isparta in Landscape Designs	• Emine AĞLAR • Şirin DÖNMEZ	1137-1146
High-Potential Medicinal and Aromatic Plants in Konya Flora and Their Use in Landscape Architecture	• Nilgül BAĞCI • Şirin DÖNMEZ	1147-1155
The Impact of Female Patrons on Urban Form in the Principalities and Ottoman Periods: The Manisa Example	• Yağmur Burcu GÜNEŞ • Şebnem ÇAKALOĞULLARI	1156-1164
Sustainability in Traditional Urban Form: Example of Tire	• İzzet YÜKSEK • Ecem UĞURLU • Yağmur Burcu GÜNEŞ	1165-1175
Hybrid Education Spaces: Spatial Strategies and Design Perspectives	• Hatice CEYLAN • Ekrem Bahadır ÇALIŞKAN	1176-1191
Stress Tolerance in Ornamental Plants	• Bahar SANCAR	1192-1202
Effects of Climate Change on the Physiology of Ornamental Plants	• Bahar SANCAR	1203-1213
Local Implementation Challenges of Sustainable Campus Certification Systems: A Critical Analysis in the Context of Türkiye	• Ertan DÜZGÜNEŞ • Beyzanur AKKUŞ	1214-1129

Marine Protected Areas and Protection Strategies	• Ertan DÜZGÜNEŞ • Duygu KARABIÇAK GÜNAYDIN	1230-1242
Media Representation of Non-Structural Elements Following the February 6 Kahramanmaraş Earthquakes in Türkiye	• Ayşan Ilgın POLAT • Şebnem ERTAŞ BEŞİR	1243-1251-
Spatial Hybridization and the Transformation of Identity: A Study on Rural Settlements and Secondary Houses in the Edremit Gulf	• Aysu ÇAKIR • Gaye BİROL	1252-1267
A Comparative Analysis of Similar Traditional Wall Construction Techniques in Different Regions	• Ayça AKKAN ÇAVDAR • Esra LAKOT ALEMDAĞ	1268-1282
Analysis of Studies on Transparent Wood and Its Potential Use in the Construction Industry	• Nilay AYKAN • Esra LAKOT ALEMDAĞ	1283-1295
Virtual Reality (VR) Technology and Interactive Design Processes in Landscape Design	• Ahmet BENLİAY • Yaren SADIK	1296-1303
Comparison of 3D Modeling and Artificial Intelligence Tools in Landscape Design Visualizations	• Türkan AZERİ • Ahmet BENLİAY	1304-1314
Natural Carbon Sinks and Ecosystem-Based Approaches in Combating the Climate Crisis	• Mahmut TUĞLUER • Mert ÇAKIR	1315-1330
Citizen Science as a Tool for Urban Biodiversity Monitoring	• Mert ÇAKIR • Mahmut TUĞLUER	1331-1343
An Investigation into the Potential of Artificial Intelligence Applications in Low Earth Orbit Satellite Systems for Urban Planning Applications	• Elif Eda TAKGİL • Ali ÇALHAN • Murtaza CİCİOĞLU	1344-1352
Acoustic Identity in Cultural Landscapes: Local Sounds, Memories, and Spatial Attachment	• Sıla GÜNAÇAN ODABAŞI • Ebru ERBAŞ GÜRLER	1353-1363
Urban Open-Green Spaces within the Framework of Türkiye's Climate Law	• Demet DEMİROĞLU • Aybike Ayfer KARADAĞ	1364-1371

Legal Vulnerability of Ecological Assets in The Post-Disaster Period in Türkiye	• Aybike Ayfer KARADAĞ • Demet DEMİROĞLU	1372-1380
Leadership, Communication, and Cognitive Skills as Drivers of Project Performance: Prioritizing Soft Skills in the Construction Industry	• Greg Odee IKWE	1381-1386
AI Tools in Architectural Design: Transforming Creativity, Efficiency, and Sustainability	• Abhigyan GANGULY • Sandipan BISWAS • Shivnath GHOSH • Nitai PAITYA	1387-1393
Quantitative Effects of Soft Skills on Project Success: Evidence from Construction Practitioners in Nigeria	• Greg Odee IKWE	1394-1398
The Development of Roman Bath Architecture in the Light of the Sebastopolis Roman Bath	• Akın TEMÜR	1399-1409
Utılızatıon of Restoratıve Desıgn Features in the Design Proposal for Resort Centre in Abuja, Nigerıa	• Ahmed T. KASIM • Abubakar D. ISAH	1410-1428
Assessing Global Covid-19 Recovery Roadmaps for Enhancing Resilience in Nigeria's Construction Sector: A Comparative Framework for Sustainable Adaptation	• Tasleemah YUSUF • Peter Gangas CHINDO • Mustapha ABDULRAZAQ	1429-1435
Evaluating Human Impact in Urban Areas, with the example of Sofia, Bulgaria	• Stefan STAMENOV • Vanya STAMENOVA	1436-1445
Cybersecurity Risks in Smart Building Infrastructure	• Moses Adeolu AGOI • Samuel Olayiwola AJAGA • David Oladimeji AJIBODE • Oluwanifemi Opeyemi AGOI	1446-1453
Design Principles for Urban Open Parking Lots in the Climate Change Adaptation Process: The Case of Isparta	• Fatma ÖZKAN BAYINDIR • Ali ÖZ • Atila GÜL	1454-1466
Urban Green Space-Sensitive Parking Lot Planning: An AI-supported Sustainable Approach	• Fatma ÖZKAN BAYINDIR • Ali ÖZ • Atila GÜL	1467-1476

Reimagining the City: Utopian and Dystopian Perspectives in Contemporary Urban Planning	• Mehmet Can AKDAĞ • Şirin Gülcen EREN	1477-1489
Integration of Green Jobs in Architectural Carpentry and Joinery Practices for a Sustainable Environment in Gombe State	• Sale Nimrod Kamo • Bala Japhet Amatiga • Yakubu Molta Nitte	1490-1499
Problem of the Quality of Groundwater from Doucen Plain Intended for Irrigation and Its Assessment	• GAAGAI Aissam • MALLEM Salah Eddine	1500-1507
Dam Failure Mechanisms and Risk Assessment	• GAAGAI Aissam • MALLEM Salah Eddine	1508-1513
Forms of Influence of Fınancıal Infrastructure on Entrepreneurshıp in the Republıc of Azerbaıjan	• Vüqar NƏZƏROV	1514-1525
Rural Displacement and Livelihoods: A Study of Farmer-Herder Conflicts in Benue State, Nigeria and its Impact on Agricultural Development	• Adoga Peter ADOGA • Ikyapa Tertese PETER	1526-1539
On the Influence of the Number and Location of Elliptical Inclusions on the Deformation Process of a Cylindrical Shell With a Circular Hole	• Eteri HART • Oleksandr SHEBANOV	1540-1546
Emerging AI Regimes and Contemporary Filmmaking in Nigeria: Governance, Practice, and Creative Futures	• Rotimi-Williams BELLO • Roseline Oluwaseun OGUNDOKUN • Pius A. OWOLAWI • Etienne A. van WYK • Chunling TU • Odunayo IMORU	1547-1556
Examining the Sustainable Development of Shopping Malls	• Chinedu OLUIGBO • Uchenna EBERENDU • Rotimi-Williams BELLO • Chidiebere MARSHALL	1557-1576
Organization of Outdoor Tourism and Planning of Outdoor Recreation Services	• Yegana AHMADOVA	1577-1582

Effectiveness of Land Use Planning and Zoning Regulations in Controlling Urban Development in Bauchi Metropolis	• Mustapha Umar SA'AD • Ibrahim Muhammad SHERA • Ibrahim IDRİS	1583-1595
Thermochemical Optimization of Microencapsulated Phase Change Materials (PCMs) for Passive Thermal Regulation in Heritage and Modern Architecture	• Aliyu Hashimu ISAH	1596-1600
The Architecture of Extracurricular Activities in Foreign Languages: Strategies for Developing Intercultural Competence	• Djulieta RUSU • Serghei VASILACHI	1601-1629
Mapping Albania's Cultural Heritage: A Spatial and Typological Analysis of Tangible and Intangible Assets	• Mishela RAPO	1630-1640
Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj	• Shahriar Hasan Mridha RATUL • Moukuri MOHIM • Ahsan REZWAN	1641-1653
Healthy Cities in Environmental Protection	• Belgin YILDIRIM • Seher SARIKAYA KARABUDAK	1654-1663
The Place and Importance of Environmental Education in Nursing	• Belgin YILDIRIM • Seher SARIKAYA KARABUDAK	1664-1672
Computer Solutıon To Replacement Models For Items That Fails Suddenly	• Alfa MOHAMMED • Abdulrahman MOHAMMED SABA	1673-1680
Evaluation of Users Preferred Biophilic Design Elements in Commercial Office Building, Abuja	• Adeniji AHMED • Muhammad ISA BALA	1681-1694
Effect of Green Wall on Residential Property Values in Ibadan, Nigeria	• Nnaemeka Bethel EZEOKOLI • Ayooluwa Adeboye ADELAKUN	1695-1707
Factors Influencing the Adoption of Green Walls in Residential Property Development In Ibadan, Nigeria	• Nnaemeka Bethel EZEOKOLI • Ayooluwa Adeboye ADELAKUN	1708-1720
Integrating Sustainable Construction Practices İnto Building Design Without Compromising Cost and Quality	• Timothy AMUSAN	1721-1723

Cost and Risk Management in Ukrainian Construction Projects through International Project Management Standards	• Volodymyr MESHCHERIAKOV • Anastasiia CHORNONOH	1724-1731
Reflections of the Bauhaus Approach to Materials in Modern and Contemporary Architecture	• İskender Emre GÜL • Şebnem Ertaş BEŞİR	1732-1738
	•	
	•	
	•	

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Design Strategy in Creating Resilient Historic Cities within the Framework of Sustainable Development Goals

Kağan GÜNÇE

ORCID: 0000-0003-1557-2987
[1]Prof. Dr., Eastern Mediterranean University, Faculty of Architecture, Famagusta – North Cyprus
kagan.gunce@emu.edu.tr

Abstract

Historic cities are comprised of tangible and intangible elements. Tangible elements encompass, in addition to the city's structure, architectural elements, the urban landscape, archaeological remains, panoramas, silhouettes, vantage points, and monumental sites. Intangible elements involve the activities, symbolic and historical functions, customs, traditions, memories, and cultural resources that constitute the essence of historical value. Historic cities are living proof of the past that shaped them and, at the same time, important settlements reflecting cultural identity. Historic cities and urban areas should be a part of daily life.

In our changing and evolving world, historic cities, which hold heritage value, must be preserved and passed on to future generations. Rapid population growth, unplanned urbanization, climate change, disaster risks, and socio-cultural, socio-economic, and technological changes and transformations make it increasingly difficult to preserve historical structures (texture) and carry them into the future. Sustainable and resilient redesign of historic cities is essential for their preservation.

This study has two primary objectives. The first one is to demonstrate how urban models can be created within the framework of the Sustainable Development Goals for historic cities that hold heritage value and require preservation. The second is to discuss how such cities can be made more resilient to potential physical, social, and cultural risks.

In the study, recommendations are also presented for safeguarding the cultural heritage values of historic cities by bringing these values to the forefront and for advancing progress toward the Sustainable Development Goals. These recommendations particularly underscore the significance of "resilience" in the preservation of historic cities. Furthermore, the study emphasizes the need to develop holistic strategies in conservation efforts concerning historic urban areas to foster sustainable and resilient cities, and it proposes design strategies aimed at creating durable historic urban environments within the framework of the Sustainable Development Goals.

Keywords: Historical Cities, Cultural Heritage, Preservation, Urbanism, Resilience, Sustainable Development Goals (SDGs), Design Strategies

1. Introduction

Historic cities and urban areas are living testimonies to the past that has shaped them. Historic or traditional districts form an integral part of everyday life, and their preservation and integration with contemporary society constitute a fundamental basis of urban planning and development initiatives. Rich in both tangible and intangible cultural heritage, historic cities not only embody the identities of their respective settlements but also safeguard their collective memory. International organizations such as UNESCO and ICOMOS approach cultural heritage as a multifaceted set of values encompassing both its tangible and intangible dimensions.

Historic cities, which contain both tangible and intangible heritage values, face numerous threats, including population growth, infrastructure projects, tourism pressure, commercialization, migration movements, disasters, climate crises, and inadequate conservation policies. While these threats physically deteriorate historic cities, they also weaken and undermine local identity, historical continuity, and social memory.

The concept of urban resilience, which has become increasingly prominent in recent years, offers a significant framework for countering these challenges. Resilient historic cities stand out not only for their physical robustness but also for their social inclusivity, cultural continuity, and environmental adaptability. Similarly, the United Nations Sustainable Development Goals, which have gained considerable attention in recent years, encompass a wide range of global priorities, including poverty reduction, environmental protection, and the promotion of well-being for all. Resilience is defined as the capacity of cities to recover, adapt, and reorganize in the face of diverse threats and the Sustainable Development Goals together provide important strategic insights for the conservation of historic cities.

The principal aim of this study is to examine the relationship between cultural heritage conservation, urban resilience, and the Sustainable Development Goals within the context of historic urban fabric. Exploring how architectural and urban design strategies can be developed in line with resilience and the Sustainable Development Goals constitutes the core purpose of this research.

2. Materials and Methods

The study began with an examination of themes such as historic cities, cultural heritage, conservation, urbanism, resilience, the Sustainable Development Goals, and design strategies. Subsequently, a theoretical framework was established to elucidate the role of design strategies in creating resilient historic cities within the framework of the Sustainable Development Goals. In this process, policy documents prepared by international organizations and the relevant academic literature were reviewed. Good practices in the field were also identified and analyzed. All research activities, reviews, and analyses conducted for this study were carried out from a holistic perspective.

The theoretical foundation of the study draws on documents published by international organizations such as the United Nations, UNESCO, ICOMOS, and the OECD. Academic publications addressing concepts such as sustainable development, cultural heritage conservation, climate change mitigation, and resilient cities were examined with a particular focus on these themes. Additionally, policy documents issued by the Council of Europe and other international actors were evaluated within the scope of the study, with an effort to understand how these documents approach the multilayered structure of historic environments.

The data collection process was conducted using documentary analysis. UNESCO World Heritage reports concerning cities, strategic documents of local administrations, urban planning materials, and scientific publications served as the principal sources. Through these documents, the implementation of sustainability and resilience policies in the historic fabrics of the selected cities Amsterdam and Fez was systematically analysed, and the outcomes were identified.

The collected data and information were evaluated using descriptive analysis. During the analysis, particular attention was given to establishing a conceptual alignment between the United Nations' 2030 Sustainable Development Goals and the strategies implemented in cities, thereby revealing how the sustainable development perspective is integrated into historic environment planning. Ultimately, the study emphasizes the importance of design strategies in creating resilient historic cities within the framework of the Sustainable Development Goals and offers recommendations in this direction.

3. Cultural Heritage in Historical Cities - Preservation and Possible Threats

Cultural heritage is a treasure that tells the members of a society about their shared past and strengthens their sense of solidarity and unity. It ensures the continuity of the experiences and traditions people have accumulated throughout history and the proper construction of the future. Cultural heritage should be protected not only because of the universal values that give it its heritage status, but also because it offers new learning and development opportunities for young people, evokes beautiful emotions and warm memories, fosters creativity and the drive for discovery, adds depth to our perspective on the world and life, and because we all have much to learn from our past. Cultural heritage encompasses all tangible and intangible values related to our identity, culture, and history. Historical cities and textures, cultural landscapes, monumental structures, archaeological sites, as well as living but intangible values such as language, traditions, dance, music, and rituals constitute cultural heritage.

Based on definitions provided by internationally respected organizations such as UNESCO and ICOMOS, cultural heritage can be classified into four main categories (ICOMOS, 1999; UNESCO 1972, 2001, 2003):

- Tangible Cultural Heritage: Movable items (artifacts, objects) and immovable assets (monuments, historic buildings).
- Underwater Cultural Heritage: Cultural properties located beneath the sea, including shipwrecks and submerged remains.
- Intangible Cultural Heritage: Living cultural expressions such as oral traditions, rituals, and folk dances.
- Natural Heritage: Natural areas and landscapes that possess cultural value.

Under the four main cultural heritage categories mentioned above, memory and memento should also be considered as an important part of heritage protection efforts. Naturally, in the context of the memory of historical cities, the phenomenon of memory is considered an integral element of cultural heritage protection efforts. While the architectural structures, monuments, squares, streets, and roads that make historical urban areas valuable and important, the textures, colors, memories, oral narratives, traditions, and all folkloric elements belonging to that place (Turangil & Ertuğrul, 2024).

The first efforts to protect tangible cultural heritage in the international arena were aimed at preventing damage to cultural assets caused by war and physical conflict. The Hague Convention No. 4 of 1907 prohibited attacks on structures used for religious, scientific, artistic, and humanitarian purposes, as well as on tangible cultural assets (Abbenhuis, 2017). As awareness in this area increased after 1950, the awareness that cultural heritage is the ‘common heritage of humanity’ came to the front. The Hague Convention of 1954 emphasized that an attack on the cultural property of any nation is considered an attack on the culture of all humanity (Toman, 2017). The 1972 World Heritage Convention stated that the degradation of cultural and natural heritage is a loss for all humanity, and the understanding that the protection of cultural heritage is a shared responsibility of the international community was officially accepted (Gruber, 1972). Since the 2000s, the Council of Europe has viewed cultural heritage as a resource for strengthening cultural diversity and promoting intercultural dialogue. With this understanding, UNESCO’s 2001 Declaration on Cultural Diversity defined cultural heritage as a source of creativity. This declaration also stated that tangible and intangible

cultural heritage must be protected, enriched, and passed on to future generations (Kitaplar, 2014).

Unfortunately, official documents published by international organizations are often not sufficiently considered or effectively implemented. Processes of change and transformation expose cultural heritage sites and historic cities to a wide range of physical, technological, economic, political, cultural, and social risks. These risks include:

- Dense construction
- Uncontrolled urban development
- Large-scale infrastructure projects
- Population pressure and migration
- Tourism pressure
- Commercialization
- Loss of identity
- Inadequate protection
- Insufficient oversight

Such challenges threaten the sustainability of cultural heritage and may result in the degradation or even the loss of the cultural identity and collective memory of historic cities.

Physical, technological, cultural, social, political, and economic pressures, as well as disasters, heighten the vulnerability of historic cities and urban areas. This growing fragility brings the need for urban resilience to the forefront. Urban resilience refers to the capacity of the urban fabric to remain flexible in the face of various risks, threats, and pressures, while also possessing the ability to recover rapidly in moments of crisis.

4. From Resilience to Sustainability: New Paradigms in Urban Design

The concept of resilience denotes the capacity to survive, endure, and remain functional in the face of complex, unexpected, and challenging events (Davoudi et al., 2013). Viewed more broadly, resilience may be defined as the ability of individuals, communities, and both natural and built environments to respond to and adapt in the face of sudden and unforeseen shocks (Büyüközkan et al., 2022; Klein et al., 2003; Norris et al., 2008).

Resilience represents an effort to cope with the challenges arising from climate change, uncontrolled urbanization, and socio-cultural, socio-economic, and socio-political instability. It has therefore emerged as a significant concept in architectural and urban design research (Cimellaro, 2016; Zengin & Yamaçlı, 2023). Research on resilience in architecture and historic urban design intersects with global sustainability frameworks such as the United Nations Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, and the Paris Climate Agreement. These global initiatives highlight resilience as a fundamental strategy for addressing climate change, reducing disaster risks, confronting physical, technological, cultural, social, and economic pressures, and promoting sustainable urbanization.

Urban resilience is more than a reactive response to immediate threats. In this regard, questions concerning how urban resilience aligns with sustainability and how it contributes to the achievement of sustainable development goals gain critical importance (Coaffee, 2008; Sharifi et al., 2017).

5. Design Strategies in Historical Cities in the Context of Resilience and Sustainable Development

The concepts of urban resilience and sustainability must be addressed together, encompassing their social, economic, and environmental dimensions. Both aim to foster safe living environments, strong community structures, and settlements characterized by a high quality of life.

The United Nations Commission on Sustainable Development (UN, 2022) emphasizes that sustainable development must adopt a more resilient structure by focusing on the resolution of social, cultural, and environmental challenges. Similarly, Marchese et al. (2018) argue that achieving sustainable development requires the explicit consideration of resilience. In this context, sustainable development in historic cities may be attained by balancing cultural heritage conservation with economic and social advancement (Appendino, 2017; Moazzeni Khorasgani, 2024). Sustainability, urban resilience, and sustainable development together offer holistic solutions to the social, cultural, structural, environmental, and economic issues confronting contemporary cities. These three concepts are inherently complementary.

In 2015, the United Nations formally announced the Sustainable Development Goals (SDGs) (European Commission, n.d.). Intended to be achieved by 2030, these goals apply to all countries. The SDGs consist of 17 core objectives / goals and 169 indicators (Bexell & Jönsson, 2017; European Commission, n.d.; Opoku, 2016). Relevant UN bodies prepare an annual SDG Progress Report, and nations publish Voluntary National Review (VNR) reports every two years (United Nations Department of Economic and Social Affairs, n.d.).

The Sustainable Development Goals cover broad themes such as ending poverty, protecting the planet, and ensuring prosperity for all. The 17 goals are listed as follows (European Commission, n.d.):

- Goal 1 - No Poverty
- Goal 2 - Zero Hunger
- Goal 3 - Good Health and Well-Being
- Goal 4 - Quality Education
- Goal 5 - Gender Equality
- Goal 6 - Clean Water and Sanitation
- Goal 7 - Affordable and Clean Energy
- Goal 8 - Decent Work and Economic Growth
- Goal 9 - Industry, Innovation, and Infrastructure
- Goal 10 - Reduced Inequalities
- Goal 11 - Sustainable Cities and Communities
- Goal 12 - Responsible Consumption and Production
- Goal 13 - Climate Action
- Goal 14 - Life Below Water
- Goal 15 - Life on Land
- Goal 16 - Peace, Justice, and Strong Institutions
- Goal 17 - Partnerships for the Goals



Figure 1. Visual representations of the 17 SDGs (European Commission, n.d.).

When developing design strategies for the survival and vitality of historic cities, the SDGs must be considered. Considering all 17 goals is essential for ensuring the sustainability and resilience of historic settlements (Mrak et al., 2022). Goal 3, Goal 4, Goal 7, Goal 8, Goal 9, Goal 13, and Goal 17 and particularly Goal 11 - Sustainable Cities and Communities directly support discussions on sustainability and resilience in design strategies (European Commission, n.d.; Lerario, 2022).

For a historic city to be considered resilient, it must possess qualities such as adaptability, robustness, redundancy, flexibility, resourcefulness, inclusiveness, and the ability to integrate and adjust (OECD, 2016). The relationship between the SDGs and resilience in historic cities should converge toward creating sustainable, inclusive, and adaptive urban environments (Lerario, 2022; Mrak et al., 2022). The concept of historic urban resilience should be regarded not as a tool to achieve goals such as sustainable development but as a goal (Pearson et al., 2014).

Fez and Amsterdam are historical cities with high cultural heritage value and are among the cities where the concepts of Sustainable Development Goals (SDGs) and resilience in historical texture are kept alive.

A. The Historic City of Fez - Morocco

The historic city of Fez, established in the late eighth and early ninth centuries CE, has served as a home to numerous civilizations. Fez reached its zenith in the 13th and 14th centuries during the Marinid period, when it replaced Marrakesh as the kingdom's capital. The urban fabric of the medina and its principal monuments such as madrasas, fountains, palaces, mansions, mosques, and public fountains, largely date from this era. Although Morocco's political capital

was moved to Rabat in 1912, Fez has retained its status as the country's cultural and spiritual centre. Each civilization that left its mark on the city enriched it with new historical layers, both tangible and intangible, traces of which remain visible today.

The historic city of Fez contains numerous significant examples of traditional Moroccan architecture. This architectural style, which developed during the Islamic period, formed part of a broader cultural and artistic complex often referred to as *Moorish* architecture characteristic of Fez, al-Andalus (Muslim Spain and Portugal), and the regions of present-day Algeria and Tunisia.

Located in Morocco on the African continent, Fez stands out as one of the most notable examples of alignment with the Sustainable Development Goals (SDGs) and the cultivation of resilience within a historic urban context. Fez is among the oldest Islamic city centres inscribed on the UNESCO World Heritage List. For centuries, its narrow, intact streets, artisan workshops, traditional architecture, and living intangible cultural practices have made it an important historic centre. Through the initiatives of international and local authorities, conservation projects were undertaken in Fez in the late twentieth century to sustain both its tangible and intangible heritage. Alongside physical restorations, these projects addressed environmental challenges such as water management, waste system operation, and energy efficiency. As a result, Fez constitutes a resilient and sustainable historic city model aligned with both Goal 11 (Sustainable Cities and Communities) and Goal 6 (Clean Water and Sanitation).



Images from the historical city of Fez (SDG Morocco, n.d; T. Experience n.d.).

Figure 2. The historical city of Fes, which still carries tangible and intangible cultural heritage, is also an exemplary city in terms of resilience and the SDGs.

B. The Historic City of Amsterdam - The Netherlands

Amsterdam is situated at the mouth of the Amstel River, which was dammed to control floods. Originally a small fishing village in the 12th century, Amsterdam became a major world port during the Dutch Golden Age in the 17th century, when the Netherlands became an economic powerhouse. Amsterdam became a leading centre of finance and trade, as well as a centre for secular artistic production. In the 19th and 20th centuries, the city expanded, and new neighbourhoods and suburbs were built. The city has a long tradition of openness, liberalism, and tolerance. Cycling is key to the city's modern character, and numerous bike paths and lanes are spread throughout.

Numerous buildings and structures are protected by national and municipal heritage lists. While the status of conservation appears complex within the context of the Amsterdam Central District (the heart of the city), the procedures governing conservation are being adhered to. The keen awareness of those responsible means that the excesses of urban growth, which were sometimes difficult to control in the recent past, particularly the visual impact of advertising within the property and high-rise buildings on the property's urban landscape, are being increasingly managed. All management measures form an effective and coherent system under the responsibility of the Amsterdam Central Municipality and the assurance of the Monuments Office. The Amsterdam World Heritage Office has now been established as a horizontal management and monitoring body for the property. Amsterdam, one of the most distinguished historical cities in Europe, is one of the examples of a city that demonstrates strong resilience and is aligned with the Sustainable Development Goals.



Images from Amsterdam (SDG House, n.d; Understand Amsterdam, n.d.).

Figure 3. The historical city of Amsterdam, which still carries tangible and intangible cultural heritage, is also an exemplary city in terms of resilience and the SDGs.

Amsterdam stands as one of Europe's leading historic cities in terms of cultural heritage preservation and climate resilience. Its canal system, bridges, well-preserved architecture, and planned urban development are complemented by effective water management strategies that address rising sea levels, making the city a model of climate adaptation. During restoration projects, both tangible and intangible cultural values have been carefully preserved. The city has also introduced systems aimed at improving energy efficiency and reducing carbon emissions, directly aligning with Goal 13 (Climate Action). Furthermore, the active participation of residents in decision-making processes provides strong examples related to Goal 16 (Peace, Justice and Strong Institutions) and Goal 17 (Partnerships for the Goals). Collectively, these initiatives position Amsterdam as a resilient and sustainable historic city aligned with Goal 13, Goal 16, Goal 17, and Goal 11 (Sustainable Cities and Communities) (Figure 3).

6. Conclusion and Recommendations

Historic cities not only represent the environments of the past but also embody tangible and intangible values that must be safeguarded for the future. Shaped by tradition and collective experience, historic urban settlements offer essential reference points for sustainability and resilience. As in every city undergoing change and transformation, similar processes take place both within and around historic urban areas. Rapidly developing new urban segments are often inserted beside or within historic fabrics, posing serious threats to the authenticity and integrity of the original urban identity. For this reason, the conservation of historic cities must be planned in harmony with emerging development areas, and integration processes should be approached holistically. Design strategies for historic cities should be developed in alignment with the United Nations Sustainable Development Goals (SDGs), and resilience-oriented planning must be incorporated. The historic fabric needs to coexist with new urban components without conflict and within a framework of mutual compatibility.

Active participation from all segments of society is a key factor in strengthening this integration. Participatory planning methods make it possible both to preserve historic urban fabrics and to ensure that new urban developments evolve within socially acceptable and sustainable parameters. Within this framework, the following recommendations are highlighted:

• *Conservation and Integration*: Historic urban fabrics should not be confined to designated 'protected zones'. Where necessary, new urban segments that emerge beside or within these areas should be integrated at functional, spatial, and cultural levels in line with contemporary needs.

• *Architectural Strategies*: New urban developments must not appear alien or disconnected from the historic environment. Insertions beside or within historic fabrics should meet contemporary requirements while adhering to design principles that support, rather than overshadow, the historic character and identity.

• *Alignment with the Sustainable Development Goals*: The relationship between historic environments and new urban development should be structured according to the 17 SDGs. Historic cities should be reassessed through the lens of all SDGs, with particular emphasis on Goal 11 (Sustainable Cities and Communities), as well as Goals 6 (Clean Water and Sanitation), Goal 13 (Climate Action), Goal 15 (Life on Land), 16 (Peace, Justice and Strong Institutions), and 17 (Partnerships for the Goals).

• *Community Participation*: For every strategy and design related to the historic city and its newly developing segments, contributions from local residents, civil society organizations, academic circles, and local and national authorities should be ensured. A societal consciousness that embraces the historic environment must be cultivated, and pathways must be opened for all segments of society to participate as stakeholders in decision-making processes.

• *Adaptive Planning*: New developments within or around historic cities should be planned according to principles of flexibility and adaptability, ensuring that no conflict arises with the historic environment. Such an approach facilitates urban resilience, continuity of identity and memory, and planning aligned with the SDGs.

In conclusion, the preservation of historic cities must be approached beyond their aesthetic or touristic value. Conservation strategies should be accompanied by considerations of social continuity, cultural identity, safety, environmental compatibility, and physical and economic livability. The presence of resilient historic cities is only possible through holistic approaches that respect these values. In this way, urban fabrics can maintain their connection to the past while evolving into sustainable and resilient environments for the future.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Abbenhuis, M. (2017). *War, peace and international order?: The legacies of the Hague Conferences of 1899 and 1907* (Vol. 23). Taylor & Francis.

Appendino, F. (2017). Balancing heritage conservation and sustainable development–The case of Bordeaux. In *IOP Conference Series: Materials Science and Engineering* (Vol. 245, No. 6, p. 062002). IOP Publishing.

Bexell, M., & Jönsson, K. (2017). Responsibility and the United Nations' sustainable development goals. In *Forum for development studies* (Vol. 44, No. 1, pp. 13-29). Routledge.

Büyüközkan, G., Ilıcak, Ö., & Feyzioğlu, O. (2022). A review of urban resilience literature. *Sustainable Cities and Society*, *77*, 103579.

Cimellaro, G. P. (2016). Urban Resilience for Emergency Response and Recovery: *Fundamental Concepts and Applications*. Switzerland: Springer International Publishing.

Coaffee, J. (2008). Risk, resilience, and environmentally sustainable cities. *Energy Policy*, *36*(12), 4633-4638.

Davoudi, S., Brooks, E., & Mehmood, A. (2013). Evolutionary resilience and strategies for climate adaptation. *Planning Practice & Research*, *28*(3), 307-322.

European Commission. (n.d.). *Sustainable Development Goals*. International Partnerships. Access date: 30.09.2025 https://international-partnerships.ec.europa.eu/policies/sustainable-development-goals_en

Gruber, S. (1972). Convention concerning the protection of the world cultural and natural heritage 1972. In *Stefan Gruber, 'Convention concerning the Protection of the World Cultural and Natural Heritage* (pp. 60-66).

ICOMOS. (1999). *International Cultural Tourism Charter: Managing Tourism at Places of Heritage Significance*. Retrieved from https://www.icomos.org/en/resources/charters-and-texts

Kitaplar, İ. R. (2014). Kültürel mirasın korunması. *İstanbul Valiliği, İstanbul Proje Koordinasyon Birimi (İPKB). Akademik Danışman: Zeynep Gül Ünal. İstanbul*.

Klein, R. J., Nicholls, R. J., & Thomalla, F. (2003). Resilience to natural hazards: How useful is this concept?. *Global Environmental Change Part B: Environmental Hazards*, *5*(1), 35-45.

Lerario, A. (2022). The role of built heritage for sustainable development goals: from statement to action. *Heritage*, *5*(3), 2444-2463.

Marchese, D., Reynolds, E., Bates, M. E., Morgan, H., Clark, S. S., & Linkov, I. (2018). Resilience and sustainability: Similarities and differences in environmental management applications. *Science of the Total Environment*, *613*, 1275-1283.

Moazzeni Khorasgani, A. (2024). Sustainable Development Strategies for Historic Cities. In *Using Data Science and Landscape Approach to Sustain Historic Cities* (pp. 63-81). Cham: Springer Nature Switzerland.

Mrak, I., Ambruš, D., & Marović, I. (2022). A holistic approach to strategic sustainable development of urban voids as historic urban landscapes from the perspective of urban resilience. *Buildings*, *12*(11), 1852.

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American journal of community psychology*, *41*(1), 127-150.

OECD. (2016). *Resilient cities: Policy highlights of the OECD report*. OECD Publishing. Access date: 30.09.2025 http://www.oecd.org/gov/regionalpolicy/resilient-cities.htm

Opoku, A. (2016). SDG2030: A sustainable built environment's role in achieving the post-2015 United Nations Sustainable Development Goals. In *Proceedings of the 32nd Annual ARCOM Conference* (Vol. 2, pp. 1149-1158). Manchester, UK: Association of Researchers in Construction Management.

Pearson, L., Newton, P., & Roberts, P. (2014). Resilient sustainable cities. *A future. Abingdon: Routledge*, *10*, 9780203593066.

SDG House. (n.d). SDG House – Amsterdam, Linkedin. Accessed September 10, 2025. https://www.linkedin.com/company/sdghouse/

SDG Morocco. (n.d). The Sustainable Development's Youth Association Morocco. Accessed August 20, 2023. https://sdgactionawards.org/the-sustainable-developments-youth-association-morocco/

Sharifi, A., Chelleri, L., Fox-Lent, C., Grafakos, S., Pathak, M., Olazabal, M., Moloney, S., Yumagulova, L., & Yamagata, Y. (2017). Conceptualizing dimensions and characteristics of urban resilience: Insights from a co-design process. *Sustainability*, *9*(6), 1032. https://doi.org/10.3390/su9061032

T. Experience (n.d.). How Is Digital Innovation Transforming the Tourist Experience in Fez?. Accessed August 25, 2025. https://www.fez-guide.com/how-is-digital-innovation-transforming-the-tourist-experience-in-fez/

Toman, J. (2017). *Protection of Cultural Property in the event of Armed Conflict*. Routledge.

Turangil, K., & Ertuğrul, A. (2024). Yeşilköy'de kentsel kültürel bellek ve miras koruma ilişkisi. *Bab Journal of FSMVU Faculty of Architecture and Design*, 5(1), 25-48. https://doi.org/10.61807/babdergisi.1291577

UN (United Nations). 2022. "World Cities Report 2022." Accessed August 20, 2023. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

Understand Amsterdam. (n.d.). National Geographic – To Understand Amsterdam. Photographer Jonathan Irish. https://www.nationalgeographic.com/travel/article/paid-content-your-next-adventure-amsterdam

UNESCO. (1972). *Convention Concerning the Protection of the World Cultural and Natural Heritage*. Retrieved from https://whc.unesco.org/en/conventiontext

UNESCO. (2001). *Convention on the Protection of the Underwater Cultural Heritage*. Retrieved from https://www.unesco.org/en/legal-affairs/underwater-cultural-heritage

UNESCO. (2003). *Convention for the Safeguarding of the Intangible Cultural Heritage*. Retrieved from https://ich.unesco.org/en/convention

United Nations Department of Economic and Social Affairs. (n.d.). *Voluntary national reviews (VNRs)*. Sustainable Development Knowledge Platform. Retrieved October 6, 2025, from https://sustainabledevelopment.un.org/vnrs/

Zengin, N., & Yamaçlı, R. (2023). Kentsel dirençlilik bağlamında Tokat Kent yapısı üzerine bir araştırma. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, *12*(3), 22-39.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Spatial Distributions of Land Use/Land Cover (LULC) in the Demre Stream Corridor: Assessment of Current Issues

Hüseyin Batuhan DÜNDAR [1*]

ORCID 3: 0009-0003-7341-970X
[1]Master's Student, Süleyman Demirel University, Institute of Science, Department of Landscape Architecture, Isparta – Türkiye
hbatuhandundar@gmail.com (Responsible Author)

Atila GÜL [2]

ORCID 1: 0000-0001-9517-5388
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
atilagul@sdu.edu.tr

Sibel AKTEN [3]

ORCID 2: 0000-0001-6242-9687
[3]Dr., Isparta University of Applied Sciences, Eğirdir Vocational School, Isparta-Türkiye
sibelakten@isparta.edu.tr

Abstract

The existence of water resources is a vital necessity for all living things. It is the basic substance of life, especially for humans, plants and animals. Water is needed for all vital and utilisation activities. Current environmental problems, increase in production and consumption tendencies with population growth, construction tendencies, wrong and unconscious land uses, climate change effects, negative human activities, etc. factors lead to the decrease, pollution and deterioration of the quality of potable water resources. This situation brings great risks and threats for natural and urban life. Demre (Myros) Stream, located in the west of Antalya, in the Demre district of Antalya, carries its waters to the Mediterranean Sea, reaches the sea from the Demre Plain, east of the Demre district centre. In this context, Demre Stream, which is an important water source for Demre district, has a critical importance for the coastal ecosystems of the Mediterranean Region. However, in recent years, rapidly developing agricultural and other activities in the region have disrupted the ecosystem and ecological balance in and around Demre Stream and Demre Stream has dried up completely today. This study analyses the pressures created by mining enterprises, industrial areas and greenhouse activities due to intensive agricultural production in the Demre Stream region from a holistic perspective. In the study, the current problems on Demre Stream were evaluated by using the findings obtained from land use data, field observations and local stakeholder interviews. The data obtained show that especially intensive greenhouse cultivation increases agricultural pressure, and the lack of waste management of mining sites and industrial facilities negatively affects aquatic ecosystems. However, Demre Stream is a vital connection line for the continuity of coastal ecosystems. The study emphasises that in order to protect the ecological value of the region, sustainable land use, monitoring of water resources and ecologically based planning decisions should be taken by local administrations.

Keywords: Demre Stream, Water resources, Land use/Land cover (LULC), Intensive agriculture, Ecological balance

1.Introduction

Rapid urbanisation, agricultural expansion and tourism activities are transforming land use and cover, particularly in coastal and river basin areas, threatening ecosystem integrity. Global studies have revealed that aquatic and coastal ecosystems are among the most vulnerable systems to anthropogenic pressures (Foley et al., 2005; Ellis & Ramankutty, 2008). Rivers and deltas are constantly changing areas where geomorphological processes intersect with human activities, possessing a complex structure where agricultural production, settlement and ecological sensitivities coexist. Rapid land use changes in these areas bring with them numerous environmental problems such as habitat loss, coastal erosion, increased flood risk and loss of

biodiversity (MEA, 2005; Turner et al., 1998). Irregular settlement, uncontrolled agricultural practices, increased sedimentation, and deterioration of surface water quality in river basins make the need for sustainable management of these areas even more important (Vörösmarty et al., 2010; Allan, 2004).

In Turkey, rivers and wetlands are under intense pressure, particularly due to the expansion of agricultural production areas, the spread of settlements towards river corridors, and infrastructure interventions. These pressures lead to the degradation of the natural structure of river corridors, disruption of habitat continuity, and weakening of ecosystem functions. Changes in land use and land cover around rivers have decisive effects not only on water quality and biodiversity, but also on flood regimes, sediment transport, and landscape integrity. This situation highlights the necessity of ecologically based approaches and comprehensive landscape restoration strategies in the planning and management processes of river corridors (Şahin et al., 2014).

Studies conducted at the scale of river valleys in Turkey reveal that human-induced activities such as settlement, tourism, and energy investments disrupt the natural functioning of river ecosystems, creating serious pressures on ecosystem integrity (Selim, 2011). Particularly in the Mediterranean Basin, increasing temperatures, decreasing flow regimes and drought trends associated with climate change are further straining the carrying capacity of river ecosystems and threatening ecosystem sustainability (Giorgi & Lionello, 2008; IPCC, 2014). Therefore, land use planning in coastal and river ecosystems should include not only spatial arrangements but also ecological resilience, water management, and comprehensive protection strategies at the landscape scale (Ahern, 2011).

The Demre Stream and its immediate surroundings are highly sensitive to these pressures, as they are an area where intensive agricultural activities and natural and cultural values are intertwined. The geomorphological development of the Demre Stream, the valley changes that occurred during palaeogeographic periods, and the delta-lagoon system shaped by the alluvium it carries reveal that the region's natural structure is highly sensitive to tectonic and climatic processes (Keser, 2012). Despite its rich conservation status, the region is at the centre of intensive agricultural activities and tourism pressure. In particular, the uncontrolled expansion of greenhouse agriculture, which constitutes a large part of the district's economy, and the increasing demand for construction pose a serious threat to existing natural and cultural conservation areas. Recent studies conducted in the region reveal that increasing agricultural land use and urban growth trends threaten the sustainability of protected areas, disrupt spatial integrity, and cause fundamental changes in landscape character (Dündar et al., 2024). In intensively farmed areas such as Demre, the transport of human-induced chemical use into watercourses also has a decisive impact on water quality and ecosystem health (Carpenter et al., 1998).

In this context, identifying the land use and land cover characteristics of the Demre Stream and its immediate surroundings and spatially assessing existing problems is of critical importance for the sustainability of the region. The study will contribute to the development of sustainable planning decisions, conservation and management approaches for the region by establishing a 1.5 km buffer zone around the Demre Stream and revealing the interaction between land use and land cover classes, ecological damage and human-induced pressures in this area. Accordingly, this study aims to analyze the spatial distribution of land use/land cover (LULC)

patterns and associated anthropogenic pressures within a 1.5 km buffer zone along the Demre Stream corridor using GIS-based analyses.

2.Materials and Methods

This study was conducted using Geographic Information Systems (GIS)-based analyses to determine land use and land cover characteristics in the Demre Stream and its surrounding area and to spatially assess human-induced pressures. The analyses were performed using ArcGIS Pro 3.5 software.

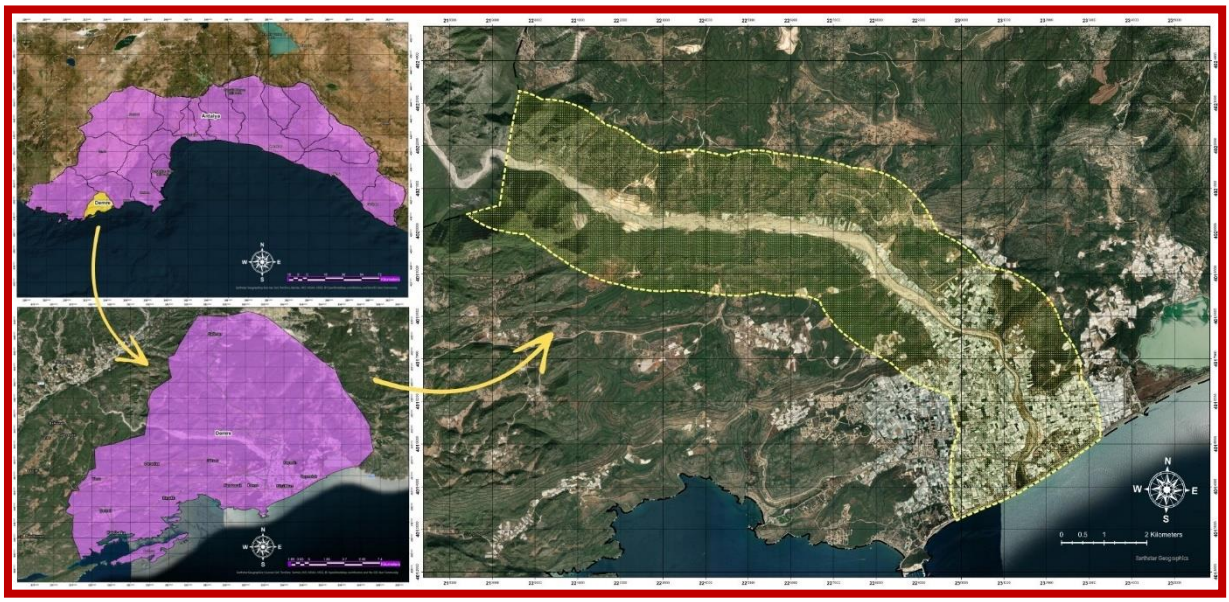


Figure 1. Research area boundary (From the authors' archive, 2025)

The district boundary of Demre district was obtained from the Antalya-Isparta-Burdur 1/100,000 Environmental Planning Map; the section of the Demre Stream included in the scope of the study is defined as the river section within the environmental planning boundaries at coordinates 36°17′3.07″ N – 29°58′1.48″ E (Figure 1.). Due to the absence of surface water within the study area and the inability to identify a continuous water surface, the stream boundaries were determined using a screen digitisation method based on current satellite imagery. Using this method, the river course was produced as vector data, taking into account the morphological traces of the Demre Stream within the boundaries of the environmental planning map.

In the assessment of the topographic structure, Digital Elevation Model (DEM) data obtained from the USGS EarthExplorer platform was utilised; contour lines and stream network data for the study area were generated using this data. In order to spatially reveal anthropogenic pressure around the stream, a 1.5 km wide buffer zone was created using the stream boundaries produced as vector data as a reference, and analyses were performed within this area. The spatial findings obtained were analysed and interpreted in comparison with the visual materials obtained.

Within the scope of the study, land use and land cover were evaluated under 7 classes, and the spatial pressures around the Demre Stream were revealed by calculating the spatial sizes and percentage distributions of each class. Planning and management recommendations were made based on the findings obtained. The current land use and land cover data are from 2024. The

LULC classes were determined based on dominant land use patterns observed in the study area and their potential ecological impacts on stream systems.

3.Findings and Discussion

Within the scope of this study, a total area of 5,325.53 hectares located within the 1.5 km wide buffer zone established around the Demre Stream and its immediate surroundings was evaluated. The findings were obtained through the combined interpretation of GIS-based land use and land cover analyses, spatial statistics, stream network assessments, and field and aerial photographs obtained from the Demre Municipality Press, Publication and Public Relations Directorate. Within this framework, the spatial distribution of land use classes and anthropogenic pressures on the stream ecosystem were comprehensively presented, taking into account the upper, middle, and lower sections along the Demre Stream.

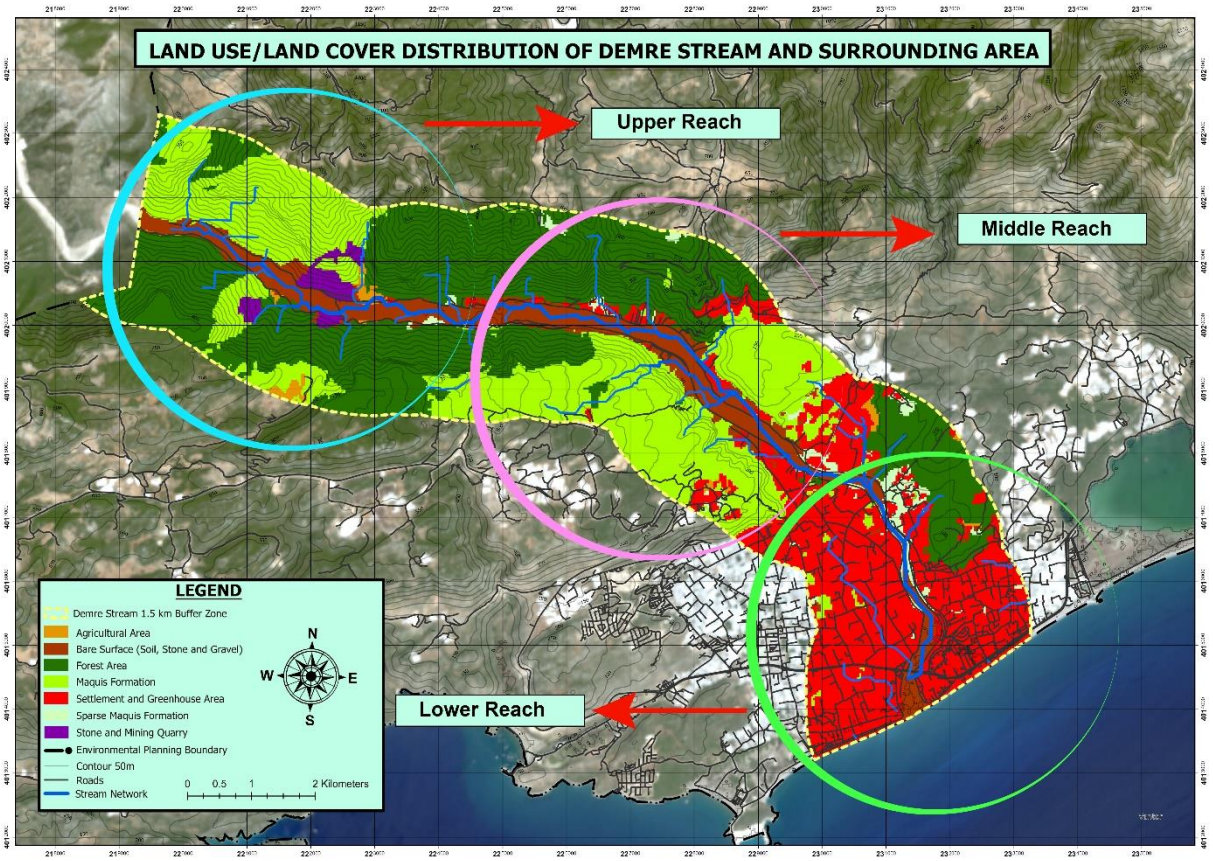


Figure 2. Land use/land cover (LULC) distribution of Demre Stream and its surroundings (From the authors' archive, 2025)

When examining the spatial distribution of land use and land cover classes, forest areas, which constitute 36.1% (1,921.13 ha) of the study area, are largely concentrated in the upper reaches of the Demre Stream. These areas play a critical role in the stream system in terms of regulating surface runoff, sediment retention and ecological continuity, and exhibit a relatively more holistic distribution. Maki formations follow forest areas with 27.4% (1,456.85 ha). These areas are particularly widespread in the middle sections and form transition zones between natural areas and human uses (Figure 2).

In contrast, settlement and greenhouse areas show a significant distribution in the study area, accounting for 23.4% (1,247.55 ha). They are particularly concentrated in the lower reaches of the Demre Stream, in areas close to the coast and delta plain. It has been determined that these areas are in direct contact with the riverbed and have largely eliminated the natural coastal zones. The spatial concentration of settlement and greenhouse areas constitutes the most pronounced anthropogenic pressure on the stream ecosystem. In particular, the covering of natural ground by large areas of greenhouses directly affects the quality of the flow reaching the stream by altering the amount and direction of surface runoff (Figure 2.).

Bare surfaces (soil, rock and gravel areas) are concentrated particularly in the stream corridor and surrounding areas where the slope increases, accounting for 8.7% (462.11 ha). These areas stand out as potential risk areas that cause accelerated surface runoff, increased sedimentation and heightened erosion risk. Stream network analyses show that some tributaries connected to the Demre Stream pass through stone and quarry areas, while others pass through or directly adjacent to residential and greenhouse areas (Figure 2). This situation leads to surface runoff reaching the stream being deprived of natural infiltration processes and an increase in the load of transported sediment and pollutants.

Sparse maquis formations cover a limited area of 2.4% (126.97 ha) within the study area, mostly located in transition zones between natural and human uses. Although quarry and mine areas cover only 1.2% (67.14 ha), they are considered areas with high ecological damage impacts due to their location near tributaries feeding the stream. Although agricultural areas account for a low percentage of 0.8% (43.79 ha), when considered together with greenhouse areas and taking into account human-induced chemical use, this becomes a significant factor increasing the pressure on the stream ecosystem (Figure 2.).

Table 1. Area and percentage of land use/land cover (LULC) classes

LULC Class No	Land Use and Land Cover	Area (Ha)	Percentage (%)
1	Forest Area	1921.13	36.1
2	Settlement and Greenhouse Area	1247.55	23.4
3	Stone and Mining Quarry	67.14	1.2
4	Agricultural Area	43.79	0.8
5	Bare Surface (Soil, Stone and Gravel)	462.11	8.7
6	Maquis Formation	1456.85	27.4
7	Sparse Maquis Formation	126.97	2.4
TOTAL		5325.53	100

Field and aerial photographs, along with spatial analyses, strongly support these findings with the current situation on the ground. Upon examination of the images, it is evident that the natural morphological structure of the Demre Stream bed has been significantly altered, particularly in its middle and lower sections, due to excavation, filling, and bed regulation works. Areas where the streambed has been widened, levelled, and the natural vegetation cover largely removed are noteworthy. Furthermore, the pressure exerted by settlement and greenhouse areas on the stream ecosystem is clearly evident in these images.



Figure 3. Field and aerial photographs of demre stream and ıts surroundings (Demre Belediyesi Basın Yayın ve Halkla İlişkiler Müdürlüğü, 2025)

Overall, the land use and land cover distribution of the Demre Stream and its surroundings reveal a distinct spatial differentiation: natural areas are relatively well preserved in the upper reaches, maquis formations dominate in the middle reaches, and settlement, greenhouse, and infrastructure interventions intensify in the lower reaches. The varying land use and land cover classes along the stream corridor directly affect the quantity and quality of surface runoff; tributaries passing through mining sites, greenhouse areas, and settlement areas, in particular, increase the intensity of pressure on the Demre Stream ecosystem. The findings reveal that the current land use pattern not only points to today's ecological problems but also to the risks of flooding, erosion and ecosystem degradation that may increase in the future. The construction of dams and reservoirs in the upper reaches of the Western Mediterranean Basin, the intense anthropogenic pressure on land use and land cover, and the resulting significant interruption of surface runoff are the main factors contributing to the lack of continuous water flow in the Demre Stream today.

4.Conclusions and Recommendations

Within the scope of this study, spatial analyses conducted within the 1.5 km buffer zone established around the Demre Stream and its immediate surroundings revealed that land use and land cover distribution exert pressures on the Demre Stream ecosystem. The findings clearly show that natural areas are relatively well preserved in the upper reaches, maquis formations dominate in the middle reaches, and settlement and greenhouse infrastructure interventions are concentrated in the lower reaches. The varying land use and land cover classes along the stream corridor directly affect the quantity and quality of surface runoff; tributary routes feeding the stream, particularly in mining areas, greenhouse areas, and settlement areas, increase the ecological pressure on the Demre Stream. The construction of dams and reservoirs in the upper basin sections, the exposure of land use and land cover to intense anthropogenic pressure, and the significant obstruction of surface runoff associated with this play an effective role in the lack of continuous water flow observed in the Demre Stream today. This situation clearly demonstrates the necessity of comprehensive, basin-scale planning approaches for the sustainability of the Demre Stream and its surroundings.

In this regard, the following conclusions and recommendations have been developed based on the findings of the study:

- A comprehensive planning approach should be adopted at the basin scale; all natural and anthropogenic factors affecting the Demre Stream should be addressed at the scale of the upper basin system (Western Mediterranean Basin) that feeds the Demre Stream, and the basin, which includes the river, should be considered within the boundaries of the Western Mediterranean-Transition Micro-Basin, located at 36.29410°N, 29.91917°E, with an area of 16,972.2 ha, (Çölleşme ve Erozyonla Mücadele Genel Müdürlüğü, n.d.).
- For the settlements and greenhouse areas concentrated in the lower reaches of the Demre Stream, ecological corridor solutions should be implemented along the stream corridor to create buffer zones, and uses in direct contact with the stream bed should be gradually restricted.
- Within the stream network, tributary routes feeding the stream that pass through mines and greenhouse areas should be identified as priority risk areas; measures to regulate surface runoff and reduce pollutant loads should be developed for these sections.
- Nature-based solutions should be implemented to reduce erosion and sedimentation risks in areas with concentrated bare surfaces and excavation/fill areas.
- The hydrological and ecological impacts of dams and reservoirs located in the upper reaches of the Western Mediterranean basin on the Demre Stream should be comprehensively assessed, and management strategies should be developed to ensure the continuity of environmental flow in areas where possible.
- Bed regulation and engineering interventions carried out along the riverbed should be approached in line with ecosystem-based approaches; practices that support natural morphology and ensure coastal zone continuity should be encouraged.
- Considering the concentration of subsurface agricultural activities in the lower reaches of the Demre Stream, controls and practices should be developed for agricultural pesticides and chemical inputs used in these areas, targeting groundwater sources that feed the stream through irrigation processes or are located within the stream corridor.
- GIS and remote sensing-based monitoring studies should be carried out periodically in and around the Demre Stream; land use changes and anthropogenic pressures should be tracked over time.
- A multi-stakeholder management model should be established between local authorities, relevant public institutions and producer stakeholders to develop a joint decision-making mechanism for the protection and sustainable management of the Demre Stream.

In conclusion, the land use and anthropogenic pressures identified in the Demre Stream and its surroundings indicate not only existing ecological problems but also potential future hydrological and environmental risks. Therefore, the sustainability of the Demre Stream depends on the implementation of long-term, basin-scale strategies that integrate ecological protection, land use planning, and water management.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning*, 100(4), 341–343. https://doi.org/10.1016/j.landurbplan.2011.02.021

Allan, J. D. (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, 35(1), 257–284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), 559. https://doi.org/10.2307/2641247

Dündar, H. B., Aydemir, Ç. & Gül, A. (2024). Ecotourism potential of Demre (Antalya) region. *5th International Urban Landscape and Art Congress*, October 25-27, 2024 / p.560-579. Paris, France. ISBN: 978-625-367-954-5. ISSUED: November 27, 2024. DOI:https://doi.org/10.5281/zenodo.14229713. https://www.iksadkongre.com/urban

Ellis, E. C., & Ramankutty, N. (2008). Putting people in the map: Anthropogenic biomes of the world. *Frontiers in Ecology and the Environment*, 6(8), 439–447. https://doi.org/10.1890/070062

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder, P. K. (2005). Global consequences of land use. *Science*, 309(5734), 570–574. https://doi.org/10.1126/science.1111772

Giorgi, F., & Lionello, P. (2008). Climate change projections for the Mediterranean region. *Global and Planetary Change*, 63(2–3), 90–104. https://doi.org/10.1016/j.gloplacha.2007.09.005

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

Keser, N. (2012). Demre Çayı'nın paleocoğrafi dönem vadi değişiklikleri ve Beymelek Lagünü'nün jeomorfolojik evrimi. *Doğu Coğrafya Dergisi*, 17(28), 175-192.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press, Washington, DC.

Selim, S. (2011). Akarsu vadisindeki insan kaynaklı faaliyetlerin ekosistem bütünlüğüne olası etkileri: Çağlayan Vadisi örneği. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 15(2), 94-101.

Şahin, Ş., Perçin, H., Kurum, E. ve Memlük, Y. (2014). *Akarsu Koridorlarında Peyzaj Onarımı ve Doğaya Yeniden Kazandırma Teknik Kılavuzu*. T.C. Orman ve Su İşleri Bakanlığı,

Doğa Koruma ve Milli Parklar Genel Müdürlüğü adına BEL-DA BeldeProje ve Dan. Tic. Ltd. Şti., 154 sayfa, Ankara.

T.C. Tarım ve Orman Bakanlığı, Çölleşme ve Erozyonla Mücadele Genel Müdürlüğü (ÇEM). (t.y.). *Mikro Havza Sınırları* [Veri Katmanı]. T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Ulusal Coğrafi Bilgi Platformu (TUCBS) Harita Görüntüleyici. Erişim adresi: https://ucbp.tucbs.gov.tr/harita-goruntuleyici (Accessed on December 13, 2025).

Turner, R. K., Lorenzoni, I., Beaumont, N., Bateman, I. J., Langford, I. H., & McDonald, A. L. (1998). Coastal management for sustainable development: Analysing environmental and socio-economic changes on the UK coast. *The Geographical Journal*, 164(3), 269. https://doi.org/10.2307/3060616

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S. E., Sullivan, C. A., Liermann, C. R., & Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, 467(7315), 555–561. https://doi.org/10.1038/nature09440

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Light Shelf Systems in Architectural Design: An Examination in the Context of Visual Comfort and Energy Efficiency

Sümeyra AKGÜN [1]*

ORCID 1: 0000-0002-0539-3603
[1] Research Assistant, Altınbas University, Faculty of Engineering and Architecture, Department of Interior Architecture and Environmental Design, Istanbul- Türkiye
sumeyra.akgun@altinbas.edu.tr (Responsible Author)

Ümit ARPACIOĞLU [2]

ORCID 2: 0000-0001-8858-7499
[2] Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, Istanbul-Türkiye
umit.arpacioglu@msgsu.edu.tr

Abstract

The controlled integration of daylight into interior spaces has become a significant design issue in contemporary architecture, as it relates directly to both energy efficiency and user comfort. In this context, light shelves, which are passive systems developed to redirect and evenly distribute daylight, are elements that must be carefully considered within the architectural design process. The performance of light shelves is determined by factors such as latitude, sky conditions, window characteristics, dimensional proportions, and ceiling surface properties. Proper consideration of these parameters enhances the functionality of light shelves and their contribution to indoor lighting quality. Beyond being merely a technical system, light shelves make a direct contribution to visual comfort, glare control, balanced illumination, and energy efficiency. In this way, they reduce the need for artificial lighting, promote energy savings, and support sustainable design goals. This study addresses the role of light shelves in the architectural design process from a theoretical perspective, demonstrating that they should not be regarded solely as daylight-directing elements but as important design tools that integrate visual comfort, reduced energy consumption, and sustainability principles. In this framework, subsequent sections will provide a detailed discussion of the definition of light shelves, their relationship with visual comfort and energy efficiency, and the key approaches emphasized in the literature.

Keywords: Visual comfort, energy efficiency, light shelf, sustainable

1.Introduction

In architectural practice, natural daylight is regarded not only as a source of illumination but also as a fundamental design element that enriches spatial experience, reduces energy consumption, and enhances user comfort. Throughout history, daylight has been introduced into interior spaces through windows, courtyards, skylights, and various types of openings; however, with the widespread adoption of deep-plan spatial typologies in modern architecture, the controlled distribution of daylight within interior spaces has become a critical design challenge. In this context, light shelf systems have gained a significant place in architectural literature as innovative passive elements that homogenize daylight distribution and reduce glare.

Daylight emerges as an effective strategy for optimizing building energy performance. The use of advanced daylighting design systems not only significantly reduces electrical energy consumption but also improves the quality of interior lighting. Although daylight is primarily introduced into spaces through window openings, the presence of windows alone is not sufficient; additional systems that direct and control daylight are required (Moazzeni & Ghiabaklou, 2016).

A light shelf installed at a window is a typical daylight-control system that reduces lighting energy consumption by delivering natural light from outside into the deeper areas of a room through the use of a reflective surface and the ceiling plane. By preventing direct entry of daylight into the room through windows, light shelves can improve illuminance uniformity (Lee et al., 2019).

This study aims to reconsider the role of light shelves within the architectural design process and to discuss them within a theoretical framework in the context of sustainable and comfortable interior environments. Consequently, the light shelf should be regarded not only as a daylight-control element but also as an architectural design tool positioned at the intersection of visual comfort, energy efficiency, and sustainability objectives. In the subsequent sections of this study, the definition of light shelves, their historical development, their relationship with visual comfort and energy efficiency, and the key findings highlighted in the literature will be examined in detail.

2.Materials and Methods

This study examines light shelf systems within the context of the architectural design process and evaluates them in terms of visual comfort and energy efficiency. Research on light shelf typologies, dimensional characteristics, and their performance under different sky conditions has been systematically reviewed. Findings from various studies have been compared in terms of shelf dimensions, orientations, surface reflectance properties, glass types, and ceiling geometries. In this way, the critical factors influencing the effectiveness of light shelves in achieving a homogeneous distribution of daylight within interior spaces have been identified. The obtained data were interpreted within the framework of sustainable architectural design. The study emphasizes that light shelves are not only systems that contribute to energy savings but also design tools that enhance visual comfort.

2.1. Emergence of the Light Shelf System

In buildings with fully glazed façades, the distribution of daylight within interior spaces is often not homogeneous. This condition becomes particularly evident in areas located farther from the façade, where daylight alone is frequently insufficient, making the use of artificial lighting unavoidable. As a solution to this problem, it is recommended to integrate systems into façade design that can collect daylight, redirect it into interior spaces, and, if possible, provide adequate daylight even to areas farthest from openings.

In this context, various studies have been conducted with the aim of protecting users from glare caused by direct sunlight while ensuring a more uniform distribution of daylight within interior spaces. As a result of these studies, light shelf systems have been developed to both reduce glare and distribute daylight more evenly (Kontadakis et al., 2017). These systems, designed to enhance daylight performance, have become prominent in contemporary architectural designs that focus on the effective use of natural lighting.

Today, light shelves are among the passive daylighting elements frequently preferred in modern buildings and are described in the literature as effective systems due to their ability to improve lighting quality and contribute to energy savings when combined with appropriate daylight control strategies (Kontadakis et al., 2017). These relatively simple systems operate through a horizontal or inclined surface installed above eye level, either on the interior or exterior side of a window, reflecting incident daylight and redistributing it into the interior space. In this

respect, light shelves divide the window into upper (clerestory) and lower (view) sections and can perform both shading and light-redirecting functions (Littlefair, 1995).

The system primarily directs a large portion of incoming daylight toward the ceiling, from where it is reflected into the space, thereby reducing glare near the window and increasing illuminance levels in deeper areas of the room. While the lower window section maintains visual connection to the exterior and supports natural ventilation, the upper section functions to deliver daylight into the interior space (Masoud, 2024). With this dual functionality, light shelves are considered an important architectural component that enhances user comfort and energy efficiency.

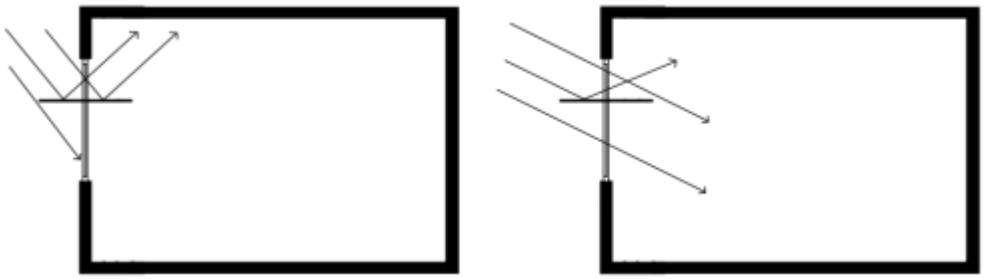


Figure 1. Summer (left) and winter (right) light shelf performance (Masoud, 2024)

Light shelves are classified into three main groups according to their placement configurations: interior, exterior, and combined interior–exterior systems. Light shelves positioned on the exterior provide shading, particularly during summer months, thereby reducing the building's cooling load, while interior light shelves have been shown to achieve higher average illuminance levels (Masoud, 2024).

2.2. Factors Affecting Performance in Light Shelf Design

2.2.1. Latitude and sky conditions

The performance of light shelves is directly influenced by latitude and sky conditions, which vary according to geographical location. In particular, under overcast sky conditions, the efficiency of light shelves is significantly reduced compared to clear sky conditions. For example, in climates characterized by predominantly overcast skies, such as the United Kingdom, light shelves have been observed to exhibit relatively low performance. Nevertheless, they can still offer advantages such as providing shading during summer months and enhancing daylight penetration into interior spaces during winter (Masoud, 2024).

Some studies have shown that under 'intermediate sky' conditions where the sky alternates between sunny and cloudy light shelves yield more effective results in terms of daylight availability and interior light distribution. While performance decreases on fully overcast days, intermittently sunny conditions allow for more homogeneous and deeper daylight penetration within interior spaces (Lim & Ahmad, 2014).

Another study reported that simulations conducted at latitudes of 30° and 45° indicated the suitability of interior light shelves, and that shelf efficiency increased significantly in conjunction with space height (Kurtay & Esen, 2019).

2.2.2 Window components

Since light shelves operate in direct integration with window systems, the physical and optical properties of window components have a direct impact on light shelf performance. As one of the main components of a light shelf system, the window must be carefully evaluated in terms of its characteristics—particularly size, position, and glazing type—for the efficient use of daylight (Uyduran & Yağmur, 2020). While the position and size of the window affect the distance daylight can penetrate into the interior space, the transmittance and reflectance of the glazing in the upper window zone directly influence the amount of light reaching the shelf surface (Rezaei et al., 2024). The type of window glazing (e.g., low-E coated, tinted, or electrochromic glass) determines not only the indoor illuminance levels but also the associated heat gains.

The mere physical presence of a window is not sufficient; daylight must be distributed into the space in a controlled manner. In this regard, the light shelf—one of the systems responsible for directing and redistributing daylight—contributes to both visual comfort and thermal comfort (Rezaei et al., 2024; Nageib et al., 2020).

2.2.3. Dimensions, types, and proportions of light shelves

The performance of a light shelf is determined by variables such as width, angle, height, and surface reflectance. Light shelves can be located either inside or outside the space (Lee, 2020). The dimensions of light shelves should be defined in relation to interior geometry and ceiling height. It is generally recommended that the depth of interior light shelves be equal to the height of the upper window. Exterior shelves, on the other hand, should be shorter than the vertical distance between the top of the window and the work plane (Kontadakis et al., 2017). The shelf length is typically designed to match the width of the window. However, in some cases, the shelf length may exceed the window width or vertical side elements may be added to prevent direct sunlight from entering from the sides. The installation height of light shelves is a critical factor for visual comfort; shelves are recommended to be positioned above eye level, at approximately 2 meters above the floor (Masoud, 2024).

Light shelves are generally classified into four main categories: horizontal, tilted, curved, and active (motorized or adjustable) systems (Kontadakis et al., 2017). The main difference among these types lies in how they modify the reflection and distribution of incoming light. Horizontal shelves are commonly preferred in standard window designs, while tilted shelves offer the advantage of delivering daylight deeper into the space. Curved shelves provide a more homogeneous light distribution and stand out in terms of energy efficiency during summer months. However, the risk of glare should also be considered in angled designs. For instance, it has been noted that a 30° reflector angle used in flat shelves may cause discomfort by reflecting light directly into the user's eye level (Kontadakis et al., 2017; Lee et al., 2019).

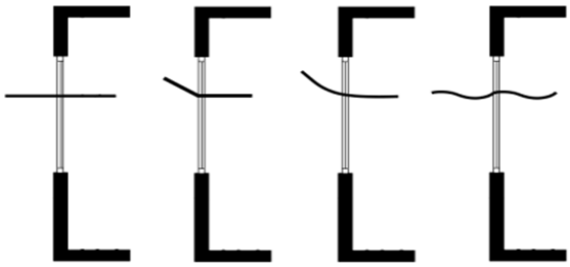


Figure 2. Shelf types (flat, angled, curved, and wavy) (Masoud, 2024)

The dimensions and types of light shelves are key factors in directing daylight into interior spaces in a homogeneous manner and ensuring visual comfort. During the design process, the shelf's angle, height, and reflectance properties should be selected in accordance with the spatial geometry and sustainability criteria, in a way that minimizes the risk of glare.

2.2.4. Effect of ceiling surfaces

The functionality of light shelves largely depends on their interaction with the ceiling surface. The distribution of reflected light into the interior space is directly related to the ceiling's form and reflectance. In a study conducted by Freewan, it was found that ceiling curvature can improve the uniform distribution of light by up to 10% (Freewan, 2010). In another study, three different ceiling types—sloped, pitched, and curved—were examined, and it was determined that curved ceilings, followed by pitched ceilings, performed better than flat ceilings (Freewan et al., 2008).

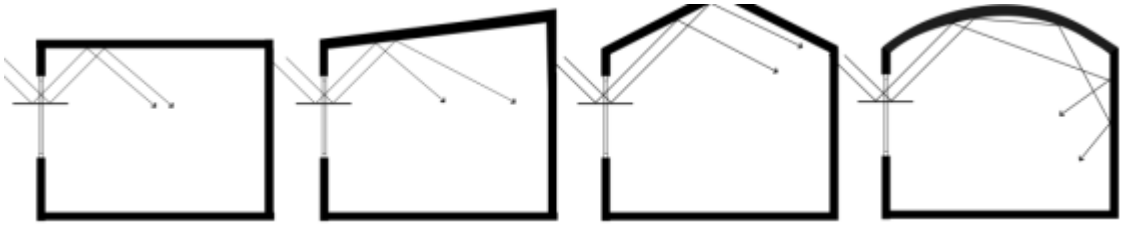


Figure 3. Effect of various ceiling surfaces on daylight penetration depth (Masoud, 2024)

The color and surface texture of the ceiling are also important factors affecting performance. Although glossy surfaces can reflect more light, they may cause undesirable effects such as light patches. Therefore, matte white ceiling surfaces are recommended to achieve a more homogeneous illumination level (Masoud, 2024).

2.3. Light Shelves in the Context of Visual Comfort

Visual comfort is an important factor that directly affects not only the spatial experience but also individuals' psychological well-being and productivity. Daylight, in particular, plays a critical role in regulating the circadian rhythm, which is fundamental to human biology. Research has shown that daylight synchronizes individuals' internal clocks with the 24-hour cycle, thereby improving overall health conditions (Tabadkani, 2021).

Ensuring visual comfort is not limited to providing adequate light levels alone. It also involves offering glare-free viewing angles, achieving a homogeneous distribution of illumination within the interior, and providing sufficient visual connection to the outdoors, all of which are critical for user satisfaction. Otherwise, limited outdoor views or sudden changes in brightness may cause visual discomfort. High luminance contrasts or distracting light sources can lead to discomfort glare, while unevenly illuminated task areas may result in visual fatigue, disability glare, and concentration problems (Tabadkani, 2021).

Numerous studies have emphasized that the presence of windows has positive effects on individuals' psychological well-being, stress levels, job satisfaction, and overall performance. However, the mere physical presence of a window is not sufficient; daylight must be distributed into the space in a controlled manner. In this context, light shelves—one of the systems designed to redirect and distribute daylight—emerge as an important tool for achieving visual comfort (Tabadkani, 2021).

Light shelves are among the most common passive system solutions developed to use daylight more effectively. Particularly preferred in side-lit spaces to control daylight, light shelves can be produced in fixed or dynamic forms and can be designed with flat, inclined, or curved surfaces. These systems, which can be easily installed on both the interior and exterior sides of windows, provide shading by blocking direct sunlight while simultaneously directing a significant portion of the light flux toward the ceiling, resulting in a more homogeneous illumination that reaches deeper into the space (Kontadakis et al., 2017).

One of the most important advantages of these systems is their ability to reduce negative effects associated with solar radiation, such as excessive brightness, heat gain, and glare. By redirecting daylight toward the ceiling, light shelves balance excessively high illumination levels near windows, thereby enhancing visual comfort and ensuring a more even distribution of daylight throughout the space (Kontadakis et al., 2017).

In conclusion, light shelves not only improve lighting quality but also create an interior experience that responds to users' psychological and physiological needs. As a significant element in achieving visual comfort, these systems play a critical role in the design of healthy, productive, and sustainable living environments through the efficient use of natural light.

2.4. Energy Efficiency in the Use of Light Shelves

In recent years, climate change resulting from the intensive consumption of fossil fuels has made it necessary to reconsider energy production and consumption patterns. In this context, the integration of renewable and sustainable energy sources, such as solar energy, in place of non-renewable resources has become increasingly important. With the aim of reducing energy consumption while maintaining spatial quality, the effective use of daylight has emerged as a strategic approach (Masoud, 2024).

Especially in buildings with deep floor plans, daylight cannot be distributed evenly throughout the interior space. This condition necessitates either the support of artificial lighting or the use of light shelves to achieve adequate illumination levels indoors. Light shelves are regarded as an effective solution for redirecting daylight and optimizing its distribution in side-lit spaces. These systems not only provide shading but also contribute to energy savings by enhancing daylight uniformity, thereby improving the overall lighting quality of the space. Light shelves are daylight-redirecting elements consisting of a horizontal or inclined surface positioned above the window. Owing to these characteristics, they perform a shading function by blocking excessive sunlight and, when installed on the exterior, help reduce solar gains, thereby lowering both lighting and cooling loads (Ghalati & Ahmadian, 2024).

In conclusion, light shelves offer an effective solution for both energy conservation and improving indoor lighting quality. Through proper design and positioning, a homogeneous distribution of daylight can be achieved while minimizing the negative effects of excessive solar radiation. Therefore, particularly for buildings with deep floor plans, the use of light shelves is considered an important component of sustainable and efficient lighting strategies.

3. Findings and Discussion

The literature review conducted reveals that light shelves are an effective passive system for delivering daylight deeper into interior spaces and ensuring a homogeneous distribution of light. The studies examined indicate that shelf dimensions, surface reflectance, installation configuration (interior, exterior, or combined), and sky conditions are decisive factors

influencing performance. In particular, high-reflectance surfaces and designs integrated with the ceiling enhance visual comfort and reduce the risk of glare.

However, the effectiveness of light shelves varies depending on different climatic conditions and orientations. Under overcast or partly cloudy sky conditions, the contribution of light shelves remains limited, whereas under sunny conditions they significantly increase illumination levels in deep spaces. Excessive enlargement of shelf dimensions may negatively affect shadow distribution within the interior and disrupt the aesthetic integrity of the design.

The discussions demonstrate that light shelves are not merely a technical system aimed at energy savings, but also a design element that directly influences user comfort and spatial perception. Therefore, approaches aimed at enhancing the performance of light shelves should be evaluated holistically within the architectural design process.

4.Conclusion and Recommendations

This study examined light shelf systems within the context of the architectural design process, evaluating them in terms of visual comfort and energy efficiency. Findings from the literature indicate that light shelves are particularly effective in providing a homogeneous distribution of daylight in interior spaces and reducing the need for artificial lighting, especially in sunny climates. Shelf dimensions, surface reflectance, installation configuration, and the geometric characteristics of the space are determining factors influencing performance.
The results demonstrate that light shelves are not merely technical lighting elements, but also architectural components that enhance user comfort and contribute to sustainable design goals. Therefore, during the design process, light shelves should be considered holistically, addressing their aesthetic, functional, and energy efficiency aspects together.
However, the present study is a theoretical review, and future experimental and simulation-based research may yield more concrete results regarding the performance of light shelves under different climatic conditions and across various spatial typologies.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. The first author contributed 60% and the second author contributed 40% to the study.

References

Esen, O., & Kurtay, C. (2017). Efficiency of light shelves according to latitudes in office buildings. *Gazi University Journal of Science*, *29*(4), p.711-721.

Freewan, A. A. (2010). Maximizing the lightshelf performance by interaction between lightshelf geometries and a curved ceiling. *Energy Conversion and Management*, *51*(8), p. 1600-1604. https://doi.org/10.1016/j.enconman.2009.09.037

Freewan, A. A., Shao, L., & Riffat, S. J. S. E. (2008). Optimizing performance of the lightshelf by modifying ceiling geometry in highly luminous climates. *Solar energy*, *82*(4), p.343-353. https://doi.org/10.1016/j.solener.2007.08.003

Keshtkar Ghalati, A., & Ahmadian, M. (2024). Effects of window and light shelve configurations on energy consumption and daylight illuminance in classrooms. *Renewable Energy Research and Applications*, *5*(1), p.107-119. DOI: 10.22044/rera.2023.12563.1194

Kontadakis, A., Tsangrassoulis, A., Doulos, L., & Zerefos, S. (2017). A review of light shelf designs for daylit environments. *Sustainability*, *10*(1), p.1-24. https://doi.org/10.3390/su10010071

Lee, H., Seo, J., & Choi, C. H. (2019). Preliminary study on the performance evaluation of a light shelf based on reflector curvature. *Energies*, *12*(22), p.1-20. https://doi.org/10.3390/en12224295

Lee, H. (2020). A basic study on the performance evaluation of a movable light shelf with a rolling reflector that can change reflectivity to improve the visual environment. *International journal of environmental research and public health*, *17*(22), p. 1-19. https://doi.org/10.3390/ijerph17228338

Lim, Y. W., & Ahmad, M. H. (2015). The effects of direct sunlight on light shelf performance under tropical sky. *Indoor and Built Environment*, *24*(6), p.788-802. https://doi.org/10.1177/1420326X14536066

Littlefair, P. J. (1995). Light shelves: computer assessment of daylighting performance. *International Journal of Lighting Research and Technology*, *27*(2), p.79-91. https://doi.org/10.1177/14771535950270020201

Masoud, S., Zamani, Z., Hosseini, S. M., & Attia, S. (2024). A review of factors affecting the lighting performance of light shelves and controlling solar heat gain. *Buildings*, *14*(6), p.1-19. https://doi.org/10.3390/buildings14061832

Moazzeni, M. H., & Ghiabaklou, Z. (2016). Investigating the influence of light shelf geometry parameters on daylight performance and visual comfort, a case study of educational space in Tehran, Iran. *Buildings*, *6*(3), p.2-16. https://doi.org/10.3390/buildings6030026

Nageib, A., Elzafarany, A. M., Elhefnawy, M. H., & Mohamed, F. O. (2020). Using smart glazing for reducing energy consumption on existing office building in hot dry climate. *HBRC Journal*, *16*(1), p.157-177. https://doi.org/10.1080/16874048.2020.1794226

Rezaei, F., Sangin, H., Heiranipour, M., & Attia, S. (2024). Multi-objective Optimization of Window and Light Shelf Design in Office Buildings to Improve Occupants' Thermal and Visual Comfort. *Journal of Daylighting*, *11*(2024), p.55-68. DOI:10.15627/jd.2024.4

Tabadkani, S., Roetzel, A., Li, H. X., & Tsangrassoulis, A. (2021). Daylight in buildings and visual comfort evaluation: The advantages and limitations, p.181- 203. DOI:10.15627/jd.2021.16

Uyduran, H., & Yağmur, Ş. (2020). *Tavan Eğiminin Işık Raflarının Performansına Etkilerinin İncelenmesi*, II. Mimarlık ve Şehircilik Lisansüstü Sempozyumu, İstanbul, Türkiye, p.34-35.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Examining Secondary School Landscape Spaces from a Design Perspective in the Climate Change Adaptation Process

Sibel AKTEN [1*]

ORCID 1: 0000-0001-6242-9687
[1]Dr., Isparta University of Applied Sciences, Eğirdir Vocational School, Isparta-Türkiye
sibelakten@isparta.edu.tr (Responsible Author)

Atila GÜL [2]

ORCID 2: 0000-0001-9517-5388
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
atilagul@sdu.edu.tr

Abstract

Mitigating the effects of climate change, one of the foremost global issues, and ensuring the spatial quality and sustainability of educational institutions in particular during the adaptation process is becoming increasingly important. A sustainable school is defined as a school designed and managed taking into account the social, environmental and economic sustainability issues that must be addressed for sustainable development. The fundamental idea of a sustainable school is to integrate sustainability into every aspect of school life. This approach envisages the use of environmentally friendly and renewable materials in the construction of buildings, ensuring energy efficiency, reducing waste production, and designing buildings in accordance with local living conditions. These structures reduce operating costs by saving energy, while also offering solutions to significant problems such as environmental pollution and climate change. In school spaces, landscape areas in particular provide multifunctional services and contributions. In order to make decisions on climate change in school spaces and reflect them in spatial design, it is necessary to consider the educational building and landscape spaces holistically and design them accordingly. This study will discuss the current situation and possible strategic actions required for the adaptation process of secondary school landscape spaces to climate change, using the example of Isparta Secondary School.

Keywords: Climate change, school landscape spaces, strategic actions.

1. Introduction

Global climate change is one of the most critical environmental issues transforming the physical, ecological, and socio-economic structure of urban life. Rising temperatures, irregular rainfall patterns, extreme weather events, and the urban heat island effect negatively impact the quality of life, particularly in urban areas. In this process, educational structures, which are an integral part of the urban fabric, and their open spaces are also directly exposed to the effects of climate change. Therefore, mitigating the negative effects of climate change on urban life is only possible through a transformation at the societal level, not just through technical or infrastructural interventions.

Sustainable development is a long-term transformation process that requires the holistic balancing of environmental, economic, and social dimensions. The success of this transformation is possible not only through technological or political measures, but also through the development of individuals' knowledge, awareness, and value systems. In this context, education is seen as a fundamental tool for achieving sustainable development. As stated by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017), prioritizing education is indispensable for a sustainable future because education fosters environmental sensitivity, ecological literacy, and sustainable living habits in individuals. Similarly, Tilbury (2011) emphasizes that sustainability awareness through education

transforms not only environmental protection behaviors but also social values and lifestyles. Therefore, aligning education systems with sustainability principles is considered a long-term strategic necessity in the processes of combating and adapting to climate change. A sustainable school is defined as an educational institution designed and managed by comprehensively addressing the social, environmental, and economic dimensions required for sustainable development (Kalaitzidis, 2012). These schools are important not only in terms of energy and resource efficiency but also in terms of developing students' awareness of climate change adaptation and environmental responsibility.

The fundamental approach of a sustainable school is to integrate the principle of sustainability into all areas of school life, management processes, teaching programs, building and landscape management, transportation arrangements, and relationships established with school management (Huckle, 2010). Papadimitriou (2010), on the other hand, defines the concept of a sustainable school through three main components (pedagogical, social-organizational, and environmental-technical-economic components). These components represent fundamental areas corresponding to different aspects of school life and requiring the holistic application of sustainability. Failure to consider climate change adaptation and sustainability principles in the planning and design processes of school landscape spaces leads to serious problems, particularly in terms of energy efficiency and student comfort. Therefore, educational buildings and their surrounding landscape spaces must be reevaluated with a climate-sensitive approach.

School landscape spaces are not merely spaces serving aesthetic functions; they are also critical environmental systems in terms of regulating the microclimate, contributing to ecological balance, and protecting user health. Open and green spaces, plant designs, and permeable surfaces in school landscape spaces reduce the urban heat island effect, improve air quality, and support biodiversity. These areas are also important learning environments where students can interact with nature, observe environmental processes, and develop their ecological awareness. Therefore, designing school landscapes in line with sustainability principles provides long-term benefits from both an environmental and pedagogical perspective.

Secondary school represents a critical developmental period during which individuals acquire environmental awareness, a sense of responsibility, and sustainable living habits. Creating nature-based and participatory learning environments that enable students in this age group to interact with the environment contributes to the permanent establishment of sustainability awareness. Therefore, evaluating secondary school landscape spaces from the perspective of climate change adaptation not only enhances the quality of the physical environment but also carries social value in terms of raising future environmentally conscious individuals.

Measuring and evaluating climate change adaptation characteristics at the school level enables institutions to identify their strengths and weaknesses in this area and develop strategies for improvement accordingly. This process contributes to the development of a comprehensive perspective that will support the transformation of schools in line with sustainability principles. In this context, the development of measurement tools to determine schools' adaptation to climate change will enable the systematic evaluation and improvement of sustainable school practices.

In this regard, the primary objective of the research is to develop a valid and reliable measurement tool that can assess sustainable school characteristics in the context of the climate change adaptation process. Such a tool will contribute to objectively evaluating schools'

sustainability and climate adaptation performance, identifying areas for improvement, and promoting the dissemination of the sustainable school model.

The research seeks to answer the following fundamental question: “How can a measurement tool be developed that can validly and reliably assess sustainable school characteristics in the context of secondary schools' adaptation process to climate change?”

2. Materials and Methods

The study aims to evaluate sustainable school characteristics within the context of the adaptation process to the effects of climate change using a holistic approach. In this regard, the measurement tool to be developed is intended to cover the fundamental components of the sustainable school concept and enable the evaluation of schools across different dimensions. The sub-objectives of the research are outlined below:

1. Determining the Physical–Environmental Dimension: Assessing the level of physical arrangements (use of open and green spaces, energy efficiency, water management, etc.) that adapt to climate change in the design of the school's indoor and outdoor spaces,

2. Examination of the Pedagogical Dimension: Determine the extent to which education and learning environments are integrated with the principles of sustainability and climate change adaptation,

3. Assessment of the Social and Administrative Dimension: Analyzing the level to which school administration, teacher, student, and parent interactions support a culture of sustainability; examining participation, awareness, and collaboration processes,

4. Examination of the Economic and Technical Dimension: Evaluate the school's efficiency in terms of resource use, maintenance and repair processes, waste management, and economic sustainability,

5. Development of a Measurement Tool: Develop a scientific tool that can measure sustainable school characteristics in the context of climate adaptation.

This research is based on a scale development model conducted within the framework of a quantitative research approach. In order to develop a valid and reliable measurement tool for assessing schools' sustainability and climate change adaptation characteristics, the research process includes the stages of (1) literature review, (2) determining performance criteria, (3) obtaining expert opinion, and (4) model creation. The original “MEBPERMOD” model, designed to determine the performance status of school facilities in the climate change adaptation process, will enable the prioritization of strategic actions by revealing the strengths and weaknesses of schools.

The study utilized descriptive and correlational survey methods. The descriptive dimension aimed to reveal the current sustainability levels of schools, while the correlational dimension focused on the relationships between the scale's sub-dimensions and the overall construct validity. The data collection tool used in the study was rated on a five-point Likert scale as “1-Equally important,” “3-Moderately important,” “5-Strongly important,” “7-Very strongly important,” and “9-Definitely important,” based on literature review and expert opinions, and weight coefficients and importance rankings were determined.

The content validity of the scale will be ensured by obtaining opinions from academic experts in the field and school administrators. The results obtained have been interpreted to represent the adaptation dimension of the sustainable school concept to climate change.

3. Findings and Discussion

In line with Türkiye's net zero carbon target by 2053, the commitment made at the 28th Conference of the Parties (COP28) requires the inclusion of school buildings, which constitute a significant portion of the public building stock, in this transformation process. In this context, efforts to develop green school buildings, zero-energy school buildings, and carbon-neutral or carbon-positive school buildings are of strategic importance in line with sustainable development goals.

The development of zero-energy school strategic plans for school facilities serves as an institutional roadmap for both mitigating the effects of climate change and supporting climate change adaptation processes. Such plans not only increase energy efficiency but also contribute to the creation of healthy, high-performance learning and working environments. This supports students in gaining environmental awareness and conservation consciousness during their development processes, while enabling school users to be more productive while saving energy and resources.

In the process of adapting to climate change, it is crucial to set measurable targets to objectively evaluate the sustainability performance of educational structures. These targets ensure that improvement and development processes in key areas such as energy, water, materials, carbon, transportation, waste, ecology, and maintenance in existing and potential school buildings become trackable. In this context, in the design and operation processes of school landscape spaces;

1. Energy use and efficiency,
2. Efficient use of water,
3. Sustainable material status and use,
4. Carbon emissions and storage capacity,
5. Environmental location and transportation relationship,
6. Waste and residue management and recycling,
7. Ecological contributions,
8. Building maintenance and repair level,
9. User perception and awareness performance-based criteria must be developed for these topics.

In determining these criteria, globally recognized green building certification systems that are also widely used in Türkiye have been taken as a basis. These include LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), CASBEE (Comprehensive Assessment System for Built Environment Efficiency), GREEN STAR, SBTool, IISBE, Green Globe, B.E.S.T., and the YeS-TR system specific to Türkiye (Çapkın, 2010).

The evaluation criteria derived from these certification systems have been classified within a framework of 15 basic criteria to determine the sustainability and climate change adaptation performance of school buildings (Table 1). These criteria enable a holistic approach to both physical environmental conditions (energy, water, materials, carbon management) and socio-pedagogical components (awareness, ecological contribution, sustainable behavior). The criteria developed in this direction provide a strategic framework for the design of climate-resilient, energy-efficient, and environmentally sustainable green school buildings and the improvement of existing structures.

Table 1. Performance criteria for secondary school spaces

Criteria	LEED	Breeam	DGNB	IISBE	Greenstar	Casbee	Green Globe	SBTool	B.E.S.T	YeS-Tr	Frekans	Weight Score
1-Energy use and efficiency	X	X		X	X	X	X	X	X	X	9	**0,13**
2-Exterior, interior quality and comfort	X			X	X	X	X	X	X	X	8	**0,12**
3-Effective use and efficiency of water	X	X			X		X		X	X	6	**0,09**
4- Sustainable material status and use	X	X			X				X	X	5	**0,07**
5- Carbon emissions and storage capacity	X		X	X	X		X				5	**0,07**
6-Innovation in spatial design	X	X	X						X	X	5	**0,07**
7-Environmental impacts and pollution	X	X	X			X		X			5	**0,07**
8-Environmental location and transportation	X	X			X	X	X				5	**0,07**
9-Evaluation of waste and residues		X					X			X	4	**0,06**
10-Ecological contributions		X	X		X						3	**0,04**
11-Building management and governance		X			X					X	3	**0,04**
12-Service and service quality				X		X		X			3	**0,04**
13-Social, cultural perception and awareness			X	X				X			3	**0,04**
14-Economic capacity			X	X							2	**0,03**
15-Level of maintenance and repair of school premises									X		1	**0,01**
										67		**1,00**

The criteria were evaluated by experts using a 5-point Likert scale: “Equally important” 1 point, “Moderately important” 3 points, “Strongly important” 5 points, “Very strongly important” 7 points, and “Definitely important” 9 points, thereby establishing the priority and weight coefficient of the criteria (Table 2). When weighing up, the opinions of 20 experts in the fields of Landscape Architecture, Architecture, Civil Engineering, Agricultural Engineering, Food Engineering, and Environmental Engineering were consulted.

Table 2. Evaluation of performance criteria for secondary school spaces

Criteria	Total Points	Total Weight
Energy use and efficiency	160	0,10
Ecological contributions	146	0,08
Effective use and efficiency of water	144	0,08
Environmental impacts and pollution	140	0,08
Exterior, interior quality and comfort	132	0,07
Sustainable material status and use	128	0,07
Carbon emissions and storage capacity	124	0,07
Evaluation of waste and residues	120	0,07
Social, cultural perception and awareness	110	0,06
Building management and governance	110	0,06
Environmental location and transportation	102	0,06
Innovation in spatial design	96	0,05
Service and service quality	94	0,05
Economic capacity	92	0,05
Level of maintenance and repair of school premises	82	0,05
TOTAL	**1780**	**1,00**

Weight scores were determined by calculating the ratio of the scores obtained by 15 basic criteria, which were scored by experts according to their importance. Accordingly, the basic criteria are ranked as follows: first, “Energy use and efficiency (0.10)”, followed by “Ecological contributions (0.08)”, “Effective use and efficiency of water (0.08)”, “Environmental impacts and pollution (0.08)”, “Exterior, interior environment quality and comfort (0.07)”, “Sustainable material status and use (0.07)”, “Carbon emissions and storage capacity (0.07)”, and “Evaluation of waste and residues (0.07)”. Thus, it is envisaged that strategic action plan decisions for school landscape spaces will be developed using holistic performance benchmarks for school spaces.

In this context, the "MEBPERMOD" model has been developed to evaluate each school's performance in adapting to climate change by scoring sub-criteria and indicators based on 15 basic criteria. In schools where performance evaluation will be conducted, the goal is to obtain the school's total performance score by multiplying the weight score of each basic criterion, which includes the sub-criteria, by 5 points for "Yes" and 1 point for "No" for each of the 69 sub-criteria (Table 3).

Table 3. Approach to evaluating the performance status of secondary school spaces with the MEBPERMOD model

Number	Basic Criteria (BC)	Sub-Criteria (SC)	Total Indicator Score (TIS)	Basic Criteria Weight Score (BWS)
1	Energy use and efficiency	1-Availability of a low-energy appliance system 2-Conversion of the heating boiler system (conversion to natural gas) 3-Reduction of capacity load during holiday periods 4-Building interior and exterior thermal insulation 5-Daylight usage 6-Renewable energy generation from solar, wind, etc. 7-Awareness training on energy consumption and conscious use 8-Availability of electricity generation with piezoelectric systems (pressurized)	Yes 5 Point No 1 Point	**0,10**
2	Exterior, interior quality and comfort	1-Ventilation environments 2-Air circulation status 3-Presence of ventilation shafts 4-Indoor acoustics 5-Natural lighting status 6-Geothermal heating availability 7-Presence of light shelves on windows 8-Sufficient space capacity 9-Cleaning frequency 10-Accessibility of space	Yes 5 Point No 1 Point	**0,07**
3	Effective use and efficiency of water	1-Presence of water conservation measures 2-Current greywater usage status 3-Photocell batteries 4-Presence of time relay batteries 5-Rainwater storage and use for garden irrigation 6-Presence of an artesian water source 7-Monitoring of water usage	Yes 5 Point No 1 Point	**0,08**
4	Sustainable material status and use	1-Use of natural materials in interior and exterior spaces 2-Use of recycled materials 3-Use of materials that do not pose a cancer risk 4-Use of natural water-based emulsion paints	Yes 5 Point No 1 Point	**0,07**
5	Carbon emissions and storage capacity	1-Indoor carbon content 2-Tree carbon storage in landscaped spaces 3-Per capita carbon content	Yes 5 Point No 1 Point	**0,07**

6	Innovation in spatial design	1-Technologies for the efficient use of renewable energy resources 2-Availability of building automation systems 3-Use of innovative construction techniques	Yes 5 Point No 1 Point	**0,05**
7	Environmental impacts and pollution	1- Presence of air pollution 2- Vehicle traffic density and noise 3- Dust density 4- Prevailing wind influence level	Yes 5 Point No 1 Point	**0,08**
8	Environmental location and	1-Availability of public transportation 2-Bicycle density 3-Parking capacity 4-Shuttle availability	Yes 5 Point No 1 Point	**0,06**
9	Evaluation of waste and residues	1-Availability of separation systems for waste and residues 2-The status of food waste utilization 3-The status of compost fertilizer made from plant residue 4-The status of waste paper utilization 5-The availability of recycled materials 6-The status of producing new materials from waste	Yes 5 Point No 1 Point	**0,07**
10	Ecological contributions	1-Indoor planting 2-Roof and terrace planting 3-Vertical planting on the building facade 4-Presence and number of trees and shrubs in the school landscape spaces 5-Presence of fruit trees in the school landscape spaces 6-Presence of plant production and cultivation areas	Yes 5 Point No 1 Point	**0,08**
11	Building management and governance	1-Awareness level of school administrators 2-Administrators' prioritization of maintenance and repair 3-Landscape planting activities 4-Green building project development 5-Support for student activities 6-Participation level in decision-making processes	Yes 5 Point No 1 Point	**0,06**
12	Service and service quality	1-The healthiness of school canteen products	Yes 5 Point No 1 Point	**0,05**
13	Social, cultural perception and awareness	1-Number of educational and cultural events 2-Number of student clubs 3-Number of activities	Yes 5 Point No 1 Point	**0,06**

14	Economic capacity	1-Prioritizing the school budget 2-Allocating funds for maintenance and repair	Yes 5 Point No 1 Point	**0,05**
15	Level of maintenance and repair of school	1-Existence of a periodic maintenance and repair program 2-Availability of support personnel	Yes 5 Point No 1 Point	**0,05**

The MEBPERMOD (Ministry of National Education Performance Model), developed to determine the sustainability and climate change adaptation levels of secondary school facilities, enables the evaluation of the physical, environmental, social, and economic dimensions of educational structures through a holistic approach (Akten, 2024).

The MEBPERMOD model is formulated as follows:

BCS: Basic criterion score

TSCS: Total sub-criterion score

n: Number of criteria

BWS: Basic criterion weight score

TPS: School's total performance score

$BCS = TSCS_n \times BWS_n$

$TPS = BCS_1 (TSCS \times BWS_1) + BCS_2 (TSCS \times BWS_2) + \ldots BCS_{15} (TSCS \times BWS_{15})$

The total performance score (TPS) has been grouped in three different ways to determine performance status. This scoring system quantifies the school's sustainability performance and its capacity to adapt to climate change.

$TSCS_{max}$ 69x5 = 345

$TSCS_{min}$ 69x1 = 69

$TSCS_{max} - TSCS_{min}$ = 345-69 =276/3 =92

- **Low Performance Schools:** 69 to 161 points
- **Medium Performance Schools:** 162 to 253 points
- **High Performance Schools:** 254 to 345 points

Based on the total performance score obtained from the model, school facilities are classified into three main groups:

1. High-Performance Schools (Green Schools):

These are schools that implement sustainability principles at a high level, provide energy and resource efficiency, and have effectively integrated climate change adaptation strategies. This group represents the highest level in the MEBPERMOD score range.

2. Medium-Performance Schools (Developing Schools):

These are schools that meet some sustainability criteria but need improvement in certain areas. These schools have made certain progress in environmental awareness and resource management and have the potential to achieve sustainable school status.

3. Low-Performing Schools (Schools Requiring Improvement):

These are schools that fail to meet most sustainability criteria and demonstrate low efficiency in areas such as energy, water, and material management. Schools in this group have the weakest capacity to adapt to climate change and require comprehensive physical and administrative improvements.

This three-tier classification enables the objective assessment of schools' current status and allows each school to develop sustainability strategies according to its own development potential. Thus, the MEBPERMOD model serves as a measurable tool that guides decision-makers in the process of transforming secondary schools into climate-resilient, sustainable, and healthy spaces.

4. Conclusion and Recommendations

The selection and evaluation of performance criteria in secondary school settings requires a process based on multiple data sources. This is important not only for increasing the reliability of results related to institutions but also for contributing to information access and decision-making processes. Indeed, approaches aimed at improving the performance measurement and management of public institutions also support this understanding (Lettieri et al., 2004).

According to Fındıkçı (2002), Barutçugil (2004), and Döngel (2006), evaluation based on multiple data sources increases measurement reliability and serves as an effective tool for analytical thinking, forecasting the future, managerial improvement, and organizational development. The evaluation process conducted within this scope enables the organization to conduct a self-assessment of its own performance. Thus, the findings obtained allow for the identification of existing deficiencies and problem areas, thereby enabling the development of targeted improvement strategies for these areas.

Based on the evaluation results, schools can define their own change and development goals by prioritizing areas with low performance. This process is an important part of sustainable school transformation and contributes to the continuous development cycle of institutions.

Schools play an important role as institutions that present a comprehensive vision by raising awareness among all stakeholders on climate change and sustainability issues. However, the effective continuation of this vision depends on the implementation of regular monitoring, auditing, and improvement processes. In this regard, “MEBPERMOD” has been developed to assess the performance status of schools' climate change adaptation processes.

The MEBPERMOD model enables the quantitative assessment of schools' effectiveness in adapting to climate change. Within the scope of the model, 15 basic criteria and 69 sub-criteria and indicators linked to these criteria are scored using specific weights to generate a total performance score for each school.

The total scores obtained categorize schools' climate change adaptation performance levels into three categories:

- 69–161 point range: Low-performing schools

- 162–253 point range: Medium-performing schools
- 254–345 point range: High-performing schools

This classification enables schools to objectively analyze their current status, identify their strengths and weaknesses, and define strategic areas for improvement in terms of sustainability. Thus, the MEBPERMOD model can be used as a scientifically based assessment tool for monitoring and managing adaptation to climate change in educational institutions.

The MEBPERMOD model serves as an important guide for identifying the current status and shortcomings of schools based on their performance scores, enabling the formulation and prioritization of strategic action decisions in the process of adapting to climate change. By highlighting the areas where each institution excels and those open to improvement, the model provides a data-driven approach to sustainability-based school management.

Additionally, by comparing schools' evaluation results, it is possible to monitor the temporal development of institutions and assess the effectiveness of improvement processes. In this respect, the MEBPERMOD model covers not only the evaluation process but also the stages of analyzing, interpreting, and translating the results into action. Therefore, the model offers a comprehensive framework that can be used both as a decision support tool and as a monitoring and evaluation mechanism in the process of developing sustainable school policies.

This study was conducted to improve the adaptation process to climate change in secondary school landscape spaces. The MEBPERMOD model developed for this purpose has a structure that can be applied not only to secondary schools but also to educational institutions at different levels. This feature of the model allows for reaching a broader sample group and obtaining generalizable results.

During the evaluation process, institutions can adapt, develop, or redefine the criteria that affect their performance, taking into account the structural, environmental, and pedagogical characteristics of their own school levels. Thus, the model provides a flexible framework for different types of schools and contributes to improving sustainability performance.

Furthermore, it is possible to conduct a comparative analysis of climate change adaptation performance outcomes by examining the model's relationships with school facilities in different cities. Such comparative studies can serve as an important reference source for evaluating both regional differences and the impact of local government policies on school sustainability.

Thanks and Information Note

This work is a publication produced under project No FDK-2023-8998, supported by the Scientific Research Projects Management Unit of Süleyman Demirel University, and I would like to thank the Scientific Research Projects Management Unit of Süleyman Demirel University for its financial support. The article complies with national and international research and publication ethics. Ethics Committee approval in the study, Ethics Committee of the University of Süleyman Demirel dated 16 January 2023 and SDU Science and Engineering Ethics Committee Decision Number 70. All authors contributed equally to the article.

References

Akten, S. (2024). Okul Peyzaj Mekanlarının İklim Değişikliği Uyum Sürecine Yönelik Stratejik Eylem Plan Modeli, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Doktora Tezi, Isparta.

Barutçugil, İ. (2004). *Stratejik İnsan Kaynakları Yönetimi.* Kariyer Yayınları, İstanbul.

Building Environment Standards and Tools (B.E.S.T.). (2015). *B.E.S.T. Building Environmental Sustainability Tool User Manual*. Milan: Politecnico di Milano.

Building Research Establishment (BRE). (2016). *BREEAM International New Construction Technical Manual*. Watford, UK: BRE Global Ltd.

Çapkın, D. (2010). Yerel Mimari Olarak Tanımlanan Projelerde Ekolojik Yapım Sistemlerinin Yeri. Beykent Üniversitesi Yüksek Lisans Tezi, İstanbul.

Çevre Dostu Yeşil Binalar Derneği (ÇEDBİK). (2020). *YeS-TR Yeşil Bina Sertifikasyon Sistemi Kılavuzu*. İstanbul: ÇEDBİK.

Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB). (2018). *DGNB System Version 2018 for Buildings*. Stuttgart, Germany: DGNB e.V.

Döngel, A. (2006). İlköğretimde Denetim ve Performans Değerlendirme Çalışmalarına İlişkin İlköğretim Müfettişlerinin Görüşleri. Gazi Üniversitesi Sosyal Bilimler Üniversitesi Yüksek Lisans Tezi, Ankara.

Fındıkçı, İ. (2002). *İnsan Kaynakları Yönetimi.* Alfa Basım, İstanbul.

Green Building Council of Australia (GBCA). (2019). *Green Star Design & As Built v1.3 Rating Tool*. Sydney: GBCA.

Green Globe. (2019). *Green Globe Standard for Sustainable Tourism and Travel*. Los Angeles: Green Globe International.

Huckle, J. (2010). Education for sustainable development: A critical review of concept, policy and practice. *Environmental Education Research,* 16(5-6), 681–692.

International Initiative for a Sustainable Built Environment (iiSBE). (2016). *SB Tool 2016: A Generic Framework for Building Sustainability Assessment*. Ottawa: iiSBE.

Japan Sustainable Building Consortium (JSBC). (2014). *CASBEE for Building (New Construction)*. Tokyo: JSBC.

Kalaitzidis, I. (2012). The sustainable school: concepts and practices in the Greek context. *Journal of Environmental Education Research,* 18(3), 257–273.

Lettieri, E., Borga, F., Masella, C., & Savodelli, A. (2004). Performance Measurement and Management Control. Superior Organizational Performance Measurement in Non-Profit Organizations: How to Link Theory and Reality? (Eds: M.J. Epstein) Bingley: Emerald Publishing, 355-374.

Papadimitriou, F. (2010). Sustainable schools: A framework for action in environmental education. *International Journal of Sustainability in Higher Education*, 11(2), 139–152.

Tilbury, D. (2011). *Education for Sustainable Development: An Expert Review of Processes and Learning*. Paris: UNESCO.

UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. Paris: United Nations Educational, Scientific and Cultural Organization.

U.S. Green Building Council (USGBC). (2018). *LEED v4 for Building Design and Construction*. Washington, DC: USGBC.

YES-TR. (2025). *Yeşil Sertifika Değerlendirme Kılavuzu. Binalar ve Yerleşmeler İçin Yeşil Sertifika Yönetmeliği.* T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Ankara.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Determining Route Selection Criteria for the Creation of a Bicycle Route in the Context of Diversifying Cultural Tourism

Sibel AKTEN [1]*

ORCID 1: 0000-0001-6242-9687
[1]Dr., Isparta University of Applied Sciences, Eğirdir Vocational School, Isparta-Türkiye
sibelakten@isparta.edu.tr (Responsible Author)

Atila GÜL [2]

ORCID 2: 0000-0001-9517-5388
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
atilagul@sdu.edu.tr

Hüseyin Batuhan DÜNDAR [3]

ORCID 3: 0009-0003-7341-970X
[3]Master's Student, Süleyman Demirel University, Institute of Science, Department of Landscape Architecture, Isparta-Türkiye
hbatuhandundar@gmail.com

Abstract

Bicycle tourism, which is a significant transportation alternative in urban and rural areas at national, regional, and local scales, is increasingly recognized as a development tool. It can also contribute significantly to the economic, socio-cultural, psychological, health, sports, recreational, technological, and environmental aspects of diversifying sustainable tourism. In this context, determining and organizing bicycle routes for bicycle tourism has become a necessity. This study aims to determine the importance and contribution of bicycle routes that will contribute to the diversification of cultural tourism, as well as the criteria and indicators for the location selection of short, medium, and long-distance bicycle routes. In this context, the opinions of decision-makers, academics, and bicycle users were gathered through a survey, and three basic criteria (physical, environmental, and visual/functional criteria) and 21 sub-criteria and indicators that could be considered in the creation of bicycle routes were determined. Thus, the most suitable bicycle paths within the scope of location selection criteria in urban and suburban tourism destination areas will provide easy and enjoyable access to cultural and natural tourism focal points. Ultimately, it will provide an alternative and economical means of access while also offering visitors the experience of using bicycles for sports, recreation, and health purposes.

Keywords: Cultural tourism, bicycle route, bicycle tourism, bicycle route selection criteria.

1.Introduction

The increase in motor vehicle use observed in recent years has led to a rise in fossil fuel consumption, seriously triggering environmental pollution and climate change at the global, national, and local levels. This situation has made the importance of sustainable transportation policies more apparent. According to the World Health Organization (WHO, 2004), sustainable transportation should be economically, safely, and socially acceptable, contribute to quality of life, operate without disrupting environmental balance, and demonstrate a solution-oriented approach to environmental issues. In this context, transportation planning plays an important role not only in the physical formation of cities but also in improving the quality of urban life. Indeed, sustainable transportation is defined as a system that meets today's transportation needs without threatening the right to life of future generations and other living species (Black, 1996).

One of the leading solutions for achieving sustainable transportation goals is to carry out travel using public transportation and non-motorized transportation modes. Urban sustainable

transportation systems are based on principles such as ensuring safe and fast transportation, planned approaches to land use, prioritizing the use of renewable energy sources, being economically low-cost, and providing quality transportation services to the community (Crawford, 2002). In this context, bicycle transportation, one of the non-motorized modes of transportation, fully complies with the definition of sustainable transportation and offers an effective alternative solution to the problems encountered in urban transportation. Compared to motorized vehicles, bicycle use significantly reduces energy consumption in the transportation sector and contributes significantly to environmental sustainability (Pucher & Buehler, 2012). In this regard, the role of bicycle use in reducing the carbon footprint caused by transportation is becoming increasingly important and is leading governments to reevaluate their policies on urban transportation systems. However, bicycles are used not only as a means of transportation but also for various purposes such as amateur and professional sports, entertainment, recreation, health, and tourism. When used for transportation, bicycles stand out as an effective alternative mode of transportation that facilitates movement between two points, is low-cost, environmentally friendly, and offers practical solutions for short distances.

Bicycles, a healthy, economical, environmentally friendly, and enjoyable mode of transportation, are considered a strong alternative to motor vehicles, especially for short and medium-distance journeys. Therefore, integrating bicycle transportation into the urban transportation system, increasing its usage rate, and promoting its widespread adoption are of great importance. As a fundamental component of sustainable and integrated transportation systems, bicycles stand out as the most effective solution capable of covering all short-distance trips (5–8 km) in cities and providing a complementary transportation alternative between the starting and ending points of public transportation systems for longer trips. Bicycle trips in cities, where the majority of the population lives, are generally considered short trips. While commuting to work and school takes place every weekday, some trips (such as for health or visits) are less frequent, and recreational, sports, and leisure trips within the city increase on weekends.

Trips between rural settlements or between the city and surrounding rural settlements share similar characteristics with urban trips, but are generally considered longer bicycle trips or bicycle trips involving public transport transfers. Long bicycle trips are typically for sports, recreation, and tourism purposes and involve cycling throughout the day. These types of bicycle rides, usually planned in advance and organized by groups of varying sizes, can take the form of nature and cultural tours on easy routes outside the city, or they can be organized on challenging trails or in rugged topography where there is no bicycle infrastructure. This diversity demonstrates that bicycles serve not only as a means of transportation but also have multifaceted functions such as physical endurance, exploration, cultural interaction, and integration with nature.

Today, the contribution of bicycles to global sustainability goals has led many countries to consider bicycles as a strategic element in their transportation and environmental policies. Accordingly, countries are developing comprehensive policies to encourage bicycle use at the national, regional, and local levels; they are preparing and implementing national bicycle strategies and regional and urban bicycle master plans. These plans aim to support sustainable transportation, reduce environmental impacts, and improve the quality of urban life. However, when evaluated specifically in Türkiye, it is observed that there is no comprehensive legal or technical framework defining the approaches, methods, and processes related to urban and rural bicycle planning.

The increasing transportation problems in our cities and the short-term effects of the solutions developed, along with growing environmental problems and economic losses on a national scale, increase the need for efforts to promote bicycle transportation. Although there are some limited technical regulations in urban areas with high bicycle usage, there is no clear, binding, and mandatory legislation on bicycle planning. As stated in the "Bicycle Paths Regulation" published in the Official Gazette, issue number 30976, dated December 12, 2019, bicycle path projects can be prepared by professionals from different disciplines, such as architects, landscape architects, cartographers, urban planners, or civil engineers. However, implementing these projects without considering the natural, cultural, and socio-economic characteristics of cities can lead to various problems. This situation creates a structural obstacle to increasing the share of bicycle transportation in the urban transportation system. Therefore, in order to make sustainable and effective decisions regarding the selection of bicycle paths, the characteristics of the region must be analyzed based on specific criteria.

The sustainable tourism approach is not only the most important economic driver at the national, regional, and local levels, but also a development tool that can make significant contributions in socio-cultural, psychological, health, sports, recreational, technological, and environmental dimensions. In developed countries, the use of bicycles, an alternative, easy, economical, and sustainable environmentally friendly transportation option, is becoming increasingly widespread (EESC, 2019). At the same time, it has brought bicycle tourism to the forefront in terms of diversifying sustainable tourism at the local level and increasing added value. In this context, determining and organizing routes for bicycle tourism has become a necessity.

This study aims to determine the importance and contribution of bicycle paths in diversifying cultural tourism, as well as the criteria and indicators for selecting locations for short, medium, and long-distance bicycle paths. Thus, the most suitable bicycle paths within the scope of location selection criteria in urban and suburban tourism destination areas will provide easy and enjoyable access to cultural and natural tourism focal points. Ultimately, this will provide an alternative and economic means of access while also offering visitors the experience of using bicycles for sports, recreation, and health purposes.

1.1. The Role of Bicycle Routes as a Sustainable Means of Transportation in Cultural Tourism

The bicycle was invented in Germany in 1818 by Baron Karl Von Drais and has evolved over approximately two hundred years to reach its current form. Today, bicycles are produced and used in various shapes and sizes depending on their intended use. The widespread use of bicycles began in England, then spread to Europe, and from there to the rest of the world (Ankaya & Aslan, 2020). During the economic crisis of the 1930s, when automobiles were not yet widespread in urban transportation, bicycle use increased in European cities, reaching a share of 80% as the most important means of transportation in some cities. Bicycle transportation continued to be important during World War II. Due to limited fuel, spare parts, and repair facilities, bicycles played a significant role in urban and rural areas when cars and buses could not provide adequate service. After the war, with the improvement of the economy and the increase in car ownership and use, the share of bicycle transportation in cities declined rapidly. This decline continued until the global oil crises of 1973 and 1978. The hardships caused by the global oil crisis, combined with growing environmental awareness and concerns, led to bicycles regaining importance as a sustainable alternative in transportation.

Bicycle transportation in Türkiye began approximately a century after the invention of the bicycle. At the beginning of the 20th century, during the Ottoman period, bicycles were used in the postal service and the military (Yılmaz, 2015). In 1940, when bicycles were widely used throughout the world, the rate of bicycle use also increased in Türkiye. The bicycle license, bicycle permit, and bicycle license plate that were implemented in Türkiye for a period demonstrate that bicycles were used as a means of transportation (Mert & Öcalır, 2010). However, in recent years, steps have been taken to increase the use of bicycles in urban transportation, both due to environmental concerns and efforts to comply with international sustainability goals. The promotion of bicycles as an environmentally friendly means of transportation is at the center of strategic efforts being made on a global scale to reduce the share of fossil fuel-powered vehicles in transportation and, consequently, minimize environmental impacts.

Bicycle transportation, being entirely powered by biological energy, does not produce harmful emissions or contribute to air pollution, unlike motor vehicles that consume fossil fuels. This feature makes it an environmentally friendly and sustainable transportation option. Additionally, bicycle use provides a high degree of flexibility in terms of time planning. While offering the same individual freedom of use as cars, it is independent of the fixed schedules that public transportation vehicles are bound to. Users can start, stop, or pause their journeys whenever they wish.

Route flexibility is also one of the important advantages of bicycles. Bicycle users have the opportunity to choose the shortest, safest, flattest, or most aesthetically pleasing route according to their personal preferences, without being tied to predetermined fixed routes. In this sense, bicycles are superior to both public transportation and cars in terms of route flexibility. In addition, the physical space occupied by bicycles while in motion, during stops, or when parked is quite small. This provides a significant advantage in terms of urban space utilization. Unlike cars, bicycles offer more efficient use of space without excessively consuming roads and other urban spaces. Therefore, bicycle transportation is of strategic importance not only for environmental sustainability but also for spatial sustainability.

Bicycle transportation stands out not only for its environmental and economic benefits, but also for the advantages it offers in terms of social and safety aspects. Since the speed of bicycles is lower than that of motor vehicles, the number of accidents they are involved in and the rates of material damage, injury, and death in these accidents are quite low. In this respect, bicycle transportation is considered a safer alternative for urban transportation. Furthermore, bicycle trips allow for more social interaction between individuals, increasing personal relationships and social solidarity within the community (Küster & Blondel, 2013). Being accessible to everyone regardless of income level makes bicycles a fair and inclusive form of transportation that reduces inequalities between income and social groups. Increasing the mobility of low-income individuals in particular makes it possible to consider cycling as a strategic tool in terms of social justice. At the same time, by supporting the mobility of women, children, young people, and the elderly within cities, cycling facilitates their participation in public life and urban activities, enabling them to be more effectively included in city life.

Today's evolving and diversifying tourism sector, driven by supply and demand and aimed at fostering economic, social, and environmental development, is transforming investments into action to support various types of activities. This is done by decision-makers (managers, political will, planners/designers etc.) in order to adapt to constantly changing conditions.

In this context, within the types of tourism, we can define bicycle tourism as trips made by bicycle by people whose main motivations are seeing the natural environment, physical fitness, experiencing adventure, seeking excitement and change, escaping routine, and feeling independence. Cycling tourism is recognized as a new market that continues to grow worldwide. In this context, it is accepted that cycling tourism has great potential in terms of tourism and that tourism regions that provide the necessary infrastructure and superstructure for cycling tourists stand out more in a competitive environment (Türkay & Atasoy, 2021).

Bicycle tourism can generally take place in nature, urban and rural areas, that is, in any location. Bicycles, which can also be described as a form of vacation transportation, are still considered a niche market in the tourism sector (Sheng, 2015). However, bicycle tourism provides opportunities to diversify and develop tourism at the national and regional levels. The creation of bicycle routes aims to attract tourists traveling in nature by providing them with a different activity (Ünüyar et al., 2017). Thus, visiting tourists contribute economically, socially, and environmentally to tourism destinations (Ritchie et al., 2010).

In the EU, it is acknowledged that the meaning attributed to and importance given to cycling, particularly in terms of environmentally conscious options, has been effective in meeting the demand for environmentally conscious tourism that aims to foster dialogue between communities at both urban and rural scales, as well as other policy approaches (Blondiau & Zeebroeck, 2014; Transport and Tourism Policy, 2019; Türkay & Atasoy, 2021).

Bicycle tourism creates certain advantages and disadvantages for tourism regions. The availability of e-bikes, the existence of different routes, and natural attractions are opportunities that tourism regions have in terms of bicycle tourism. On the other hand, the fact that it can only be carried out during certain periods of the year due to unsuitable weather conditions, the cost of creating bicycle routes, the difficulty of establishing technological infrastructure, and safety issues are cited as disadvantages that bicycle tourism brings to countries or regions (Innovation Norway, 2016).

However, there are also some physical, environmental, and individual limitations that hinder the widespread use of bicycles. Firstly, bicycles are sensitive to topographical features; cycling becomes difficult on sloping terrain, which directs users towards public transportation. However, electric bicycles (e-bikes), which have become widespread in recent years, significantly eliminate this difficulty, enabling bicycle transportation to be sustainable in different geographical conditions. Bicycles are also highly sensitive to climatic conditions. Adverse weather conditions such as rainfall, extreme heat, or cold reduce bicycle usage rates. However, even in Northern European countries with unfavorable climatic conditions, bicycle transportation does not disappear entirely; despite seasonal declines, it continues to be an important part of urban transportation systems (Türkay & Atasoy, 2021). In addition, travel distance is also an important factor affecting bicycle use. As distance increases, bicycle use becomes more difficult, especially for individuals with limited physical capacity, the elderly, or those with physical disabilities, leading to a decline in usage rates. Therefore, for bicycles to be used effectively as a means of transportation, urban planning must take these physical and environmental limitations into account, and infrastructure and supportive policies must be shaped accordingly.

For bicycle tourism to develop to the desired level in a region, infrastructure and well-defined bicycle routes are required. These conditions, in turn, require significant political power. Similarly, when discussing bicycle tourism, other important factors include natural attractions,

scenery, as well as accommodation facilities offering quality services, bicycle rental and transfer companies (luggage transport). At this point, providing the infrastructure and superstructure needed by tourism regions brings the political environment to the fore. For this reason, the EU supports bicycle tourism in the political environment. In this context, the German Cyclists' Association (ADFC) is one of the official organizations established to secure the political environment's support for bicycle tourism (Innovation Norway & NCE Tourism Fjord Norway, 1998).

2.Materials and Methods

The criteria considered in the creation of bicycle routes in this study were determined through a literature review. During the process of establishing the criteria for the research topic, the "Bicycle Paths Regulation" published in the Official Gazette dated December 12, 2019, with the number 30976, and the relevant TSE standards were examined. In addition, international standards such as AASHTO, 2012; CROW, 2017; ECF, 2019 were taken into consideration. In this context, the opinions of decision-makers, academics, and bicycle users were collected through a survey, and three basic criteria (physical, environmental, and visual/functional criteria) and 21 sub-criteria and indicators that could be taken into account in the creation of the bicycle route were determined. The criteria identified in the study include: Bicycle path types, vehicle and pedestrian lane width, slope, road surface material quality and condition, land use type, usage intensity, transportation system integration, property status, traffic density, traffic speed, building density, building layout, network continuity, integration with open and green spaces, landscape and user experience, lighting conditions, visibility distance, road traffic signs and signage, bicycle parking facilities, noise and safety level.

One of the most important factors in ensuring that CBS-based bicycle path selection is sustainable and understandable is the ranking of criteria according to their importance levels using the analytic hierarchy process. Therefore, the defined criteria were ranked in order of priority by a total of 30 people, including decision-makers, academics, and bicycle users, using a 9-point Saaty scale via a survey. The weighted scores for the criteria obtained as a result of the priority ranking were calculated. Thus, the basic/sub-criteria and indicators for determining the location of bicycle routes and their prioritization were established.

3.Findings and Discussion

3.1.Bicycle Path Location Selection Criteria

Bicycle users can be divided into different groups based on various criteria such as purpose of use, experience level, comfort expectations, and behavior patterns in traffic. These classifications play an important role in the development of bicycle transportation policies, infrastructure design, and determining the target audience for awareness campaigns.

The size and characteristics of user groups should be taken into account when developing bicycle strategies and plans. To increase bicycle usage rates, the lines between groups should be lowered to increase the number of users and the proportion of bicycle trips. The literature shows that bicycle users are classified in different ways according to their travel purposes (e.g., commuting to work, school, shopping, recreation), frequency of use (regular users, occasional users), or individual characteristics (age, gender, physical ability, etc.). Defining user groups is important because it is necessary to determine the needs of bicycle users within the city and to plan and design accordingly.

In our country, the criteria set forth in the 2017 Urban Bicycle Paths Guide issued by the Ministry of Environment, Urbanization, and Climate Change are applied. Bicycle paths should be planned with the minimum criteria necessary for cyclists to move around in mind and in a way that does not disrupt vehicle traffic. There are numerous factors that influence whether a bicycle is used or not, as well as the number, route, speed, distance, and frequency of bicycle trips, apart from personal characteristics.

Three basic criteria and 21 sub-criteria have been identified that should be considered in the planning and design of bicycle use, including physical, environmental, and visual/functional criteria. The identified criteria are shown in Table 1.

Table 1. Proposed bicycle path design criteria

Physical Criteria	Environmental Criteria	Visual/Functional Criteria
Bicycle path types	Land use type	Integration with open and green spaces
Road widths	Usage intensity	Landscape and user experience
Slope	Transportation system integration	Lighting
Road Surface Material Quality and Condition	Property status	Visibility distance
	Traffic density	Traffic signs and signage
	Traffic speed	Bicycle parking facilities
	Building density	Noise level
	Building layout	Safety level
	Network continuity	

a. Physical criteria

Bicycle path types; Bicycle transportation is one of the fundamental components of sustainable urban mobility strategies. Effective bicycle path planning depends not only on the existence of infrastructure but also on the quality and condition of this infrastructure, including path types, path width, slope, road surface material quality and condition, visibility distance, lighting, network integrity, traffic signs and directional signage, bicycle parking facilities, noise level, traffic density, usage density, land use type, building layout, building density, property status, traffic speed, and transportation system integration. In this context, the correct determination of road types plays a critical role in the safety, comfort, continuity, and attractiveness of bicycle transportation.

Bicycle paths are generally divided into three main types (AASHTO, 2012; ECF, 2019):

• Segregated Cycle Tracks: These are paths physically separated from motor vehicle traffic and designed exclusively for cyclists.

• Shared Lanes: Local roads where cyclists and motor vehicles share the same lane, typically with low speed limits.

• Bike Lanes: Special bicycle lanes on motor vehicle roads, separated by paint or markings.

This classification directly affects cyclists' perception of safety, speed preferences, and route choices (Parkin, 2018). The choice of road type is decisive for cyclists' safety. Studies show that physically separated bicycle lanes reduce the risk of traffic accidents by 30–50% compared to roads shared with motor vehicles (Pucher & Buehler, 2016). Furthermore, separated lanes provide visual and psychological comfort for cyclists, which increases bicycle use, especially among vulnerable user groups such as women, children, and the elderly. The choice of road type should be consistent with the characteristics of the urban fabric. For example, physically separated bicycle lanes are preferred in high-density city centers, while shared lanes may be more appropriate in low-density residential areas. This approach optimizes land use and ensures cost-effectiveness, in line with urban design principles (Litman, 2020).

Road widths; Road width on bicycle paths is a decisive design criterion in terms of user safety, mutual passage, comfort level, and capacity. Recommended bicycle lane widths in international standards (Table 2) vary depending on the type of use (AASHTO, 2012; CROW, 2017; ECF, 2019);

When planning road width, existing urban area constraints must also be taken into account. Buehler & Pucher (2012) stated that there is a significant relationship between the physical characteristics of roads (length, width, etc.) and the number of users. Furthermore, width directly affects not only safety but also user comfort. Sufficient width facilitates cyclists passing each other, riding side by side, and maintaining a steady speed, which makes bicycle traffic flow smoothly (Parkin, 2018).

Table 2. Width values according to international standards

Road Type	Recommended Minimum Width (m)	Suitable Width (m)	Description
One-way separated bike path	1.50	1.75–2.00	Suitable for low-density, short-distance routes.
Two-way separate bicycle path	2.50	3.00–3.50	It provides mutual passage and safe maneuvering area.
Bicycle lane (on the road)	1.25	1.50–1.80	It is applied on main arteries shared with motor vehicle traffic.
Shared road	—	—	Suitable for local roads where vehicle speed is ≤30 km/h.
Pedestrian-bicycle shared path	3.00	3.50–4.00	Visual or structural separation is recommended to avoid user conflicts.

Slope; Slope on bicycle paths is one of the fundamental physical design variables that determine the comfort, energy requirements, and speed of bicycle transportation (Table 3). Maintaining appropriate slope values encourages bicycle transportation by reducing the physical effort required by users. Excessively steep routes, however, have a deterrent effect, particularly for children, the elderly, and everyday users (AASHTO, 2012; CROW, 2017).

Table 3. Recommended slope values according to international standards

Slope Type	Maximum Slope (%)	Description
Ideal slope	0–2	Provides comfortable riding on flat terrain.
Acceptable slope	3–5	Acceptable for short distances (≤150 m).
Maximum short-term slope	6–8	Applicable only in cases of topographic necessity.
Downward slopes (maximum)	10	Requires safe braking distance and speed control.

The topography's long-distance steep inclines and descents negatively affect the number and length of bicycle trips. The gradient value directly affects the rider's required pedaling power and energy expenditure. According to CROW (2017), a cyclist's comfort level begins to decrease on gradients above 3%; gradients above 5% are acceptable for short climbs but are not sustainable over long distances. Broach et al. (2012) illustrate the slope-distance relationship by citing a 1-mile (1.6 km) route with a gentle slope (2-4%) uphill as an example of a route where cyclists would be willing to pedal.

Road surface material quality and condition; The quality of road surface material used on bicycle paths is a critical factor in terms of riding comfort, safety, maintenance costs, and the longevity of the road. Appropriate material selection determines not only structural durability but also skid resistance, vibration levels, and water drainage performance (CROW, 2017; Parkin, 2018).

The skid resistance of the material used on bicycle paths is particularly important in wet conditions. A longitudinal slope of at least 0.5–1% should be provided to prevent water accumulation on the surface (ECF, 2019). For proper drainage, the bicycle path surface should have a 2% cross slope. If the bicycle path level is above the vehicle road level, it is constructed in the direction of vehicle traffic (TS 7249). Providing cross slope on one side generally facilitates longitudinal drainage design and surface construction. If there are points where channels and grates intersect with the bicycle path for water drainage, they must be placed crosswise for driving safety.

b. Environmental Criteria

Land use type; In bicycle route planning, land use type is one of the key determinants in terms of route selection, user density, safety level, and accessibility. Different land use types (residential, commercial, industrial, educational, recreational, etc.) directly influence cyclists' travel motivations and routes (Pucher & Buehler, 2012).

Therefore, in the bicycle path planning process, not only the physical infrastructure but also the spatial distribution of urban functions must be taken into account. One of the most important factors determining the effectiveness of bicycle paths is the land use type of the surrounding area along the route. Land use type forms the spatial backbone of bicycle path planning. The relationships between different functional areas determine route selection, capacity, and design decisions. Planning bicycle paths to connect residential, commercial, educational, and

recreational areas both increase usage rates and supports sustainable urban mobility. Therefore, land use analysis should be considered a strategic guiding element in bicycle planning.

Usage intensity; Usage intensity on bicycle paths is defined as the number of cyclists passing through a unit width in a unit of time and is usually expressed in the unit of bicycle/hour/meter (b/h/m). Usage intensity is a decisive indicator in terms of bicycle infrastructure capacity planning, comfort level, safety requirements, and maintenance policies (CROW, 2017). Studies show that overcrowding on bicycle lanes reduces user riding comfort, increases stress levels, and encourages a shift to alternative modes of transportation in the long term (Kaparias et al., 2015). The maximum comfortable capacity on bicycle lanes is the density level at which cyclists can comfortably pass each other and maintain a steady speed. Table 4 shows the recommended capacity values based on road width:

Table 4. Relationship between capacity and comfort

Bicycle Facility Types	Average Width (m)	Comfortable Capacity (bicycles/hour)	Peak Capacity (bicycles/hour)
One-way path	1.5 – 2.0	600 – 800	1000 – 1200
Two-way path	2.5 – 3.0	1000 – 1500	2000 – 2500
Shared path	—	< 300	< 500

Transportation system integration; The integration of bicycle lanes into the physical environment should be evaluated not only in terms of user safety and comfort, but also in terms of urban integrity and their relationship with transportation systems. In this context, the Bicycle Lanes Regulation (2019) Article 4(27) states that bicycle lanes may be constructed on pedestrianized streets to allow bicycle use during certain hours. This regulation is an important planning principle that enables the integration of pedestrian and bicycle transportation in city centers. In this regard, one-way roads and pedestrianized streets are considered suitable areas for bicycle lane applications, while two-way roads are highlighted as areas with limited suitability. This classification is based on the impact of factors such as road width and traffic density on bicycle transportation. The integration of bicycle lanes into the transportation system plays a key role in creating flexible and sustainable transportation infrastructure in cities. McBain & Coulfield (2017) stated that in the city of Cork (Ireland), bicycle stations connected to buses or rail systems were used more frequently for transfers. This integration transforms bicycle use into a natural part of daily life while also making urban mobility more efficient, accessible, and environmentally friendly.

Property status; In bicycle path planning, property status is a fundamental planning component that determines the type of property areas (public, private, foundation, or mixed) through which the route passes, directly affecting implementation processes and investment costs (Litman, 2020). Failure to accurately analyze the property structure can lead to significant problems in bicycle network projects, such as fragmented connections, expropriation issues, access restrictions, and implementation delays. Therefore, property status must be addressed in detail in bicycle path planning, along with land use decisions. Furthermore, it is important for the sustainability of the implementation that the corridors allocated for bicycle paths in zoning

plans remain within public property boundaries. Although the Bicycle Paths Regulation (2019) does not contain detailed provisions directly related to property status, it adopts a general planning principle that local governments should take the property structure into account in design and route planning.

Traffic density; Traffic density on bike paths is a key performance indicator representing the number of bicycles passing through a section in a given time period and is typically measured in units of bicycles per hour. Accurately determining traffic density is critical for both assessing infrastructure capacity and improving user safety and comfort. Approaching capacity on bike paths during peak hours can lead to negative consequences, such as reduced speeds, reduced following distances, increased collision risk, and increased user stress levels. Therefore, density management is closely linked to urban design components such as the width of separated bike paths, intersection designs, signaling arrangements, and alternative route planning.

Traffic speed; The speed of bicycle transportation varies depending on numerous factors, including the type and technical adequacy of the bicycle used, the purpose of the journey, the physical and geometric condition of the bicycle path, its topography, slope, regional wind conditions, traffic density, and the physical condition of the rider. As traffic speed increases, the risk of accidents and the severity of collisions rise exponentially.

Research shows that speeds of 30 km/h and below are a safe threshold for cyclists (OECD, 2020).

≤ 30 km/h: Safe speed, suitable for mixed-use areas.

30–50 km/h: Separated bicycle lanes are recommended.

> 50 km/h: Physical barriers are mandatory.

Therefore, instead of a fixed speed limit, design speeds that can vary according to different conditions should be considered. The maximum cruising speed generally preferred by bicycle users should be taken as the basis for determining the design speed. However, in areas where the longitudinal gradient exceeds 4% or where strong prevailing winds are effective, a design speed of 50 km/h is recommended. This recommendation is particularly important in terms of controlling bicycle traffic and speed increases on downhill sections.

Building density, directly affects physical space usage, traffic load, microclimate, and user safety in bicycle path planning (Litman, 2020). At the urban planning scale, building density determines the prioritization of bicycle paths and investment strategies. This strategic approach increases both infrastructure efficiency and sustainable transportation rates. In urban areas with high building density, especially in central areas, the intensity of motor vehicle traffic poses a threat to bicycle transportation; at the same time, it becomes difficult to allocate sufficient physical space for bicycle lanes. However, medium-density residential areas offer more favorable physical conditions for bicycle lanes, providing advantages in terms of both road safety and user accessibility (Pucher et al., 2010). Therefore, bicycle lanes should have width and design standards that are compatible with the surrounding building density.

Building layout; A concept that defines the arrangement of buildings, facade layout, building approach distances, and height relationships. This element, which determines the physical character of the urban space, has a direct impact on the spatial continuity, safety, and user experience of bicycle paths (Gehl, 2010). Building layout (detached, attached, block, etc.) plays a decisive role in planning bicycle lane routes and crossing areas. Taking these physical

differences into account, decisions must be made during the planning process regarding the layout of bicycle lanes and how they will be constructed with protection or lane separation.

Since bicycle lanes generally extend along urban street corridors, the surrounding building layout shapes both the physical environment quality and psychological perception. The distance and layout of buildings relative to bicycle lanes also affect the field of view and sense of safety. The Bicycle Paths Regulation (2019) emphasizes that physical barriers and environmental development conditions must be taken into account in route planning; however, it does not provide a specific classification regarding building layout.

Network continuity; refers to the level at which bicycle paths form a seamless, safe, and connected system. An effective bicycle transportation system is based on the principles of continuity, connectivity, and integration not only in specific corridors but throughout the city (ECF, 2019; Pucher & Buehler, 2016). A bicycle network is a consistent route system that provides users with seamless transportation between home, work, education, commerce, and recreation areas, supported by safe crossing points. In cities with weak network continuity, bicycle paths remain fragmented, and users avoid these areas. Research shows that bicycle usage rates increase by up to 30% in cities with high network integrity (Hull & O'Holleran, 2014).

c. Visual/Functional Criteria

Integration with open and green spaces; The integration of bicycle paths with open and green spaces ensures that sustainable transportation systems become not only a means of transportation but also an ecological and recreational connecting element. This integration supports the holistic structure of the city's green infrastructure system, producing both environmental and social benefits (Beatley, 2011; ECF, 2019). This reduces the carbon footprint and mitigates the urban heat island effect (Jim & Chen, 2009). Furthermore, it positively impacts physical and psychological health by increasing users' interaction with nature.

Landscape and user experience; Bicycle paths are also experiential spaces that enable users to interact with the natural and urban environment. In this context, “landscape and user experience” is a fundamental design component that determines the spatial quality, visual continuity, and psychological comfort of bicycle paths. Cyclists' perception of their surroundings is shaped by changing perspectives while in motion. Therefore, the quality of the scenery along bicycle routes is not only an aesthetic element but also important in terms of orientation and spatial memory (Appleyard, 2013).

Lighting; Lighting on bicycle paths is a factor that directly affects user safety, visual comfort, and encourages nighttime use. Inadequate lighting limits visibility for both cyclists and pedestrians, increasing the risk of accidents. Therefore, the appropriate lighting level for bicycle paths should be planned within the framework of traffic safety, perceptual comfort, and urban safety principles (CROW, 2017; ECF, 2019).

Visibility distance; is the minimum field of vision required for cyclists to maneuver safely, detect sudden obstacles, and stop. On bicycle paths, factors such as slope, curve radius, environmental obstacles, and landscaping directly affect sight distance. Insufficient sight distance increases the risk of collisions both between cyclists and in cyclist-vehicle interactions (AASHTO, 2012).

Traffic signs and signage; Traffic signs and signage systems on bicycle paths are a fundamental component for enabling users to move safely, comfortably, and consciously. These elements provide cyclists with right-of-way, route information, hazard warnings, and guidance support. An effective signage system not only enhances safety but also strengthens the perceived integrity of the bicycle network (CROW, 2017; AASHTO, 2012). Today, smart guidance systems are being integrated into bicycle infrastructure alongside traditional signs.

Bicycle parking facilities; Bicycle parking facilities are an integral part of the bicycle transportation system. Planning areas where cyclists can safely and conveniently leave their bicycles at their destinations directly increases bicycle usage rates (Pucher & Buehler, 2012). The Bicycle Paths Regulation (2019) in force in Türkiye also supports these requirements. According to the provisions of Article 4(4) and Article 17(3) of the Regulation, bicycle parking areas must be connected to bicycle paths. These regulations reflect the structural planning principles aimed at encouraging the adoption of bicycles as a daily means of transportation. In recent years, bicycle parking systems have gained importance in terms of efficient space utilization and security optimization by being integrated with smart technologies.

Noise level; Noise level on bicycle paths is a design parameter that directly affects both user comfort and environmental sustainability. Noise is not only a physical nuisance; it is also an important environmental factor that determines cyclists' perceived safety, psychological comfort, and riding satisfaction levels (Basner et al., 2014). When planning urban bicycle networks, factors such as traffic density, motor vehicle speed, road surface material quality, and environmental sound reflections should be considered for their impact on noise during route selection. Quiet, comfortable, and safe bicycle paths are among the most important components that strengthen cities' sustainable transportation vision.

Safety level; Traffic speed is one of the most critical parameters determining the safety level of bicycle lanes, user comfort, and route preferences. In the planning and design of bicycle lanes, specific speed criteria must be adhered to, based on user safety, comfort, and transportation efficiency. The legal basis for the minimum speed limit to be applied on bicycle lanes is set out in the “Bicycle Lanes Regulation” (Official Gazette, November 3, 2020, Number: 31293), which specifies a minimum design speed of 15 km/h and a maximum design speed of 30 km/h. These speed limits have been established to ensure that bicycle users can travel in a safe, comfortable, and continuous transportation environment. The regulation also requires that speed limits be reassessed and necessary safety measures taken when the road gradient exceeds 4% (ÇŞB, 2020).

Within the scope of the study, a route recommendation for bicycle paths was made using an analysis tool based on the results obtained by ranking the criteria sets according to their importance (Table 5).

Table 5. Order of importance of criteria

Criteria number	Basic criteria	Sub-criteria	Criterion weighted score	Criteria importance order
1	**Physical Criteria**	Bicycle path types	5,51	5
2		Road widths	5,37	9
3		Slope	6,12	2
4		Road Surface Material Quality and Condition	5,61	4
5	**Environmental Criteria**	Land use type	4,96	15
6		Usage intensity	4,83	17
7		Transportation system integration	5,33	10
8		Property status	5,09	13
9		Traffic density	4,61	19
10		Traffic speed	5,46	7
11		Building density	5,06	14
12		Building layout	5,45	8
13		Network continuity	5,75	3
14	**Visual/Functional Criteria**	Integration with open and green spaces	5,26	11
15		Landscape and user experience	5,16	12
16		Lighting	4,93	16
17		Visibility distance	5,49	6
18		Traffic signs and signage	6,30	1
19		Bicycle parking facilities	4,73	18
20		Noise level	4,16	20
21		Safety level	4,15	21

4.Conclusion and Recommendations

In recent years, there has been a need for modern and innovative approaches based on planning to solve the most important transportation problem in cities. Cities with bicycle transportation networks are healthier and more livable.

The first regulation on bicycle lanes in Türkiye was issued in 2015 and updated in 2019. Another development regarding bicycle lanes in Türkiye is the requirement for bicycle lanes to be included in the zoning plans of newly developed areas. The requirement for bicycle lanes in zoning plans is only valid for newly developed areas and has been in effect since June 2019. This requirement does not apply to existing built-up areas or areas without zoning plans. This situation prevents the continuity of bicycle use and discourages the choice of bicycles as a means of transportation (ÇŞB, 2015; ÇŞB, 2019). As individuals' incomes increase, it is crucial to raise public awareness by highlighting the positive effects of bicycle use on human health, the environment, and family budgets as an alternative to the preference for automobiles for transportation.

In terms of Türkiye's sustainable tourism potential, promoting bicycle transportation between destinations and integrating it with other types of tourism is of great importance. Organizing bicycle routes in such a way that they integrate not only within cities but also with tourist areas in the surrounding rural and natural areas is one of the top priorities. Cycling tourism, especially in tourist destinations, requires well-equipped infrastructure (safety, technological maps, well-defined signs and markings) and superstructure (shops selling first aid supplies, accommodation and food and beverage facilities, etc.). To provide the infrastructure and superstructure required for bicycle tourism in urban and rural/natural areas, relevant stakeholders must act in unison within the scope of national and local government tourism and transportation policies.

As a result, the approach of conducting evaluations based on local criteria sets in determining the bicycle route, bringing together different stakeholders in this process, and using an analysis tool highlights the original aspect of the study. The parallelism between the criteria and the recommendations in the final outcome and the fact that the recommendations are based on cause-and-effect relationships within the criteria sets are also important issues. From this perspective, unlike the observation-based bicycle path selection studies found in the literature, the study must demonstrate a comprehensive and scientific approach.

On the other hand, it is anticipated that the approach presented can be replicated across different regions and sample groups using different sets of criteria, thereby contributing to the selection and implementation of sustainable bicycle routes. Since this process can be shaped according to the dynamics specific to each region, it is anticipated that this approach will also provide flexible spatial planning and design opportunities.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

AASHTO. (2012). *Guide for the Development of Bicycle Facilities* (4th ed.). American Association of State Highway and Transportation Officials.

Ankaya, F.Ü. & Aslan, B. G. (2020). Kent içi ulaşımda bisiklet yollarının planlaması; Dünya ve Türkiye örnekleri. *Ulusal Çevre Bilimleri Araştırma Dergisi,* 3(1), 1-10.

Appleyard, D. (2013). Livable Streets Revisited. *Journal of the American Planning Association,* 79(1), 9–20.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet, 383*(9925), 1325-1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Beatley, T. (2011). *Biophilic Cities: Integrating Nature into Urban Design and Planning.* Island Press.

Bisiklet Yolları Yönetmeliği. (2019). Çevre ve Şehircilik Bakanlığı'ndan Resmi Gazete Sayı: 30976, Access date: December 12 2019. https://www.resmigazete.gov.tr/eskiler/2019/12/20191212-1.htm

Black, W.R. (1996). Sustainable transportation: A US perspective. *Journal of Transport Geography*, 4(3), 151–159.

Blondiau, T. & Zeebroeck, B. (2014). Cycling works - Jobs and Job Creation in the Cycling Economy. Brussels.

Broach, J., Dill, J. & Gliebe, J. (2012). Where do cyclists ride? A route choice model developed with revealed preference GPS data. *Transportation Research Part A: Policy and Practice*, 46(10), 1730-1740.

Buehler, R. & Pucher, J. (2012). Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. *Transportation*, 39, 409-432.

Crawford, J.H. (2002). *Carfree Cities*. International Books.

CROW. (2017). *Design Manual for Bicycle Traffic*. CROW Fietsberaad, Ede, Netherlands.

ECF (2019). *Cycling Infrastructure Quality Criteria.* European Cyclists' Federation.

EESC. (2019). European Cycling Lexicon. ISBN: 978-92-830-4499-4

European Cyclists' Federation (ECF). (2019). *Cycling Infrastructure: Design Manual for Urban and Suburban Areas*. Brussels: ECF Publications.

Gehl, J. (2010). *Cities for People.* Island Press, Washington, D.*C.*

Hull, A., & O'Holleran, C. (2014). Bicycle Infrastructure: Can Good Design Encourage Cycling? *Urban, Planning and Transport Research*, 2(1), 369–406.

Innovation Norway. (2016). Cycling tourism. Oslo.

Innovation Norway, & NCE Tourism Fjord Norway. (1998). Cycling tourism. Retrieved from http:// books.google.com/books?id=3UksAQAAMAAJ

Jim, C.Y., & Chen, W.Y. (2009). Ecosystem services and valuation of urban forests in China. *Cities*, 26(4), 187–194.

Kaparias, I., Bell, M. G. H., Miri, A., Chan, C., & Mount, B. (2015). Analysing the perceptions of pedestrians and drivers to shared space. *Transportation Research Part F: Traffic Psychology and Behaviour, 30*, 115–127. https://doi.org/10.1016/j.trf.2015.02.002

Küster, F., & Blondel, B. (2013**).** *Cycling safety and speed management in urban environments.* European Cyclists' Federation Report, Brussels.

Litman, T. (2020). *Evaluating Active Transport Benefits and Costs: Guide to Valuing Walking and Cycling Improvements and Encouragement Programs*. Victoria Transport Policy Institute.

McBain, L., & Caulfield, B. (2017). Cycling trends and transport policy in Dublin. *Case Studies on Transport Policy, 5*(4), 633–642. https://doi.org/10.1016/j.cstp.2017.07.008

Mert, A., & Öcalır, E.V. (2010). Sürdürülebilir ulaşım kapsamında bisiklet ulaşımının planlanması. *İTÜ Dergisi/a: Mimarlık, Planlama, Tasarım*, 9(2), 45–58.

OECD/ITF (2020). *Speed and Crash Risk.* International Transport Forum, Paris.

Parkin, J. (Ed.). (2018). Designing for Cycle Traffic*: International Principles and Practice*. ICE Publishing.

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine*, 50, 106–S125.

Pucher, J., & Buehler, R. (2012). *City cycling*. MIT Press.

Pucher, J., & Buehler, R. (2016). Safer cycling through improved infrastructure. *American Journal of Public Health, 106*(12), 2089–2091. https://doi.org/10.2105/AJPH.2016.303507

Ritchie, Brent. W, Tkaczynski, A., & Faulks, P. (2010). Understanding the motivation and travel behavior of cycle tourists using involvement profiles. *Journal of Travel and Tourism Marketing*, 27(4), 409–425. https://doi.org/10.1080/10548408.2010.481582

Sheng, Y. (2015). Understanding the motivations of bicycle tourists in New Zealand: The case of the Haurakı Rail Trail (Auckland University of Technology in). Retrieved from http://aut.researchgateway.ac.nz/ bitstream/handle/10292/9956/ShengY.pdf?sequence=3

Transport and Tourism, (2012). The European cycle route network Eurovelo. Retrieved From http:// www.Europarl.Europa.Eu/Studies Disclaımer.

Türkay, O., & Atasoy, B. (2021). Sürdürülebilir turizmin bir aracı olarak bisiklet turizmi: Avrupa Birliği (AB) örneği. *Turizm ve İşletme Bilimleri Dergisi,* 1(1), 50-69.

Ünüyar, O., Kaya, M., & Sezgin, M. (2017). Bicycle tourism in Konya tourism perspective and A Study on its effect on marketing Konya tourism as a destination by using PEST Analysis. *Selçuk Üniversitesi Sosyal Bilimler Meslek Yüksekokulu Dergisi*, 20(2), 175–182.

World Health Organization (WHO). (2004). *Health and environment in sustainable development: Five years after the Earth Summit*. WHO Press.

Yılmaz, C. (2015). Kent içi bisiklet ulaşımının planlanması ve tasarımı üzerine bir değerlendirme. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 21(8), 320–330.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Effects of Material on Spatial Atmosphere in Architectural Design Approaches Adopting a Minimalist Attitude

İremnur MUSLU [1*]

ORCID 1: 0000-0002-3098-0762
[1] Mimar Sinan Fine Arts University, Institute of Science, Department of Architecture, Building Physics and Materials Program, Istanbul-Türkiye
20222101021@ogr.msgsu.edu.tr (Responsible Author)

Ümit ARPACIOĞLU [2]

ORCID 2: 0000-0001-8858-7499
[2] Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, Istanbul-Türkiye
umit.arpacioglu@msgsu.edu.tr

Abstract

This study examines the spatial effects of material in architectural design approaches adopting a minimalist attitude through a comparative analysis based on user perception. In minimalist architectural approaches, material is regarded not merely as a technical or structural element but as a determinant of spatial atmosphere, a shaper of sensory experience, and a carrier of conceptual simplicity. Within the scope of the research, eight architectural examples constructed between 1950 and 2000 were analyzed: Chapel of Notre Dame du Haut, Ronchamp (Le Corbusier, 1954); Taliesin West (Frank Lloyd Wright, 1959); Indian Institute of Management Building (Louis Kahn, 1974); Thorncrown Chapel (E. Fay Jones, 1980); Koshino House (Tadao Ando, 1984); Vitra Fire Station (Zaha Hadid, 1993); Church of Light and Sunday School (Tadao Ando, 1999); De Blas House (Alberto Campo Baeza, 2000). The findings were systematically evaluated through comparative tables. To strengthen the reliability of the study, a survey was conducted with a group of 50 architects. The survey consisted of 17 questions structured into four sections: spatial atmosphere perception, material authenticity, sensory perception, and minimalist attitude perception. The responses revealed the effects of material on spatial unity, simplicity, authenticity, sensory qualities, and the capacity to reflect minimalist principles. The findings demonstrate that in minimalist architecture, material is not solely an aesthetic element but a fundamental component shaping atmosphere, user experience, and conceptual integrity. Accordingly, the study concludes that considering user perception in material selection can provide significant contributions to the discipline of architecture.

Keywords: Minimalism, architecture, material, spatial atmosphere, user perception, material authenticity

1.Introduction

In recent years, minimalist approaches that have gained prominence in architectural theory and practice have brought forward a profound design understanding constructed through the use of materials, extending beyond mere formal simplicity of space. Within this approach, building materials are not considered solely as structural or cladding elements; rather, they are regarded as fundamental components that actively contribute to the formation of spatial atmosphere, guide user perception, and add a conceptual layer to architectural design (Cheng, 2006).

In minimalist architecture, material selection, together with principles such as simplicity, clarity, and the elimination of superfluous elements, becomes one of the primary factors shaping the sensory qualities of space. In this context, the texture, color, interaction with light, and the explicit expression of the inherent properties of materials play a decisive role in the formation of spatial experience (Islakoğlu, 2006). However, existing literature reveals a limited number of studies that address these multi-layered effects of material use in minimalist architecture through measurable and comparable systematic frameworks (Ramussen, 2021).

The aim of this paper is to evaluate the effects of building materials on spatial atmosphere and user perception through selected architectural examples that adopt a minimalist design approach. Within the scope of the study, the relationship between material, space, and user is examined through the lenses of spatial atmosphere perception, material honesty, sensory perception, and minimalist design attitude, thereby offering a holistic evaluation framework.

Accordingly, this paper focuses on two main objectives:

1. to analytically reveal how materials shape spatial experience in selected minimalist architectural examples, and
2. to propose an applicable evaluation approach for designers by addressing the meaning of material in the architectural design process from both theoretical and experiential perspectives.

2.Materials and Methods

This study was conducted within the framework of qualitative research methods and aims to investigate the role of building materials in shaping spatial atmosphere in minimalist architectural design. Rather than addressing materials solely through their technical or structural properties, the research adopts a perception-oriented approach, focusing on their experiential, sensory, and conceptual impacts within architectural space.

2.1. Research Design

The research was structured in three main stages:

1. Selection and analysis of architectural case studies,
2. Development of an analytical evaluation framework,
3. Validation of the proposed framework through a questionnaire survey applied to professional architects.

This multi-layered methodological structure enabled both qualitative interpretation and comparative evaluation of material-related spatial effects.

2.2. Selection of Case Studies

The material scope of the study consists of eight architectural works that explicitly reflect a minimalist design attitude. The selected buildings were constructed between 1954 and 2000 and represent different decades of modernist and postmodern architectural production. The temporal distribution of the cases allows for observing variations in material use and spatial expression across distinct periods while maintaining a consistent minimalist approach.

The selected case studies are as follows:

- Chapel of Notre Dame du Haut, Ronchamp – Le Corbusier (1954)
- Taliesin West – Frank Lloyd Wright (1959)
- Indian Institute of Management – Louis Kahn (1974)
- Thorncrown Chapel – E. Fay Jones (1980)
- Koshino House – Tadao Ando (1984)
- Vitra Fire Station – Zaha Hadid (1993)

- Church of Light and Sunday School – Tadao Ando (1999)
- De Blas House – Alberto Campo Baeza (2000)

These buildings were selected based on their clear material expression, architectural significance, and their contribution to minimalist spatial discourse.

2.3. Analytical Framework

In order to systematically evaluate the relationship between building materials and spatial atmosphere, an original analytical framework was developed. The framework is structured around four main evaluation categories:

- Spatial Atmosphere Perception
- Material Honesty Perception
- Sensory Perception
- Minimalist Design Attitude

Each case study was qualitatively examined through these categories, focusing on how material properties such as texture, surface continuity, light interaction, and structural expression contribute to spatial experience and atmospheric quality.

2.4. Questionnaire Survey and Data Analysis

To test and support the findings derived from the case study analyses, a questionnaire survey was conducted with 36 architects. The survey consists of 17 statements organized under the same four evaluation categories defined in the analytical framework. Responses were collected using a Likert-scale format, enabling the quantification of professional perceptions regarding the role of materials in minimalist architecture. The collected data were analyzed comparatively to identify patterns, similarities, and differences among the case studies. This process allowed the qualitative observations obtained from architectural analysis to be supported by quantitative data derived from user and expert perception.

2.5. Methodological Contribution

By combining qualitative architectural analysis with perception-based survey data, the study proposes a transferable and applicable evaluation model for assessing material-driven spatial atmosphere in minimalist architecture (Deniz, 2016). The methodology not only enables the measurement of otherwise abstract concepts such as atmosphere and material honesty, but also provides a structured assessment tool that can be utilized in future architectural research and design practice.

3. Findings and Discussion

The findings of this study demonstrate that, in architectural designs adopting a minimalist attitude, building materials function not merely as structural necessities but as primary agents that shape spatial atmosphere, construct architectural meaning, and guide user perception. Although the eight selected case study buildingsRonchamp Chapel, Taliesin West, Indian Institute of Management, Thorncrown Chapel, Koshino House, Vitra Fire Station, Church of Light, and De Blas House belong to different periods, geographies, and tectonic traditions, the analysis reveals a set of shared perceptual patterns through which minimalist atmosphere is consistently produced and interpreted by users.

The evaluation framework of the study is based on four main criteria derived from an extensive literature review and qualitative analysis of the case studies: Spatial Atmosphere Perception, Material Honesty Perception, Sensory Perception, and Minimalist Attitude Perception. A total of 17 statements corresponding to these criteria were developed and assessed by 36 professional architects using a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). This approach enabled the transformation of subjective spatial experiences into systematic, comparable, and measurable data, allowing minimalist architectural effects to be evaluated quantitatively rather than solely through interpretive discourse.

3.1. Spatial Atmosphere Perception

Findings related to spatial atmosphere perception indicate that most case study buildings successfully generate a calm, legible, and low-stimulus environment, while simultaneously providing a sense of openness and spatial coherence. These results suggest that minimalist atmosphere does not emerge solely from formal reduction or geometric simplicity, but rather from the interaction between material presence, light, texture, and spatial continuity.

In Ronchamp Chapel, the sculptural use of exposed concrete establishes a strong relationship between materiality and spiritual atmosphere (Deniz, 2016). The whitewashed concrete walls, combined with carefully controlled natural light, create a perceptual depth that transcends structural function. Similarly, Taliesin West demonstrates how spatial atmosphere is strengthened through the direct use of locally sourced stone, whose rough texture and layered arrangement reinforce the building's integration with the surrounding landscape. In De Blas House, the contrast between the heavy stereotomic concrete base and the lightweight tectonic upper structure generates a dual atmospheric reading simultaneously introverted and expansive thereby enriching spatial perception through material opposition.



Figure 1. Ronchamp by Le Courbusier (URL5)

These findings confirm that spatial atmosphere in minimalist architecture is not a byproduct of visual economy alone, but a result of material-driven spatial articulation that engages users at both perceptual and experiential levels.

3.2. Material Honesty Perception

Material honesty constitutes the conceptual core of this research. The findings clearly indicate that buildings in which materials are used without concealment, imitation, or surface masking are perceived as more authentic, coherent, and convincingly minimalist by users. Material honesty emerges as a measurable determinant in the perception of minimalist architectural identity. At the Indian Institute of Management, brick is not employed as a superficial finish

but as a structural and conceptual generator of architectural form. Kahn's approach often summarized by his metaphor of "asking the brick what it wants to be" positions material as an active participant in design rather than a passive construction element (Deniz, 2016). Likewise, in Koshino House and Church of Light, Tadao Ando's exposed concrete surfaces retain formwork traces and construction joints, allowing the production process itself to become part of the architectural expression.



Figure 2. Indian Institute of Mana Gemenet Building by Louis Kahn, 1974 (URL3)

Taliesin West exemplifies material honesty through the untreated surfaces of stone, wood, and plaster, while Thorncrown Chapel achieves transparency and tectonic clarity by exposing timber and glass in their natural states. In De Blas House, the monolithic concrete mass functions as an extension of the ground, reinforcing the perception of material as both spatial and conceptual substance (Öncan, 2023). Although Vitra Fire Station also employs exposed concrete, its dramatic and dynamic formal language differentiates it from the contemplative minimalism observed in other examples, highlighting that material honesty alone does not automatically result in a calm minimalist atmosphere. Overall, these findings confirm that material honesty is a critical, perceivable parameter through which users assess the authenticity and minimalist quality of architectural space.



Figure 3. Taliesin West by Frank Lloyd Wright, 1959 (URL2)

3.3. Sensory Perception

The sensory perception findings reveal that tactile qualities, surface textures, and thermal associations of materials significantly influence users' spatial experience. In many cases, high material honesty corresponds with heightened sensory awareness; however, sensory intensity

varies depending on scale, accessibility, light conditions, and material continuity (Şimşek, 2011).

Thorncrown Chapel exhibits the strongest sensory engagement, where timber surfaces, transparency, and constantly changing daylight conditions foster a direct bodily relationship between the user and the environment. In Ronchamp and Church of Light, sensory perception is shaped through the contrast between the cold, massive character of concrete and the immaterial presence of light, transforming physical materiality into an abstract spatial experience (Bektaş, 2024).



Figure 4. Church of Light and Sunday Scool by Tadao,1999 (URL1)

In De Blas House, the contrast between the heavy, enclosed concrete base and the luminous interior surfaces produces a tactile and atmospheric duality that enhances user perception. These results support the hypothesis that sensory perception is not solely dependent on material selection, but on the way material properties are spatially articulated and perceptually accessible (Şimşek, 2011).



Figure 5. De Blas House by Alberto Campo Baeza, 2000 (URL4)

3.4. Minimalist Attitude Perception

Minimalist attitude perception defined through the absence of unnecessary ornamentation, clarity of spatial organization, and the dominance of material as a primary design element received consistently high evaluations across all case studies. This outcome confirms that the selected examples successfully represent minimalist architectural principles.

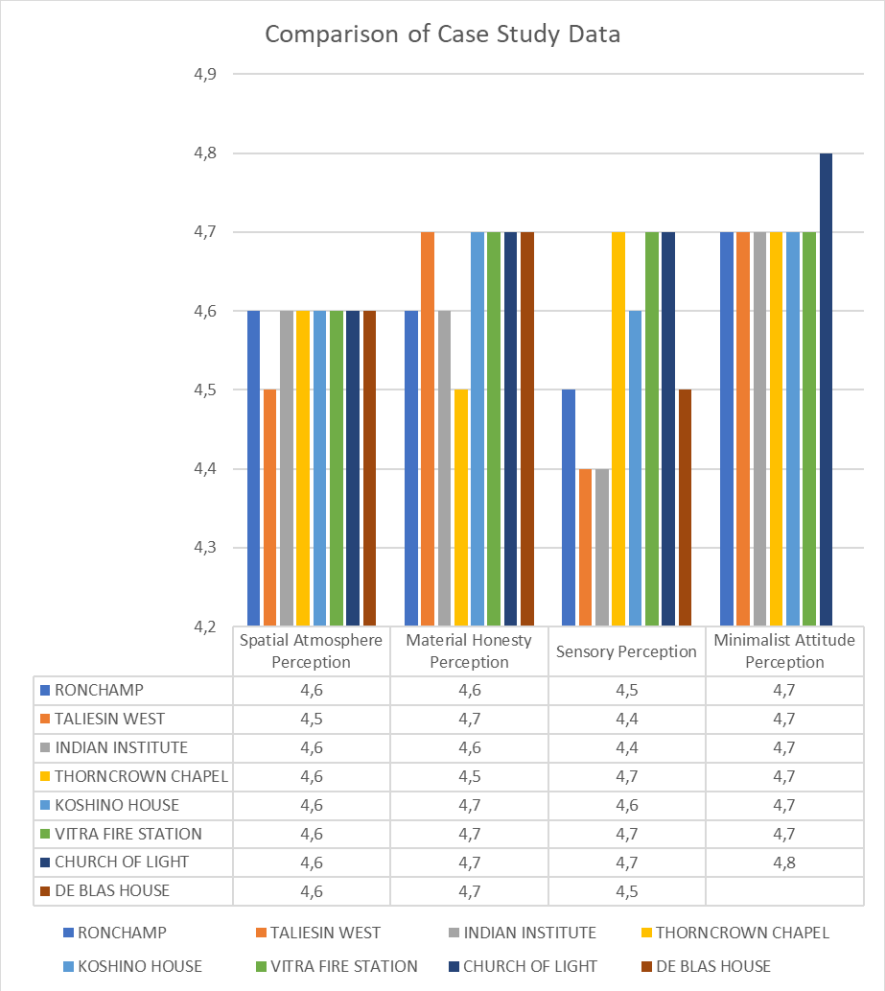
Church of Light and De Blas House achieved the highest minimalist attitude scores, indicating that users strongly associate minimalism with conceptual clarity, material restraint, and expressive reduction rather than with stylistic uniformity. The results demonstrate that minimalist architecture is perceived not as a singular visual language, but as a holistic experiential condition formed through the integration of material honesty, sensory engagement, and spatial atmosphere (Özçam, 2022).

3.5. Discussion Based on the Comparative Analysis

The comparative analysis table reveals a consistent pattern across the evaluated buildings: while spatial atmosphere perception remains relatively balanced across cases, material honesty and minimalist attitude perception emerge as the most influential variables in shaping users' overall evaluation of minimalist architecture. Despite variations in material type concrete, brick, timber, glass, or steel the findings indicate that minimalist atmosphere is reinforced when materials are used in direct relation to their intrinsic properties and contextual conditions, rather than through decorative or representational strategies. The case studies demonstrate that minimalist architecture can accommodate different emotional registers, ranging from contemplative calmness (Church of Light, De Blas House) to sensory immersion (Thorncrown Chapel) and dynamic tension (Vitra Fire Station).

These results support the main hypothesis of the study: in minimalist architecture, building materials operate as measurable agents that shape spatial atmosphere through their inherent physical, sensory, and conceptual qualities. The integration of qualitative architectural analysis with quantitative user-based data confirms the applicability of the proposed evaluation model for both academic research and architectural design practice.

Table 1. Comparison of the Table and Graphical Representation of Interaction Scores Across All Case Studies by Categories



	Spatial Atmosphere Perception	Material Honesty Perception	Sensory Perception	Minimalist Attitude Perception
RONCHAMP	4,6	4,6	4,5	4,7
TALIESIN WEST	4,5	4,7	4,4	4,7
INDIAN INSTITUTE	4,6	4,6	4,4	4,7
THORNCROWN CHAPEL	4,6	4,5	4,7	4,7
KOSHINO HOUSE	4,6	4,7	4,6	4,7
VITRA FIRE STATION	4,6	4,7	4,7	4,7
CHURCH OF LIGHT	4,6	4,7	4,7	4,8
DE BLAS HOUSE	4,6	4,7	4,5	

4. Conclusion and Recommendations

This study demonstrates that, within the framework of minimalist architecture, building materials cannot be reduced to purely technical or structural components, but function as determinative and measurable agents in the formation of spatial atmosphere. While minimalist architecture has frequently been discussed in the literature through the lens of formal reduction and visual simplicity, systematic investigations that examine the relationship between materiality and spatial experience through an analytical evaluation model remain limited. In this respect, the present study contributes to the field by proposing an original framework that enables the assessment of material use in minimalist architecture through the dimensions of spatial atmosphere perception, material honesty perception, sensory perception, and minimalist attitude perception.

Through the evaluation model developed in this research, selected architectural examples from different periods and employing diverse material palettes were analyzed based on expert assessments. The resulting data were translated into weighted interaction scores, allowing the relationship between material choice and spatial experience to be examined not only qualitatively, but also within a measurable and comparable analytical structure. This approach offers a methodological contribution by bridging subjective architectural experience with structured evaluation criteria.

The findings reveal that material selection plays a central role in shaping spatial experience in minimalist architecture. Moreover, the results indicate that a minimalist atmosphere is not dependent on a specific material type; rather, it emerges when materials are used in accordance with their intrinsic physical, sensory, and contextual properties. In this sense, material honesty appears as a key parameter through which minimalist identity is perceived and evaluated, reinforcing the idea that minimalism is produced through material authenticity rather than formal abstraction alone.

Overall, the findings confirm the main hypothesis of the study, which argues that materials in minimalist architecture actively determine spatial experience and can be systematically examined at a measurable level. The subsidiary hypotheses that minimalist attitude is generated not solely through formal simplicity but through the inherent qualities of materials, and that material honesty constitutes one of the fundamental criteria of minimalist design are also supported by the results.

The evaluation model proposed in this study is not limited to the analyzed cases; it offers a transferable framework that may be applied to different building typologies and architectural movements. In this regard, the study can be considered a prototype for analytically examining the material–space relationship, contributing to both architectural research and design practice by providing a structured tool for assessing the experiential impact of material use.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Cheng, F. (2006). *Boşluk ve Doluluk.* İmge Kitapevi.

Deniz, B. (2016). *The Significance of Materials Within the Context of Architectural Design.* Yüksek Lisans Tezi. Middle East Technical University.

Ertürk, M. (2011). *Minimalizmin Doğuşu ve Mimaride Biçim Açısından Minimalizm Değerlendirilmesi.* Yüksek Lisans Tezi. İTÜ.

Irmak, C. (2002). *Mimarlıkta Yalınlık ve Minimalist Tavır. Yüksek Lisans Tezi. İTÜ.*

Islakoğlu, P. M. (2006). *Minimalizm Kavramı ve Mimarlıkta Minimalist Yaklaşımlar.* Yüksek Lisans Tezi. İzmir: Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü.

Kültür, M. (2002). *Minimalizm Akımının Ortaya Çıkışı ve Tüketim Kavramı Bağlamında İncelenmesi.* Yüksek Lisans Tezi. Fatih Sultan Mehmet Vakıf Üniversitesi.

Öncan, M. (2023). *Mimarlıkta Dürüstlük Kavramının Yapı Malzemesi Üzerinden İncelenmesi ve Dürüstlüğün Manipülasyonu.* Yüksek Lisans Tezi. Konya Teknik Üniversitesi.

Özçam, I. (2002). Fenomenolojik yaklaşımın mimaride tasarımcı kimliği ve malzeme kullanımı üzerinden okunması. *Mimarlık ve Yaşam Dergisi.*

Ramussen, S. (2021). *Yaşanan Mimari.* Remzi Kitapevi.

Şimşek, A. (2011). *Tectonic Expression of Concrete as an Architectural Material.* Yüksek Lisans Tezi. Middle East Technical University.

Taşdelen, G. (2024). *Az ve Öz Arasında Melez Bir Yaklaşım: Minimalizm ve Grafik Tasarım.* Yüksek Lisans Tezi. Kütahya Dumlupınar Üniversitesi.

URL1: https://www.archdaily.com/101260/ad-classics-church-of-the-light-tadao-ando. (2025).

URL2: https://www.archdaily.com/123117/ad-classics-taliesin-west-frank-lloyd-wright. (2025).

URL3: https://www.archdaily.com/83697/ad-classics-indian-institute-of-management-louis-kahn. (2025).

URL4: https://www.archdaily.com/office/alberto-campo-baeza. (2025).

URL5: https://www.arkitektuel.com/ronchamp/. (2025).

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Principles and Guidelines for Planning Restoration in Forest Fire-Affected Areas

Ufuk COŞGUN[1]

ORCID 1: 0000-0003-4738-6636
[1] Prof. Dr. Karabük University Faculty of Forestry Department of Forest Engineering, Karabük-Türkiye
ufukcosgun@karabuk.edu.tr,

Sohaib K. M. ABUJAYYAB[2]

ORCID 1:0000-0002-6692-3567
[2]Assoc. Prof. Dr., Karabük University Faculty of Humanities and Social Sciences Department of Geography, Karabük-Türkiye
sjayyab@karabuk.edu.tr,

Abstract

Forest fires in our country are becoming increasingly frequent and difficult to combat. Climate change has a significant impact on this trend. An increase in the number of extremely hot and dry days and above-average wind speeds can cause a fire that has just started to spread very quickly, turning into large or even mega forest fires. This process is clearly evident when looking at forest fires in previous periods. For example, between 1987 and 1996, the annual number of forest fires was 1,881, and the area burned was 12,446 ha. For the period 2015-2024, the same figures are 2,733 and 25,762 ha, respectively. While the fire that burned approximately 10,000 hectares in Marmaris in 1997 is considered the largest fire in the history of the Republic, the Serik-Taşağıl fire in 2008, which burned 15,000 hectares of forest, took first place. On the other hand, 2021 has overturned all statistics. During this period, approximately 60,000 ha burned within the Manavgat Forest Management Directorate alone, and 145,000 ha of forest area burned nationwide, and the fires of this period have been called "Mega Forest Fires."

The first step in restoration work to be carried out in large burned forest areas is planning the area. The first step in planning is to decide which production-marketing and silvicultural regimes should be applied in which areas. This requires examining the entire area. However, just driving around the terrain to see the mega forest fire areas takes a week or two. The forest fires of 2025 have revealed a different dimension in terms of their nature. As of September, the number of fires exceeds 4,000. The amount of burned area has not yet been reflected in the statistics. It is observed that forest fires in this period have spread not only in the Mediterranean climate belt areas but also towards other ecosystem types. In particular, the forest fires in Eskişehir and Karabük involve not only red pine forest types but also black pine forest types. It is emphasized that some forest fires in the Antalya Forest Regional Directorate have also shifted towards the black pine belt. This situation reveals that we need to adapt ourselves to restoration efforts in a new and relatively unfamiliar area, different from the usual red pine forest belt restoration. This study presents and discusses various approaches for the restoration of the forest fire that broke out in Karabük province on July 22, 2025, affecting approximately 6-7 thousand hectares of forest area and three forest management offices affiliated with the Forest Management Directorate. In this context, fundamental approaches are presented for issues such as the production and marketing of the area's resources, determining the intensity of the fire, identifying the stands, analyzing fine and coarse material, identifying the species that make up the stands, and discussing the appropriate silvicultural regime.

Keywords: Forest fires, restoration of burned forest areas, restoration planning

1-Introduction

Forest fires are increasingly affecting our country in a destructive manner, as they do worldwide. The rapid destruction of forest ecosystems leads to a decrease in carbon sink areas, thereby contributing to the progression of climate change effects. Climate change, in turn, causes forest fires to spread and advance rapidly. Thus, a vicious cycle is created.

In Mediterranean-type ecosystems, the number of forest fires is rapidly increasing, and the amount of area burned is also on the rise. Human factors are the primary cause of these fires. Humans fundamentally alter fire regimes in three ways: by changing the distribution and intensity of fires, by altering the seasonality of fires, or by changing the available fuel (Balch, 2017).

There is a large body of research on restoration efforts in forest ecosystems following wildfires. Since wildfires are more common in Mediterranean-type ecosystems, studies have concentrated on these areas. Post-fire biological diversity, the development of vegetation processes, success rates, the development processes of red pine and other species in the ecosystem along with it in burned areas, etc. (Barrett et al., 2024; Becker and Lutz, 2023; Blanco-Rodríguez et al., 2023; Calda, 2020).

With climate change, forest ecosystems are becoming more sensitive, and even the smallest unnoticed action can start a forest fire. The increase in the number of hot days, the decrease in relative humidity, and high wind speeds encourage an existing forest fire to rapidly escalate into a mega forest fire. Forest rangers fighting fires in the Mediterranean region have adapted to these conditions over time, but in recent years, they have been helpless in combating forest fires that have become mega fires due to the effects of climate change.

On the other hand, they have gained considerable experience in the rehabilitation of red pine ecosystems. This is because a wide variety of scientific studies have been conducted in these areas, namely Mediterranean-type ecosystems (Güney and Gülsoy, 2023; Kaniewski et al., 2008; Keeley, 2009; Keeley et al., 2005; Keeley et al, 2012; Tavşanoğlu and Gürkan, 2009; Tavşanoğlu, 2009; Tavşanoğlu and Gürkan, 2014; Tavşanoğlu, 2021a; Tavşanoğlu 2021b).

Climate change is increasingly causing forest fires to spread to higher elevations in the Mediterranean coastal region. This belt can be described as the 600m-900m elevation areas of the Central Anatolia Region, the Eskişehir province area, and the interior of the Western Black Sea region, such as the Karabük province. This change and development indicate that there are also changes in forest ecosystems. These areas appear as mixed black pine-red pine forests and pure black pine forests. Scientific studies on the restoration of black pine ecosystems after forest fires in these areas are limited (Karadağ, 1999; Keleş and Kavgacı, 2025; Bricca, 2025; Ertekin et al., 2011).

Therefore, scientific field studies should be conducted to quickly address the lack of information on these areas. In this study, the amount of burned forest areas was determined using Sentinel satellite imagery. By classifying these areas according to slope and burn intensity, various information was generated for post-fire restoration efforts. It is also known that a wide variety of studies have been conducted in this direction (Iverson et al., 19889, Jaafar and Mourad, 2021).

The data obtained were overlaid with digital forest management plans to identify compartments and forest types in the burned areas. The values of these forest compartments according to the plan data were compared with the standing sale value data for the same compartments obtained from the Forest Management Directorate. The results obtained were quite promising. Some recommendations were also made based on these results.

2- Materials and Methods

The study material consisted of the following stages.

1- Sentinel satellite images of the burned forest areas were obtained in this stage.

2- The satellite images were down sampled to the local area.

3- The burned forest areas were grouped according to burn intensity classes (Table 1).

Table 1. Fire severity classification for burned forest areas

Burn Severity Class	ΔNBR
Enhanced Regrowth, High	< -0.25
Enhanced Regrowth, Low	- 0.25 to -0.10
Unburned	- 0.10 to 0.10
Low Severity	0.10 to 0.27
Moderate-low Severity	0.27 to 0.44
Moderate-high Severity	0.44 to 0.66
High Severity	> 0.66

4- Using digital elevation maps of the four regions, slope groups for burned forest areas were created (Table 2).

Table 2. Slope classes and slope groups for burned forest areas

Slope Class	Slope Group
1	%0-%20
2	%21-%40
3	%41-%60
4	%61 +

5- The aim was to access forest management plan data for forest management units located within forest fire boundaries. To this end, the amount of burned area and the ranking of burn intensity classes were created at the compartment and forest type levels from digital forest management plan data (Table 3).

6- The tree wealth in the compartments was determined using forest management plan data. For this purpose, the total wealth was calculated by multiplying the area and wealth value of each forest type in the compartments by the total area of forest types and forest wealth values and the total burned forest areas.

7-. The total wealth in the burned forest areas was compared with the wealth in the compartments auctioned by the Karabük Forest Management Directorate through open bidding (Figure 2).

Table 3. Burned area, fire severity, slope groups, and forest type distribution

BLM_MESC	BLM	MESC	Total Area m2	Bolme Total Area Hectare	Burned AREA	Burned AREA Hectare	Severity code MIN	Severity code MAX	Severity code MEAN	Severity code MAJORITY	Severity code MINORITY	Slope code MIN	Slope code MAX	Slope code MEAN	Slope code MAJORITY	Slope code MINORITY
100_BÇk	100	BÇk	97968,95726	9,796895726	59836,81	5,983681	2	4	2,944374	3	4	1	2	1,007042	1	2
100_Çka	100	Çka	23224,101	2,3224101	75,64704	0,007565	3	3	3	3	3	1	2	1,060606	1	2
100_Çkc3	100	Çkc3	15469,84054	1,546984054	529,5293	0,052953	3	4	3,142857	3	4	1	2	1,545455	2	1
100_Çkcd1	100	Çkcd1	16784,40034	1,678440034	5522,234	0,552223	2	4	2,986301	3	4	1	2	1,4	1	2
100_Çkcd2	100	Çkcd2	18527,5222	1,85275222	<Null>	#DEĞER!	<Null>	<Null>	<Null>	<Null>	<Null>	1	1	1	1	1
100_Çke1	100	Çke1	61331,94639	6,133194639	5446,587	0,544659	2	3	2,972222	3	2	1	2	1,047059	1	2
100_ÇsÇkbc3	100	ÇsÇkbc3	547365,691	54,7365691	104317,3	10,43173	2	4	3,024656	3	2	1	2	1,027127	1	2
100_OT	100	OT	33534,8434	3,35348434	4841,411	0,484141	2	3	2,984375	3	2	1	2	1,04	1	2
101_Çka3	101	Çka3	132385,2894	13,23852894	132231	13,2231	3	5	3,881579	4	5	1	3	2,751323	3	1
101_Çkc3	101	Çkc3	149007,0723	14,90070723	104090,3	10,40903	2	5	3,268895	3	5	1	3	2,066038	2	1
101_Çkcd1	101	Çkcd1	34857,11258	3,485711258	17928,35	1,792835	2	4	2,966245	3	4	1	2	1,254902	1	2
101_Çkcd2	101	Çkcd2	280384,014	28,0384014	265369,8	26,53698	2	4	3,480616	3	2	1	3	2,421429	3	1
101_Çkcd3	101	Çkcd3	114887,5804	11,48875804	42059,76	4,205976	2	4	2,989209	3	4	1	3	2,060241	2	1
101_Çkd/a	101	Çkd/a	62083,28797	6,208328797	60820,22	6,082022	2	5	3,645522	4	2	2	3	2,588889	3	2
101_Mbc2	101	Mbc2	78069,04384	7,806904384	43875,28	4,387528	2	3	2,97069	3	2	1	3	2,017544	2	1
102_BM	102	BM	38595,5809	3,85955809	18836,11	1,883611	2	4	2,947791	3	4	1	2	1,381818	1	2
102_Çkc3	102	Çkc3	330556,7948	33,05567948	186016,1	18,60161	2	4	3,0183	3	2	1	3	2,241164	2	1
102_Çkde1	102	Çkde1	147370,1208	14,73701208	116496,4	11,64964	2	4	3,201948	3	2	1	3	2,30531	2	1
102_Çkde2	102	Çkde2	43438,52075	4,343852075	43497,05	4,349705	3	4	3,389565	3	4	1	3	2,064516	2	1
102_KnÇkbc3	102	KnÇkbc3	24654,95627	2,465495627	24207,05	2,420705	3	5	3,821875	4	5	2	3	2,432432	2	3
102_Mab3	102	Mab3	89311,84453	8,931184453	35781,05	3,578105	2	4	2,989429	3	4	1	3	1,838235	2	3
102_Z	102	Z	62513,38148	6,251338148	44026,58	4,402658	2	4	2,957045	3	4	1	2	1,153846	1	2
103_Çkbc3	103	Çkbc3	128409,1073	12,84091073	128524,3	12,85243	2	4	3,318423	3	2	1	3	2,17801	2	1
103_Çkcd2	103	Çkcd2	17288,7761	1,72887761	8169,881	0,816988	2	4	2,953704	3	4	1	2	1,916667	2	1
103_Çkd1/ÇkGnab3	103	Çkd1/ÇkG	73845,11946	7,384511946	56281,4	5,62814	2	4	3,247312	3	2	1	3	2,581818	3	1
103_ÇkKncd3	103	ÇkKncd3	40385,12371	4,038512371	40244,23	4,024423	3	5	3,827068	4	5	2	3	2,775862	3	2
103_ÇkMab3	103	ÇkMab3	84969,05853	8,496905853	41151,99	4,115199	2	4	3,056985	3	2	1	3	2,709677	3	1
103_ÇkMbc3	103	ÇkMbc3	98875,90114	9,887590114	95693,51	9,569351	2	5	3,539921	4	2	1	3	2,57931	3	1
103_Knb3	103	Knb3	71521,62301	7,152162301	63240,93	6,324093	2	4	3,662679	4	2	1	3	2,394231	3	1
103_Kncd3	103	Kncd3	170944,7212	17,09447212	107040,6	10,70406	2	4	3,365371	3	2	1	3	2,629032	3	1
103_KnÇkbc3	103	KnÇkbc3	21535,59775	2,153559775	21635,05	2,163505	3	5	3,863636	4	5	2	3	2,677419	3	2
103_MÇkab3	103	MÇkab3	11867,24467	1,186724467	12027,88	1,202788	3	4	3,421384	3	4	2	3	2,833333	3	2
103_Z	103	Z	25945,88803	2,594588803	23147,99	2,314799	2	4	3,22549	3	2	1	1	1	1	1
104_Çkbc3	104	Çkbc3	151637,3745	15,16373745	101669,6	10,16696	2	4	3,008185	3	2	1	3	2,292793	3	1
104_Ckd/a	104	Ckd/a	208604,5151	20,86045151	124061,1	12,40611	2	4	2,978049	3	4	2	3	2,960912	3	2

The aim is to determine the total amount of forest area burned in the forest areas affected by the fire that broke out in Karabük province on July 22, 2025, affecting approximately 6-7 thousand hectares of forest area.

At this stage of the study, knowing the intensity of the fire will help in deciding which sections and what type of application will be used for silvicultural intervention according to forest types. Slope Groups: The aim is to use this information to decide up to which slope groups production work will be carried out in the burned forest areas. For this reason, the slope groups used in forestry afforestation studies were used in the classification (Table 2).

After obtaining the maps of the burned forest areas, burn intensity, and slope groups in the studied area, the tables of these maps were organized to obtain the burn intensity and slope group values of the burned forest areas based on compartments and forest types (Figure 1).

The distribution of forest areas affected by the forest fire that occurred in July 2025 according to Forest Management Directorates and Forest Management Departments was determined by practitioners who physically visited the burned areas and made markings at the compartment and stand levels.

The comparison of the area data obtained by the field units with the area information obtained from satellite imagery was also carried out within the scope of this study (Table 4).

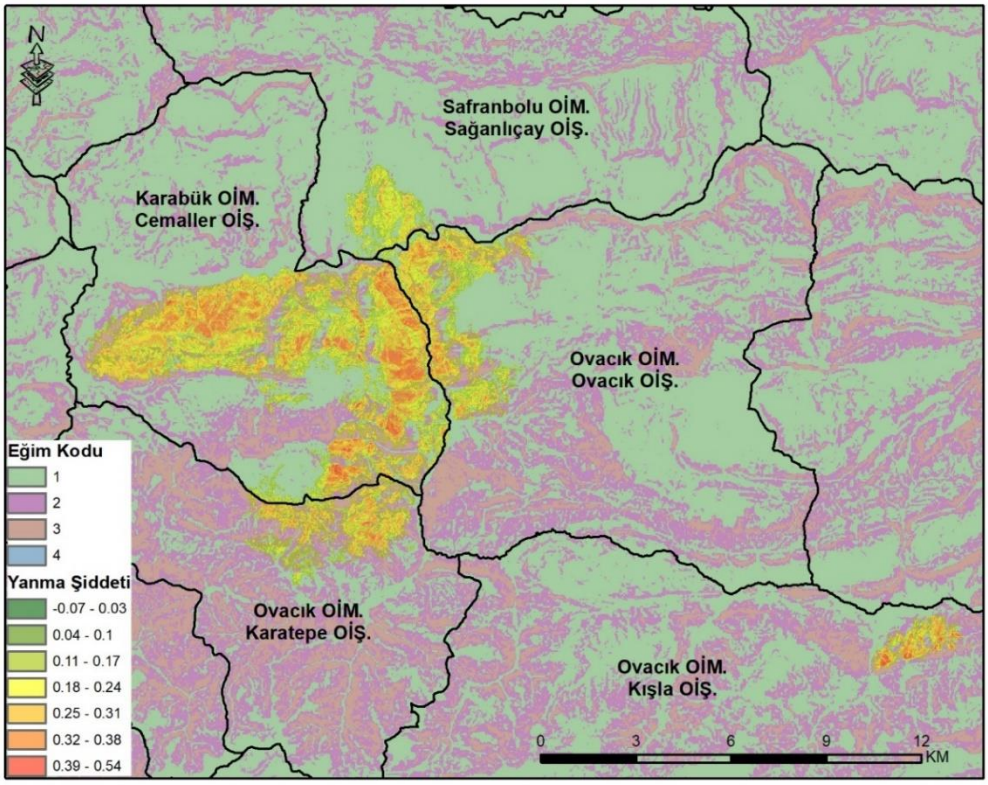


Figure 1. Map of fire severity and slope groups for burned forest areas

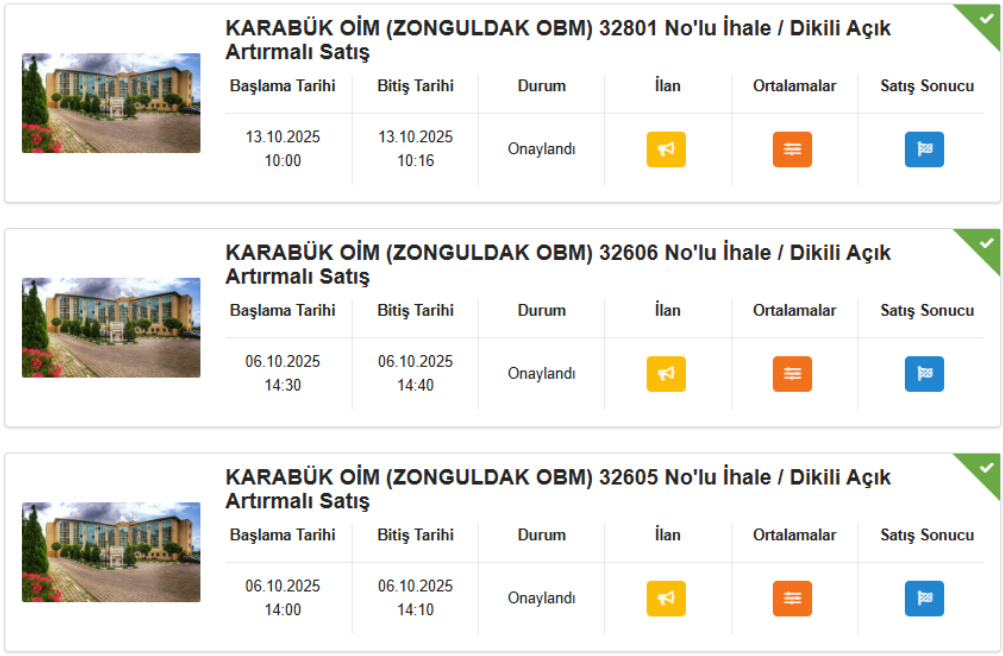


Figure 2. Burning wood raw material standing sale applications

3.Findings and Discussion

3.1. Presence of Burning Forest Areas

When the data on burning areas obtained by processing Sentinel satellite images is overlaid with digital forest management plan data, the areas affected by forest fires in the July 2025 period are revealed (Table 4).

Table 4: Distribution of Forest Areas Burned in Karabük Province in July 2025

Forest Enterprise Chef	Sentinel Data		Forest Enterprise Directorate Data	Change Rate (%)
	Bolme Total Area Hectare	Burned Area Hectare		
Karatepe Cemaller	9.940,42145	4.046,0804	3966,51448	-1,97
Kışla	1.043,66609	239,42334	238,5000	-0,38
Soğanlıçay	1.684,74310	338,9872	333,8581	-1,51
Ovacık	3.125,00285	1.083,3847	1096,9000	1,25
Toplam	15.793,83349	5.707,8755	5635,772533	-2,61

The data on burned areas obtained by cross-referencing the assessments made by forest management offices in forest management directorates for burned forest areas in the field with Sentinel satellite imagery and management plans are shown in Table 4. These data indicate that there are no significant discrepancies. What is important here is the consistency of the assets identified for the forest types in the forest management plans. This consistency is crucial for the rapid and reliable marketing of timber raw materials for post-fire restoration work by estimating the assets.

3.2. Wealth of Burned Forest Areas

In order to determine the wealth of burned forest areas, it is necessary to identify the forest types in the burned compartments and their wealth according to the forest types in the forest management plans. This study used the standing sale application data compiled by the Karabük Forest Management Directorate. This is because all trees with a diameter of 8 mm or more in the compartments of all burned areas were measured. The measurements taken were recorded in the “measurement report.”

Table 5. Standing sales and forest management plan data

Bölme No	Meşçere Type	Quantity of Wood Raw Material Sold by Standing Sale (m^3)	Forest Management Plan Data (m^3)
37	Çkbc3	1.051,251	1.608,045
43	ÇkÇzc2	2.624,932	2.240,713
35	Çkbc3/Çkcd1/ÇkGnab3	1.998,932	3.187,613
63	KDA/ÇkÇzc2/ÇzÇkbc2	2.103,691	1.184,455
56	BçzM/Çzab3/Çzbc2/T/Çzc1	1.745,159	2.099,631
31/34/33/32	ÇkMbc2/Çkbc3/Çzab	3.703,668	3.694,5149
38	Çkbc3	6.497,526	7.056,3021
	TOPLAM	19.725,159	21.071,234

Calculations were made based on the wealth amount according to forest types in the compartments of burned areas in forest management plans using standing sales marketing (Table 5). Plan data was found to be 6.82% higher than actual sales data. This forest management unit covers a 20-year planning period. The final year of the planning period is currently underway. A new management plan will be developed in 2006. A significant reason for the higher plan data may be the positive results of silvicultural practices implemented in the compartments in previous years or increases resulting from illegal logging in earlier periods.

3.3. Restoration Planning Principles

Forest fires cause enormous damage, partly due to the effects of climate change. The amount of burned area is rapidly increasing. In addition, it has been observed that fires are not only occurring in low-altitude Mediterranean ecosystems but are increasingly spreading to higher Mediterranean ecosystems. Therefore, forest fires have begun to affect not only red pine ecosystems but also black pine ecosystems. A significant portion of the forest fires that occurred in Türkiye in 2025 took place in mixed red pine-black pine forests and mixed black pine-red pine or pure black pine forests. Satisfactory scientific studies have been conducted on the adaptation of the red pine species to fire and the restoration of burned red pine forests in Türkiye (Ulus et al., 2025; Güney et al., 2024; Kavgacı et al., 2011; Viedma et al., 2017; Blanco-Rodríguez, 2024; Öztürk, 2025). Turkish foresters do not experience difficulties in rejuvenating burned red pine forests. Except for very large mega red pine forest fires. However, experience in the rehabilitation of burned black pine forests is quite limited (Karadağ, 1999; Keleş and Kavgacı, 2025; Bricca, 2025; Ertekin et al., 2011).

Rehabilitation plans should be developed with the priority of restoring black pine seedlings in pure black pine and mixed black pine-red pine stands affected by forest fires. The amount of seed required per unit area in burned areas is crucial (Alan, 2025). The methods for black pine seed sowing and the appropriate techniques for different terrain types must be determined. At this stage, it is necessary to consider the slope group classification used in Türkiye's afforestation efforts. Areas with a slope of 60% or more should be left to nature, and the progress of the ecosystem in these areas should be observed. As these areas will be very steep, no timber production should be carried out in them. This is because there will be a very serious risk of erosion with rainfall. On land with a slope of 0-20%, full-area medium-depth plowing can be carried out, followed by covering the soil and continuing the work. On land with a slope of 21-40%, taking into account the stoniness of the land, strip tillage should be carried out in large strips (6m-8m) with staggered spacing and rows, and the tillage should reach a soil depth of 8-10 cm. On land with a slope of 41-60%, small strips (2m-3m) and small spacing should be used for line planting at approximately 1.5m-2m. In restoration work, trial applications should be created using other planting methods, taking into account elevation, slope, and aspect, and scientific studies including success and economic analyses should be conducted.

4. Conclusion and Recommendations

As is the case worldwide, forest fires in Türkiye are evolving due to the effects of climate change. They are no longer confined to the Mediterranean coastal belt but have also begun to occur in mid-elevation areas. A progression from the Mediterranean belt towards the inland regions of Central Anatolia and the Western Black Sea is being observed. This situation means that forest fires are also affecting different key components of the ecosystem. Not only red pine ecosystems but also black pine ecosystems are now facing forest fires. Forest fires occurring in Türkiye in 2025 are giving us serious warnings.

While fighting Mediterranean-type forest fires, Turkish forestry is forced to combat large mega forest fires rather than small or medium-sized ones. While trying to adapt to this change, new developments show that different ecosystems will also be greatly affected by forest fires. In this context, black pine ecosystems are in serious danger. Forest fires that occurred this year in the provinces of Eskişehir and Karabük in these ecosystems show that black pine ecosystems are also at risk. Restoration efforts after forest fires are the most important way to ensure that destroyed ecosystems can return to their natural state. In this context, based on restoration experiences with Mediterranean-type red pine forest fires, forestry units that lack sufficient experience in black pine ecosystems must establish principles and guidelines that will enable them to succeed. It is essential to adhere to basic principles such as complying with seed transfer zones, paying attention to seed collection from selected seed orchards, and creating seed stocks to be prepared for large fire areas. The forest fires that occurred in black pine ecosystems in 2025 have created an opportunity to fill various information gaps for these areas. In these ecosystems, it is crucial to conduct research on which natural regeneration methods will be successful under which slope and soil conditions, which aspects and elevations, and which topographic structure conditions, as well as to perform economic analyses of all these factors. This is because it is necessary to quickly restore the burned forest areas.

In this study, the area affected by the forest fire that occurred in Karabük province in July 2025, the compartments and forest types where it occurred were estimated using Sentinel satellite imagery. Classifications were made according to slope, elevation, and fire intensity. These data are presented in comparison with the data obtained in the application (Table 4). This comparison showed a high degree of consistency in the areas. A second finding was the comparison of the wealth of the stands created by processing Sentinel satellite data with the wealth in the forest management plans, as determined by the Forest Management Directorate (Table 5). Here, too, a difference of approximately 7% in favor of the state was observed. This difference is also acceptable.

With this study, instead of labor-intensive work in the field for days or even weeks in large burned areas, it will be possible to carry out restoration work in these areas within a few days by obtaining more detailed satellite imagery. The draft restoration plan to be made can be completed in a short time, supported by rapid field assessment. Completing this planning quickly will save a significant amount of time and labor, especially when considering that it is being done for mega fire areas. Determining the wealth in the burned forest area in a short time will enable production for restoration purposes, i.e., clearing the area. In this context, time will be saved for restoration work, which will increase the chances of success of the restoration work.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Alan, M. (2025). Karabük'teki orman yangınları sonrası için silvikültürel öneriler, *Türkiye Ormancılar Derneği Dergisi*, Cilt: 103, Sayı: 4. Ankara.

Barrett, S., Yates, C. J., Dillon, R., Dilly, M., Varcoe, B., Martin, D., Castlehow, B., & Gosper, C. R. (2024). "Mitigation of disease and browsing impacts, and translocation, supports

post-fire threatened flora recovery". *Australian Journal of Botany,* 72(3). https://doi.org/10.1071/bt23081.

Becker, K. M. L., & Lutz, J. A. (2023). "Differences in regeneration niche mediate how disturbance severity and microclimate affect forest species composition". *Forest Ecology and Management,* 544, 121190. https://doi.org/10.1016/j.foreco.2023.121190.

Blanco-Rodríguez, M. Á., Ameztegui, A., Gelabert, P., Rodrigues, M., & Coll, L. (2023). "Short-term recovery of post-fire vegetation is primarily limited by drought in Mediterranean forest ecosystems". *Fire Ecology,* 19(1), 1-10. https://doi.org/10.1186/S42408-023-00228- W/FIGURES/4.

Bricca, A., Jiménez-Alfaro, Chytrý, M., Chytrý, Cubino, J.P., Fernández-González, F., Ciaramella, D.i Alessi, N., Argagnon, O., Cerabolini, B., Chiarucci, A., Dang-Le, A.T., Fratte, M.D., Dziuba, T., Kavgacı, A., Jandt, U., Niinemets, Ü., Šibíková, M., Vassilev, K., Valachovič, M., Willner, W., Bonari, G. (2025). Biodiversity within and beyond the native distribution of tree species: The case of *Pinus nigra* Forests in Europe. *Global Ecology and Biogeography,* 34:e70036 https://doi.org/10.1111/geb.70036

Calda, B., An, N., Turp, M. T., & Kurnaz, L. (2020). "İklim değişikliğinin Akdeniz Havzasındaki orman yangınlarına etkisi". *International Journal of Advances in Engineering and Pure Sciences,* 32(1), 15-32. https://doi.org/10.7240/JEPS.571001. forests. *Front. Environ. Sci*. https://doi.org/10.3389/fenvs.2025.1661652

Ertekin, M., Özel, H. B., Baygın, G., (2011). Yangın sonrası bozulan alanların yeniden bitkilendirilmesi "Kütahya, Emet, Kovalı yangını örneği. *Bartın Orman Fakültesi Dergisi* 2011, Cilt: 13, Sayı: 20, 10-17 ISSN: 1302-0943. ISSN: 1308-5875

Güney, C.O., Güney, A., Sarı, A., Kavgacı, A., Hood, S., Ryan, K. (2024). Modeling post-fire mortality of Turkish pine (*Pinus brutia* Ten.). *Forest Ecology and Management*. 572, 122265, https://doi.org/10.1016/j.foreco.2024.122265

Iverson, L. R., Graham, R. L., & Cook, E. A. (1989). Applications of satellite remote sensing to forested ecosystems, *Landscape Ecology,* 3(2), 131-143. https://doi.org/10.1007/BF00131175.

Jaafar, H., & Mourad, R. (2021). "GYMEE: A global field-scale crop yield and ET mapper in Google Earth engine based on Landsat, Weather, and Soil Data", *Remote Sensing*, 13(4). https://doi.org/10.3390/rs13040773.

Jennifer K. Balch, Bethany A. Bradley, John T. Abatzoglou, R. Chelsea Nagy, Emily J. Fusco, Adam L. Mahood, (2017). Human-started wildfires expand the fire niche across the United States Pnas, Vol:114, No:11, Pages: 2946-2951. Colorado, Usa.

Kaniewski, D., Paulissen, E., De Laet, V., & Waelkens, M. (2008). "Late Holocene fire impact and post- fire regeneration from the Bereket Basin, Taurus Mountains, southwest Turkey", *Quaternary Research*, 70(2), 228-239. https://doi.org/10.1016/J.YQRES.2008.04.002.

Karadağ, M. (1999). Batı Karadeniz Bölgesinde Karaçam (Pinus nigra Arnold ssp. pallasiana Lamb. Holmboe) doğal gençleştirme koşulları üzerine araştırmalar. *Batı Karadeniz Ormancılık Araştırma Enstitüsü, Teknik Bülten* No 4. Bolu.

Kavgacı, A., Salis M., Arca, B., Coşgun, U., Güngöroğlu, C., Spano, D. (2011). Historical relationship between climate and fire regime in Aşağı Köprüçay Basin (Antalya, Türkiye). In: D Sapano, V. Baccui, M. Salis, K. Sirco (eds.) Modelling Fire Behaviour and Risk. Proterina C project, pp. 70-77.

Keeley, J. E. (2009). "Fire intensity, fire severity and burn severity: A brief review and suggested usage", *International Journal of Wildland Fire,* 18(1), 116-126. https://doi.org/10.1071/WF07049.

Keeley, J. E., Fotheringham, C. J., & Baer-Keeley, M. (2005). "Determinants of postfire recovery and succession in Mediterranean-climate shrublands of California", *Ecological Applications*, 15(5).

Keeley, J. E., Bond, W. J., Bradstock, R. A., Pausas, J. G., & Rundel, P. W. (2012). "Fire in Mediterranean ecosystems: Ecology, evolution and management", *Fire in Mediterranean Ecosystems: Ecology, Evolution and Management,* 58, 123-135. https://doi.org/10.1017/CBO9781139033091.

Keleş, E.S., Kavgacı, A. (2025). Post-fire succession of black pine (Pinus nigra) forest vegetation under different fire regimes. *Acta Botanica Croatica*. https://doi.org/10.37427/botcro-2025-023

Öztürk, A. (2025). *Akdeniz Bölgesinde Yangın Sonrası Vejetasyon Yenilenmesine Etki Eden Coğrafi Faktörlerin Uzaktan Algılama ve Yapay Zekâ Yöntemleriyle Analizi.* TÜBİTAK Program Kodu: 1002. Proje No: 223O312

Tavşanoğlu, Ç., & Gürkan, B. (2009). "Post-fire regeneration of a Pinus brutia (Pinaceae) forest in Marmaris National Park, Turkey". *International Journal of Botany,* 5(1), 107-111. https://doi.org/10.3923/ijb.2009.107.111.

Tavşanoğlu, Ç. (2009). "Akdeniz Havzası ormanlarında yangın sonrası kendiliğinden gençleşme". Orman Yangınları ile Mücadele Sempozyumu Tebliğleri, 310-317.

Tavşanoğlu, Ç., & Gürkan, B. (2014). "Long-term post-fire dynamics of co-occurring woody species in Pinus brutia forests: the role of regeneration mode". *Plant Ecology,* 215(3), 355-365. https://doi.org/10.1007/S11258-014-0306-2/TABLES/1.

Tavşanoğlu, Ç. (2021a). "Akdeniz Bölgesindeki Büyük Orman Yangınlarının Sebepleri ve Yangın Sonrası Yapılması Gerekenler". Teknik Rapor. Hacettepe Üniversitesi, Ankara.

Tavşanoğlu, Ç. (2021b). "Kızılçam (*Pinus brutia*) ormanlarının yangın sonrası doğal onarımı ve ormanların geleceği için öneriler". *Orman ve Av*, 14-17.

Ulus, Y., Wang, S., Tsz-Ki, Tsui, M., Landau, N., Lekki, O., Bayazıt, T., Uzun, H., Aslan, F., Kavgacı A. (2025). Post-fire forest management effects on soil metal dynamics in Mediterranean

Viedma, O., Moreno, JM., Güngöroğlu, C., Cosgun, U., Kavgacı, A. (2017). Recent land-use and land-cover changes and its driving factors in a fire-prone area of southwestern Turkey. *Journal of Environmental Management.* 197: 719-731.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Current Status and Analysis of Demre (Antalya) Urban Green Areas

Atila GÜL [1*]

ORCID 1: 0000-0001-9517-5388
[1]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
atilagul@sdu.edu.tr (Responsible Author)

Sibel AKTEN [2*]

ORCID 2: 0000-0001-6242-9687
[2]Dr., Isparta University of Applied Sciences, Eğirdir Vocational School, Isparta-Türkiye
sibelakten@isparta.edu.tr

Hüseyin Batuhan DÜNDAR [3*]

ORCID 3: 0009-0003-7341-970X
[3]Master's Student, Süleyman Demirel University, Institute of Science, Department of Landscape Architecture, Isparta – Türkiye
hbatuhandundar@gmail.com

Çağrı YOLUK [4*]

ORCID 4: 0009-0008-9040-803X
[4] Director of Parks and Gardens at Demre Municipality Demre, Antalya– Türkiye
cagriyoluk@gmail.com

Abstract

Urban green areas are one of the most important vital components of the city and are considered as a fundamental element in terms of sustainability of the urban ecosystem, protection of biological diversity and supporting the physical and mental health of urban residents. Demre district was first mentioned in historical documents in 1904 when it gained village status under the name of Eynihal. Later on, a municipality was established in 1968 with the merger of four villages, it became a district on 4 July 1987 under the name of Kale, and in 2005 it took its current name Demre. The district, which is 147 km away from the centre of Antalya, consists of 17 neighbourhoods today. This study was carried out to reveal the current status of urban green areas in Demre district and to evaluate their ecological, social and aesthetic values with a holistic approach. Within the scope of the research, parks, recreation areas, street afforestation and coastal green corridors were analysed by using municipal inventory data, satellite images and on-site observations. The results of the analysis show that there are significant differences between neighbourhoods in the amount and spatial distribution of green areas, and in some regions, the amount of green space per capita is below the minimum values recommended by the World Health Organization. However, plant species specific to the Mediterranean climate and landscape elements integrated with the historical-cultural texture have a high potential in terms of the ecological identity of the city. The study emphasises that planned growth principles, planting strategies that adapt to climate change and sustainable urban green space management models will play a critical role in improving the urban life quality of Demre.

Keywords: Urban green areas, Demre (Antalya), sustainability, climate change adaptation

1. Introduction

According to the UN, 55% of the world's population currently lives in urban areas. This figure is expected to rise to 68% by 2050. According to TUIK (February 6, 2025), 67.2% of Türkiye's population lives in densely populated cities, 15.5% in moderately populated cities, and 17.2% in rural areas (Türkiye İstatistik Kurumu, 2025).

Parallel to the increase in the world population, rapid migration from rural to urban areas has led to an increase in urbanization and the number and spatial size of urban areas. The growing

and diversifying need and demand for resources in rapidly growing cities has accelerated urbanization and construction activities. Today, the increase in production-consumption trends has further increased the pressure and damage of global capital actors and sectors on natural resources. However, it is accepted that the excessive use and destruction of natural resources, urbanization trends, misuse and misappropriation of land, and other physical interventions lead to environmental problems, primarily climate change and carbon emissions, a decline in biological diversity, an increase in natural disasters, and a growth in waste and residue problems.

Urban areas are responsible for 80% of global production and 70% of total greenhouse gas emissions, and they are also the living spaces most intensely exposed to the effects of climate change, such as heat waves, floods, water scarcity, rising sea levels, food crises, and environmental pollution (The Global Comission on the Economy and Climate, 2014). Urban areas are extremely important priority areas in combating and adapting to climate change. Cities are considered both the primary source of the problem and the target of climate disasters, and at the same time, the most important actors in the solution (Balaban, 2017).

The rapid growth of the urban population, coupled with changes in social, economic, political, and cultural conditions, has led to an increase in horizontal and vertical urbanization and speculative tendencies in land use, particularly due to the demand and dominance of residential, industrial, and other sectors in cities. This has resulted in a decrease in green spaces in both horizontal and vertical dimensions. Green areas are gradually decreasing or becoming insufficient in both horizontal and vertical directions (Gezer & Gül, 2009).

Urban green spaces are one of the most important vital components of a city. They are considered a fundamental element, particularly in terms of the sustainability of the urban ecosystem, the preservation of biological diversity, and the support of the physical, mental, and psychological health of city residents. (Gül & Küçük, 2001; Gül et al., 2020; Gezer & Gül, 2009).

The physical structure of a city is shaped by the ecological, economic, social, and cultural characteristics of the people living in that city and their interactions with each other. However, regardless of the founding purpose of today's cities, almost all of them contain sections or spaces that enable the community to engage in activities related to living, working, entertainment, and recreation. These spaces can be classified according to their functions as residential areas, open and green spaces, commercial and business areas, industrial areas, transportation areas, social facilities, and natural areas (Gül & Küçük, 2001; Gül et al., 2020; Gezer & Gül, 2009).

The overall character of a city emerges from the relationship and interaction between architectural structures, open and green spaces, and transportation areas. Open and green spaces play an important role in balancing the disrupted relationship between humans and nature and improving urban living conditions. Therefore, in developed countries, the quality and quantity of open-green spaces are considered an indicator of civilization and quality of life (Gül & Küçük, 2001; Gül et al., 2020; Gezer & Gül, 2009).

In this context, many developed countries are striving to plan and create urban spaces or ecosystems suitable for human life, taking into account people's physical, intellectual, and mental needs. Urban green spaces are public, semi-private, or private physical spaces covered with natural and cultivated plants, which provide multifaceted biological, climatic, physical,

social, psychological, economic, and aesthetic services and contributions to the city's ecosystem and its inhabitants within and around the city. They are organized according to different green space typologies at the level of the city unit they serve. (Gül et al., 2020; Gezer & Gül, 2009; Türker & Gül, 2022).

In this context, in order to realize the multifaceted services and contributions of open and green spaces, urban planning, design, and management processes must be organized holistically according to certain standards in terms of quality and quantity. In our country, issues such as the conceptual framework, typologies, functionalities, and standards of urban green spaces are addressed in academic circles in both discourse and action. However, it is observed that there are differences and uncertainties in legislation and practice on this issue. In our country, spatial planning and design processes are attempted to be implemented as defined in the relevant legislation. In the Spatial Plans Construction Regulation No. 29030 dated 14.06.2014, open and green spaces are included under the title of urban "Social Infrastructure Areas." Green spaces are defined as Parks, Picnic and Entertainment (Recreation) areas, Children's Gardens, and Public Gardens (Added: RG-01/03/2019-30701) According to the same Regulation (Article 11 and Annex-2 Table); for a population between 0 and 501 thousand, the area for children's playgrounds, parks, botanical parks, zoos, recreation areas, and recreation areas is 10 m^2 per person. In provincial plans, a minimum of 15 m^2 per person is envisaged, including 5 m^2 per person for zoos, urban forests, afforestation areas, fair, fair and festival areas, and hippodromes in settlements with a population between 0 and 501 thousand (Gül et al., 2020; Türker & Gül, 2022).

Urban green spaces are an important part of social infrastructure and public spaces. They provide important services and contributions to the health of society and individuals, as well as to a comfortable and healthy spatial environment. Therefore, public urban green spaces must be easily accessible to all population groups and distributed equitably and fairly at the urban and neighborhood scale (WHO, 2017). It is widely accepted that the urban green space system in Türkiye is addressed solely in terms of quantity, and that green spaces, in particular, are not distributed evenly and evenly throughout the urban area, lack organic connections between green spaces, lack accessibility, and exhibit fragmented distribution within the city (Bilgili et al., 2011; Gül et al., 2020). In this context, legislation needs to address not only quantity but also quality (e.g., green space quality, multifaceted functionality, accessibility, services and contributions, and equitable and fair distribution across the neighborhood and city scales, taking into account the relationship with the population, etc.) as a holistic system. In this context, it is of great importance to integrate the existing urban open and green space inventory into zoning plans, urban design and management processes in detail and to analyze and construct it by taking into account certain standards (Gül et al., 2020; Türker & Gül, 2022).

Demre District, which is affiliated to Antalya Province and 147 km away from the city center, gained village status under the name Eynihal in 1904, became a municipality with the merger of four villages in 1968, gained district status under the name Kale on July 4, 1987 and took its current name, Demre, in 2005.

This study presents the current status of urban green spaces in the Demre district at the urban and neighborhood scales. A holistic approach is employed to analyze and interpret green space typologies, spatial distribution, and population, and to provide strategic recommendations. Using municipal inventory data, satellite imagery, and on-site observations, the current status of urban green spaces (parks, playgrounds, sports fields, recreational areas, etc.) is analyzed

and interpreted at the neighborhood scale in terms of the quantity and spatial distribution of green spaces.

2. Materials and Methods

This study explores the current status of open-green spaces in 17 neighborhoods in the Demre district and conducts quantitative analyses. In this context, quantitative analyses were conducted and interpreted at the neighborhood and urban scales, taking into account the typologies of urban active green spaces in the study area.

2.1. Demre District General Information

Demre District is located on the Mediterranean coast within the borders of Antalya Province, between 29° 20' - 32° 35' east longitude and 36° 07' - 37° 2' north latitude, and is 142 km from Antalya city center. Demre, a district of Antalya Province, is a small, developing rural-urban settlement. Agriculture and tourism are driving forces in the city's economy. Residential construction and greenhouse farming play a significant role in urban development. Demre has a deep and important cultural history dating back to the ancient Lycian period. Rivers originating in the northern mountains converge at the Myros Canyon (Demre Stream) and reach the sea. The current settlement is situated in the plain surrounding this stream. Dalyan lies at the eastern end of this plain, the famous port city of Andriake to the west, and the ancient city of Myra to the northern end.

Demre has fertile agricultural lands in terms of spatial location, and has a very suitable structure for agriculture with its wide plains and red-brown Mediterranean soils, especially enriched by the alluvial soil brought by the Demre Stream (Western Mediterranean Development Agency (BAKA, 2021).

The region, which stands out for its intensive greenhouse farming and citrus production (especially oranges and lemons), is known for its renowned agricultural products such as the "Demre green pepper." The diversity and quality of agricultural products provide the region with high potential for agricultural tourism opportunities such as agrotourism, farm tourism, and organic farming. Economically, Demre stands out with its high-value seafood such as blue crab and shrimp, and makes significant contributions to the local economy thanks to its aquaculture resources.

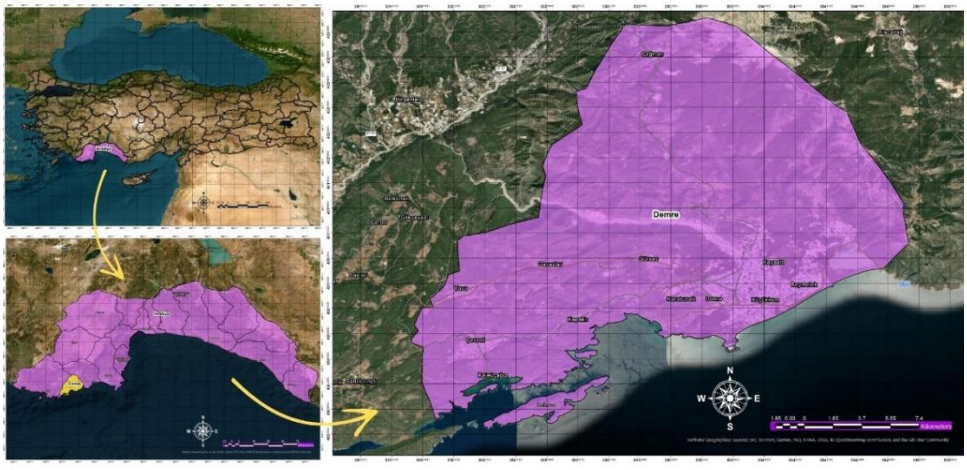


Figure 1. Demre District and its location

The Demre district has a rich potential in terms of its historical and cultural architectural structures and ruins, as well as its unique natural heritage values. Furthermore, the presence of St. Nicholas, known as the birthplace of Demre and a significant figure in Christian history, and his church are considered significant identity assets (Dündar et al., 2024).

Tourist arrivals in Antalya exceeded 14 million in 2025 (between January and September), with more than 13 million foreign tourists and 856,698 domestic tourists. It is estimated that more than 2 million visitors came to the Demre region alone (Turizm Proje Dergisi, 2021).

Within the scope of the Law No. 6360 on the "Establishment of Metropolitan Municipalities and Twenty-Seven Districts in Fourteen Provinces and Amendments to Certain Laws and Decree Laws", all settlements in Antalya province gained the status of "urban settlement" with the borders of the Antalya Metropolitan Municipality becoming the provincial border. However, the settlements that transformed from villages to neighborhoods are of a different nature and are defined as "rural settlement areas" (Antalya Büyükşehir Belediyesi, 2018).

In order to evaluate the socio-cultural and socio-economic potentials of the Demre District, to protect cultural values, to protect rock tombs and protected areas and areas suitable for agriculture, to ensure the continuity of agricultural production, to plan tourism activities to be spread throughout the year and thus to ensure a homogeneous distribution of socio-economic development in the region, the Antalya Demre Culture and Tourism Protection and Development Region was declared (Official Gazette Decision dated 26.07.2010 and numbered 27653) (Antalya Metropolitan Municipality, 2018).

The total area within the boundaries of Demre District with the integrated 1 / 5,000 Scale Master Zoning Plan and the 1 / 1,000 Scale Implementation Zoning Plan is approximately 2,590 hectares. The integrated zoning plans are located within the boundaries of the Demre Culture and Tourism Protection and Development Zone, the repealed Beymelek Municipality, St. Nicholas Church and its surroundings, and Kayaaltı Neighborhood. In these areas, the boundaries of the Master Zoning Plan and the Implementation Zoning Plan cover the same areas. The Demre Culture and Tourism Protection and Development Zone zoning plan covers an area of approximately 1,680 hectares within the boundaries of the Alakent, Büyükkum, Gökyazı, Karabucak, Yaylakaya, and Küçükkum neighborhoods. (Antalya Büyükşehir Belediyesi, 2018).

In the 1/25000 Scale Zoning Plan Report for the Demre District of Antalya Province, the total area of planned open and green spaces within the district borders is 130.0 hectares. Of this area, 76.2 hectares are within the plan approval boundaries, while 53.8 hectares are outside the plan approval boundaries. This report presents the status of open and green spaces according to approved plan decisions; (Antalya Büyükşehir Belediyesi, 2018).

- Park and Green Space 34 Ha
- Afforestation Area: 6.7 Ha
- Recreational Area 9.5 Ha
- Cemetery Area 3 Ha
- Shore and Beach 23 Ha

3. Findings and Discussions

Demre District has 17 neighborhoods. Belören Neighborhood covers approximately 25% of the district's surface area, and Beymelek Neighborhood 13%. However, the neighborhoods with the smallest surface area are Kayaaltı (0.30%) and Alakent (0.52%) (Figure 2. Table 1).

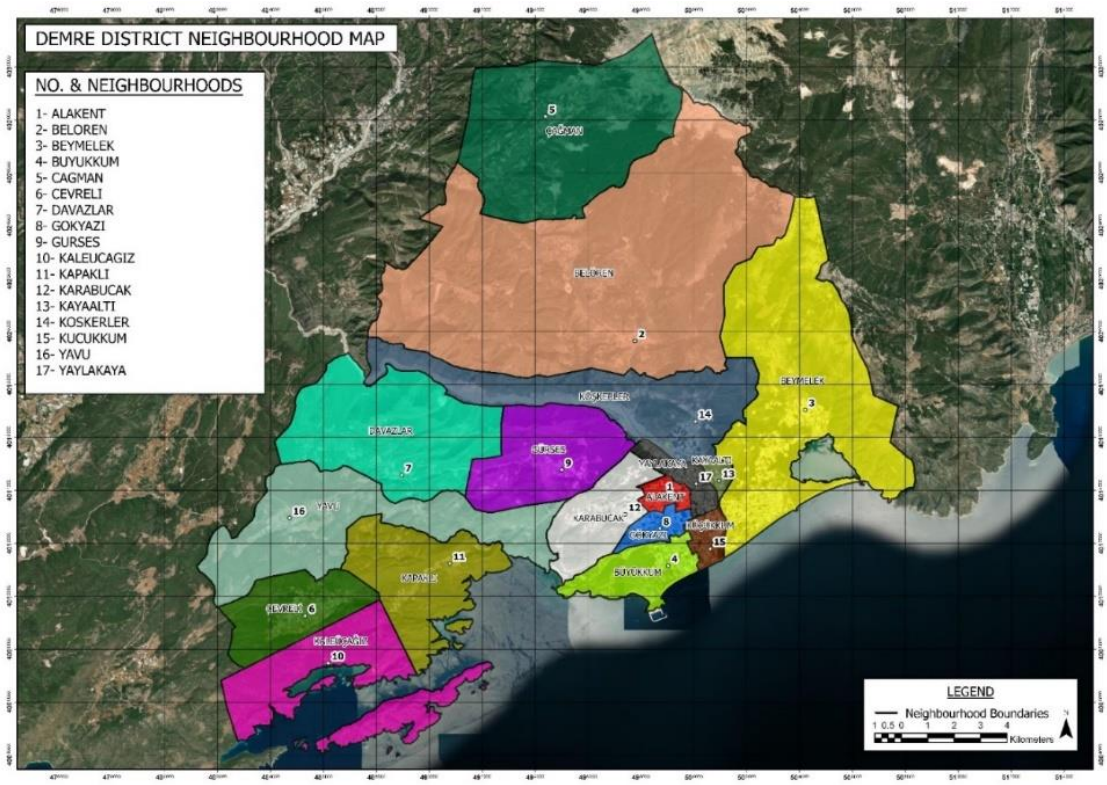


Figure 2. Neighborhoods of Demre District

Table 1. Areas and ratios of 17 Neighborhoods in Demre District

No.	Neighborhoods	Neighborhood Areas (Ha)	Ratio of Neighborhood Area to Demre Area (%)
1	Alakent	195,18	0,52
2	Belören	9583,18	25,73
3	Beymelek	5095,74	13,68
4	Büyükkum	798,77	2,14
5	Çağman	3987,28	10,71
6	Çevreli	1236,97	3,32
7	Davazlar	2981,68	8,01
8	Gökyazı	265,01	0,71
9	Gürses	1759,57	4,72
10	Üçağız	2127,59	5,71
11	Kapaklı	1881,29	5,05
12	Karabucak	1044,76	2,81

13	Kayaaltı	111,65	0,30
14	Köşkerler	2566,26	6,89
15	Küçükkum	251,55	0,68
16	Yavu	3027,94	8,13
17	Yaylakaya	328,93	0,88
Total		37243,33	100,00

The amount of green space (m^2) per capita in Demre District according to neighborhood populations shows an unbalanced and unequal distribution. According to Table 2, the neighborhoods with the highest per capita green space amounts above 10 m^2 are Beymelek (23.00 m^2), Büyükkum (21.73 m^2), and Küçükkum (11.76 m^2). The other 14 neighborhoods have unbalanced and unequal ratios below 10 m^2. Gürses, in particular, has 0 m2 of green space. However, despite the uneven and unbalanced distribution of green space among neighborhoods in Demre District, the total amount of green space per capita, when compared to the urban population, drops to 12.41 m^2 (Figure 3, Table 2).

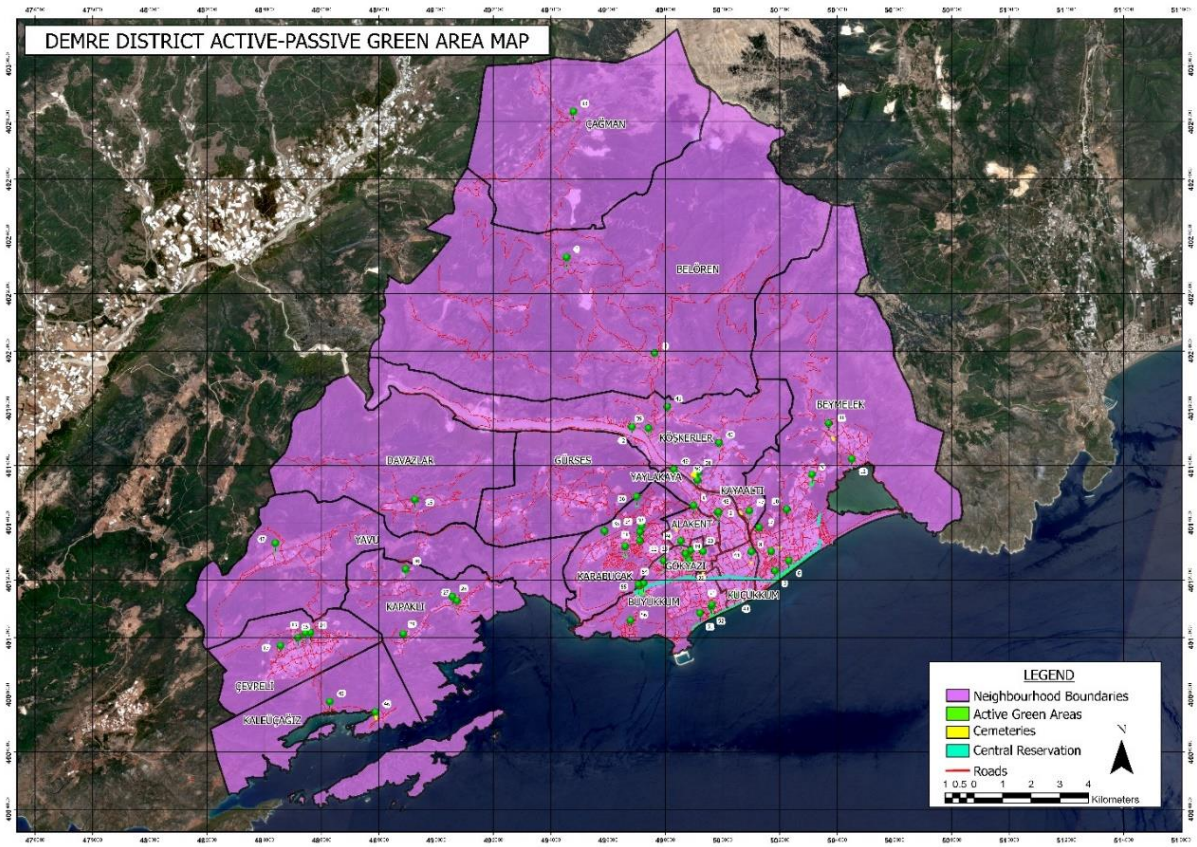


Figure 3. Active green areas of neighborhoods in Demre District

Table 2. Population of the 17 Neighbourhoods of Demre District, green space ratios and green space per capita (m²)

No.	Neighborhoods	Neighborhood Population (TÜİK, 2024)	Total Active Green Space Area (m²)	Amount of Green Space per Person (m²)
1	Alakent	1640	1931,75	1,17
2	Belören	496	3431,71	6,91
3	Beymelek	3686	84786,10	23,00
4	Büyükkum	2878	62556,72	21,73
5	Çağman	250	2051,35	8,20
6	Çevreli	786	2407,58	3,06
7	Davazlar	160	1171,23	7,32
8	Gökyazı	8129	18953,86	2,33
9	Gürses	402	0,00	0,00
10	Üçağız	502	228,82	0,45
11	Kapaklı	519	1249,17	2,40
12	Karabucak	2700	14576,19	5,39
13	Kayaaltı	404	1170,72	2,89
14	Köşkerler	2328	8245,90	3,54
15	Küçükkum	1344	15809,41	11,76
16	Yavu	411	3989,91	9,70
17	Yaylakaya	1179	1566,49	1,32
Total at Neighborhood Level		27814	224127	
Amount of Green Aeas Per Person at the Urban Scale				12,41

Within the scope of urban green areas types, there are 55 in total, including 22 parks, 26 children's playgrounds, 4 sports fields, and 2 squares (Table 3).

Table 3. Number of green space types of Demre City

Number of Green Space Types	Number (Sayısı)
Park	22
Children's Playgrounds	26
Sports Field	4
Recreation and Picnic Area	1
Square	2
Total	55

Apart from urban active green areas, the total area of other passive green areas (Roadside and median green areas and Cemeteries) and the amount of green space per person is 8.10 m2, and a total of 20.51 m2 of green space per person is calculated (Table 3).

Table 4. Passive green space types of Demre City

Neighborhood	Passive Green Area Type	Amount of Total Green Area
Büyükkum	Demre Cemetery	8977,65
Büyükkum	Roadside and Median Green Areas	22886,39
Alakent	Alakent Cemetery	7420,60
Beymelek	Beymelek Cemetery	7641,99
Kayaaltı	Kayaaltı Cemetery	6663,80
Köşkerler	Köşkerler Cemetery	26028,40
Beymelek	Upper Beymelek İskele Cemetery	9551,28
Beymelek	Roadside and Median Green Areas	23072,99
Üçağız	Üçağız Cemetery	9507,55
Küçükkum	Küçükkum Cemetery	5191,01
Küçükkum	Roadside and Median Green Areas	8690,87
Total (m^2)		135632,54
Amount of Passive Green Areas Per Person at the Urban Scale		8,10 m^2

Table 5. Active green area types and total areas of Demre City

No	Neighborhood	Active Green Area Type	Total Area (m^2)
1	Alakent	Children's Playground	678.24
2	Alakent	Yaylakaya Football Field	1,253.51
3	Belören	Children's Playground	124.01
4	Belören	Park	3,307.75
5	Beymelek	Tahtalı Park	10,095.12
6	Beymelek	Beymelek Coastal Park	55,048.21
7	Beymelek	Children's Playground	1,198.50
8	Beymelek	Children's Playground	202.52
9	Beymelek	Beymelek Kızıl Area – Picnic Area	16,012.92
10	Beymelek	Children's Playground	395.98
11	Beymelek	Children's Playground	878.49
12	Beymelek	Children's Playground	954.35
13	Çağman	Park	2,051.35
14	Çevreli	Children's Playground	548.11

15	Çevreli	Children's Playground	554.21
16	Çevreli	Park	1,040.04
17	Çevreli	Children's Playground	265.22
18	Davazlar	Park	1,171.23
19	Gökyazı	Demre District Square	7,871.45
20	Gökyazı	Demre Municipality Front Square	5,485.81
21	Gökyazı	Park	1,299.21
22	Gökyazı	Park	1,612.90
23	Gökyazı	Park	1,460.71
24	Gökyazı	Park	1,074.57
25	Gökyazı	Children's Playground	149.21
26	Kapaklı	Children's Playground	512.69
27	Kapaklı	Children's Playground	141.78
28	Kapaklı	Children's Playground	242.84
29	Kapaklı	Children's Playground	351.85
30	Karabucak	Demre Atatürk Park	7,102.49
31	Karabucak	Children's Playground	208.39
32	Karabucak	Children's Playground	212.54
33	Karabucak	Park	2,374.46
34	Karabucak	Children's Playground	268.48
35	Karabucak	Demre Agricultural Park	4,410.34
36	Kayaaltı	Children's Playground	1,170.72
37	Köşkerler	Köşkerler Arena – Recreation Area	7,089.36
38	Köşkerler	Children's Playground	387.49
39	Köşkerler	Children's Playground	443.88
40	Köşkerler	Park	155.46
41	Köşkerler	Children's Playground	169.72
42	Küçükkum	Demre Coastal Park (Partial Area)	15,476.14
43	Küçükkum	Children's Playground	333.27
44	Üçağız	Children's Playground	119.11
45	Üçağız	Children's Playground	109.71
46	Yavu	Park	3,989.91
47	Yaylakaya	Yaylakaya Social Facility Park	423.24
48	Yaylakaya	Park	1,019.39
49	Yaylakaya	Children's Playground	123.86
50	Büyükkum	Taşdibi Coastal Park	14,256.10

51	Büyükkum	Demre Coastal Park (Partial Area)	23,808.12
52	Büyükkum	İbrahim Sami Özek Open Sports Facility	5,785.55
53	Büyükkum	Demre Football Field	12,967.41
54	Büyükkum	Demre Football Training Field	5,470.30
55	Büyükkum	Park	269.24
Total			**224,127.00**

Table 6. Percentage of green areas according to neighborhood area of Demre District

No.	Neighborhoods	Neighborhood areas (m^2)	Total active green space areas (m^2)	Percentage of green areas according to neighborhood area
1	Alakent	1951784,64	1931,75	0,10
2	Belören	95831805,48	3431,71	0,00
3	Beymelek	50957439,91	84786,10	0,17
4	Büyükkum	7987655,46	62556,72	0,78
5	Çağman	39872779,45	2051,35	0,01
6	Çevreli	12369711,30	2407,58	0,02
7	Davazlar	29816783,87	1171,23	0,00
8	Gökyazı	2650118,35	18953,86	0,72
9	Gürses	17595702,89	0,00	0,00
10	Üçağız	21275863,70	228,82	0,00
11	Kapaklı	18812857,50	1249,17	0,01
12	Karabucak	10447598,45	14576,19	0,14
13	Kayaaltı	1116523,63	1170,72	0,10
14	Köşkerler	25662569,79	8245,90	0,03
15	Küçükkum	2515472,93	15809,41	0,63
16	Yavu	30279367,16	3989,91	0,01
17	Yaylakaya	3289298,72	1566,49	0,05
Total		372433333,24	224126,91	0,06

General Assessment of Demre City's Green Spaces

- The current amount of active green space per capita in Demre is 12.41 m^2, which can be considered sufficient.
- The distribution among neighborhoods is observed to be unequal and unbalanced.
- The ratio of green spaces to the neighborhood's total surface area is less than 1% in all neighborhoods.
- The areas covered by parks within the city are generally small.
- The largest area is Sahil Park, located within the boundaries of Beymelek, Büyükkum, and Küçükkum neighborhoods. It covers 94,332 m^2. There are four parks covering over 1 hectare. Other green spaces range from 2,000 m^2 to 250 m^2.
- The organic connection between parks within the city and with natural areas outside the city is insufficient.
- The variety of activities and facilities in children's and sports playgrounds is limited.

4. Conclusions and Recommendations

To create livable, healthy, and high-quality urban spaces, the city's urban planning process must address the open and green space system in a spatial, locational, and functional hierarchy, with equal, fair, and adequate resources at the city, district, and neighborhood scales, and with functional facilities that will provide multifaceted ecosystem services.

- In order for the municipality to be effective and competent in the management of public green areas for which it is responsible (such as planning/design, implementation, protection, maintenance, repair), its organizational unit should be strengthened with technical staff and auxiliary personnel.
- Urban green spaces should be integrated with green spaces and natural areas within and around the city to create an organic, continuous, and holistic green network system. Green corridors that provide organic connections should be established. Plant species used in green spaces should always be chosen from the region's native species.
- Urban heat islands, green space needs, and wind corridors should be identified and ecological corridors should be created within the urban fabric with accessible green areas and dense natural surfaces.
- Rainwater management should be provided in urban areas and peripheral areas, rain gardens, sponge city details, rain ditches and natural water surfaces should be created, and public spaces should be transformed into a design that collects water during heavy rainfall and transfers it to the storage system.
- Newly planned parks should be designed in larger areas, with the concept of City Parks, Public Gardens and multi-purpose recreation areas.
- Complex children's and sports playgrounds should be positioned in urban green areas and diversified to appeal to all age groups of the city and fit the purpose.
- Empty and unused areas in and around the city should be converted into green areas or these areas should be used as urban agricultural areas to contribute to the food needs of the city.
- Ecological bridges should be designed on the intercity highway passing through the city.
- Green areas should be designed and implemented with sustainable and innovative drainage and infrastructure systems.
- The active participation of urban residents in the planning and management of urban green areas should be ensured and demands and trends should be taken into account.
- To prevent climate change, carbon emissions and biodiversity crisis in the city, a resilient urban fabric should be targeted by creating green areas specific to local conditions (urban parks, green corridors, river corridors, rain gardens, roof gardens, etc.) that include nature-based or hybrid solutions in urban areas.

It is not possible to create smart, healthy and livable cities and ensure their sustainability without designing green areas in integrity and balance with the city.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Antalya Büyükşehir Belediyesi (2018). Antalya İli Demre ilçesi 1 /25000 Ölçekli Nazım İmar Planı Raporu, Mayıs-2018. İmar ve Şehircilik Dairesi Başkanlığı Nazım Plan Şube Müdürlüğü. Antalya.

Balaban O. (2017). İklim değişikliği ve kentler. *ODTÜ'lüler Bülteni Dosya*, p 30. Temmuz-Ağustos 2017 https://www.odtumd.org.tr/odtubulten/2017/07082017/resources/_pdfs_/07082017__.pdf (Access date; September, 12, 2025)

Batı Akdeniz Kalkınma Ajansı (BAKA) (2021). Antalya Demre Mevcut Durum Analizi Sorunlar ve Çözüm Önerileri. BAKA Yayın No: 2021/114, s 56.

Bilgili B.C., Çığ, A. & Şahin, K. (2011). Van kenti kamusal yeşil alanlarının yeterliliğinin ulaşılabilirlik yönünden değerlendirilmesi. *YYÜ Tar. Bil. Derg. (YYu J. Agr. Sci.*) 2011, 21(2): 98-103.

Dündar, H. B. Aydemir, Ç. & Gül, A. (2024). Ecotourism Potential of Demre (Antalya) Region. 5th Internatıonal Urban Landscape and Art Congress October 25-27, 2024 / p.560-579. Paris, France. ISBN: 978-625-367-954-5. ISSUED: November 27, 2024. DOI: https://doi.org/10.5281/zenodo.14229713. https://www.iksadkongre.com/urban

Gezer, A. & Gül, A. Eds. (2009). Kent Ormancılığı (Kavramsal-Teknik ve Kültürel Boyutu). SDU Orman Fakültesi, Kitap Yayın No: 86, s: 01-246. Isparta. 2009. (ISBN: 978-9944-452-30-4) SDU Basım evi- Isparta. https://www.researchgate.net/profile/Atila-Gul/publication/348522666_KENT_ORMANCILIGI_Kavramsal_teknik_ve_Kultur el_Yaklasimlar/links/600216b445851553a049292f/KENT-ORMANCILIGI-Kavramsal-teknik-ve-Kueltuerel-Yaklasimlar.pdf

Gül, A. & Küçük, V. (2001). Kentsel açık-yeşil alanlar ve Isparta Kenti örneğinde irdelenmesi. Süleyman Demirel Üniversitesi, *Orman Fakültesi Dergisi,* A (2), 27-48.

Gül, A., Dinç, G., Akın, T. & Koçak, A. İ. (2020). Kentsel açık ve yeşil alanların mevcut yasal durumu ve uygulamadaki sorunlar. *Kent Araştırmaları Dergisi (Journal of Urban Studies) İdeal Kent, Kentleşme ve Ekonomi Özel Sayısı,* Cilt Volume 11, Yıl Year 2020-3, 1281-1312, ISSN: 1307-9905 E-ISSN: 2602-2133DOI:10.31198/idealkent.650461

Turizm Proje Dergisi, (2021). Antalya Turizm Sezonunu Uzatıyor: İlk 9 Ayda 14 Milyon Ziyaretçi. https://www.turizmprojedergisi.com/haber-detay/antalya-turizm-sezonunu-uzatiyor-ilk-9-ayda-14-milyon-ziyaretci/5801#:~:text=Toplam%20Ziyaret%C3%A7i%3A%202025%20y%C4%B11%C4%B1n%C4%B1n%20ilk,milyon%2091%20bin%20318%20ki%C5%9Fi**).**

Türkiye İstatistik Kurumu. (2025). *Adrese Dayalı Nüfus Kayıt Sistemi Sonuçları, 2024*. https://data.tuik.gov.tr/Bulten/Index?p=Adrese-Dayali-Nufus-Kayit-Sistemi-Sonuclari-2024-53783 Access date: December 14, 2025.

Türker, B. H., & Gül, A. (2022). Kentsel açık ve yeşil alanlarının niceliksel analizi ve irdelenmesi: Uşak Kent Merkezi örneği, *Kent Akademisi Dergisi,* 15(4):2088-2109. https://doi.org/10.35674/kent.999451

WHO, (2017). Urban green spaces: A brief for action. p 11. https://www.euro.who.int/en Access date: December 14, 2025.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Assessment of Key Factors Sustainable Smart Cities

Ahmet FİDAN [1]

ORCID 1: 0000-0002-7390-4831
[1] Assist. Prof., Ordu University, Fatsa Faculty of Maritime Sciences, Department of Maritime Transportation and Management Engineering., Ordu-Türkiye
afidan@odu.edu.tr

Esra BAYIR [2]

ORCID 2: 0000-0002-2298-8326
[2] Assist. Prof., İstanbul Medipol University, Faculty of Fine Arts Design and Architecture, Department of Interior Architecture and Env Design, İstanbul-Türkiye
ebayir@medipol.edu.tr (Responsible Author)

Pelin KARAÇAR [3]

ORCID 3: 0000-0002-9469-3711
[3] Assist. Prof., İstanbul Medipol University, Faculty of Fine Arts Design and Architecture, Department of Interior Architecture and Env Design, İstanbul-Türkiye
pkaracar@medipol.edu.tr (Responsible Author)

Aysun Ferrah GÜNER [4]

ORCID 4: 0000-0003-4558-7952
[4] Assoc. Prof., İstanbul Medipol University, Faculty of Fine Arts Design and Architecture, Department of Architecture, İstanbul-Türkiye
afguner@medipol.edu.tr

Abstract

A sustainable smart city exemplifies urban sustainability, representing a desirable state where a city maintains its socio-ecological system balance through sustainable development. This long-term goal necessitates connecting scientific and social research on urban sustainability with technological innovations, institutional practices, and policy design. It also requires a long-term vision, an interdisciplinary approach, and a systems perspective addressing environmental, economic, and social issues. Sustainable smart cities have become understandable and manageable through new dynamic methods and urban science. They are crucial for optimizing operational functioning, management, planning, and governance in line with sustainable development goals. Smart buildings, characterized by energy efficiency, automation, data analytics, and sustainable design, are significant in shaping the smart urban environment. Technological innovations have transformed factor-driven urban development into innovation-driven systems and reduced inequalities between leading and mid-tier cities. However, uneven progress persists, particularly in mobility and infrastructure readiness. By conceptualizing the sustainable smart city as a technological system, this study identified 26 key factors across five infrastructure domains: smart energy, mobility, water, security, and waste management. The study identifies and examines these key factors through a holistic, multidimensional assessment framework derived from the literature review. Consequently, the potential of data-driven smart solutions, termed "environmentally data-driven sustainable smart cities," in advancing urban sustainability will be evaluated.

Keywords: Sustainability, smart city, technological innovation, sustainable smart city, smart systems.

1. Introduction

The acceleration of urbanization, climate change, and resource constraints have highlighted the need to transform cities into more sustainable, resilient, and data-driven systems. In this context, the concept of “smart cities” emerged, but over time, the necessity of integrating technology with sustainability goals has become increasingly emphasized.

Smart cities are characterized as resilient and inclusive urban areas developed collectively, utilizing various technologies and data to enhance the quality of life for all residents. They may

be regarded as cities excelling in six attributes: economy, populace, government, mobility, environment, and quality of life (Giffinger et al., 2007), (Figure 1).

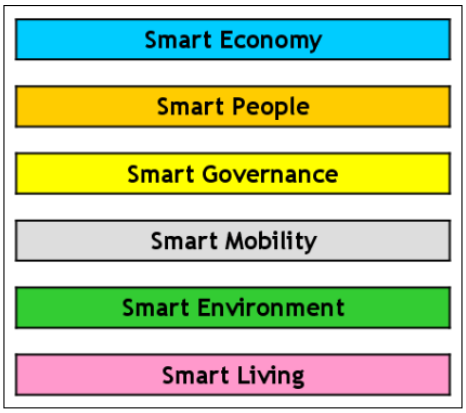


Figure 1. Characteristics of a smart city (Giffinger et al., 2007).

Currently, several nations are developing smart cities to address urban sustainability challenges. Information and Communication Technologies (ICT) are being used to address many fundamental issues such as traffic, pollution, overcrowding, energy, water, and poverty. The literature on sustainable cities encompasses approaches that aim to integrate the environmental, economic, and social dimensions of cities. Within this framework, the goals of resource efficiency, low-carbon infrastructure, social inclusiveness, and long-term livability are emphasized (Javidroozi et al., 2023). In particular, it is emphasized that cities must become systems that can be monitored and guided through indicators such as energy consumption, waste management, water use, and carbon emissions. In this context, sustainable cities are not solely about environmental solutions but also incorporate contributing factors such as social equity and economic vitality (Bibri, 2021).

Sustainable cities focus on renewable energy, water and electricity efficiency, compact urban design, building upgrades, green spaces, inexpensive transportation, and trash management and recycling systems. Urban areas in developing nations require resources to facilitate the transfer of green technologies and enhance capacity development. Furthermore, it is essential to enhance access to built housing, water, sanitation, power, healthcare, and education. Figure 2 illustrates the four principal pillars of sustainable cities and their prerequisites (Konbr, 2019)

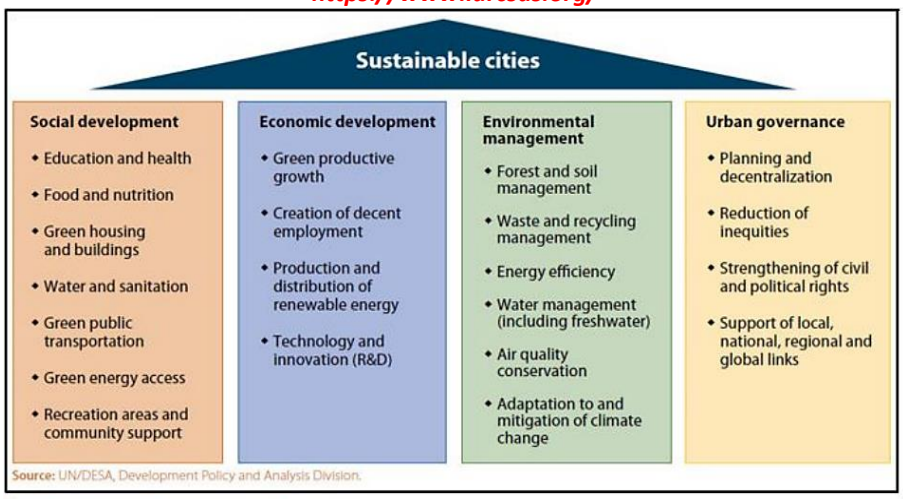


Figure 2. The four main pillars of sustainable cities (Konbr, 2019)

The acceleration of urbanization, the increasing impacts of climate change, and the narrowing of environmental boundaries related to resource use have brought to the forefront the need to transform cities into more sustainable, resilient, and data-driven systems (Ateş, 2024). Cities must now not only expand their infrastructure but also redesign it in an integrated manner from technological, environmental, and social perspectives (Angelidou, 2017). In this context, the concept of "smart cities" emerged; however, over time, the need to combine this technology-focused approach with sustainability goals has also been expressed (Javidroozi et al., 2023). In this process, the more effective role of data in city management has paved the way for new conceptual orientations such as "data-driven smart sustainable cities" (Bibri, 2021).

The concept of smart cities initially focused on optimizing infrastructure and services through information and communication technologies (ICT), sensor networks, big data, and IoT systems. On the other hand, sustainable city literature embraces broad approaches that combine environmental, social, and economic dimensions. City models at the intersection of these two streams-particularly those that combine environmental goals with technology and participation mechanisms-are increasingly emphasized in the literature (Toli and Murtagh, 2020).

In intelligent sustainable cities, an integrated and comprehensive urban planning model emphasizes the amalgamation of the advantages of sustainable and smart cities to enhance the creative, data-driven technologies provided by smart cities and their role in achieving sustainability objectives. (Bibri and Krgostie, 2020).

Due to the fact that the literatures on smart cities and sustainable cities have developed separately, there is a gap regarding the integration of these two movements. One concept that fills this gap is "smart sustainable cities". This paradigm proposes not only equipping cities with technology but also managing technology in tandem with sustainability goals (Kramers et al., 2014).

For a city to earn the label "smart," it must have an urban plan that both promotes sustainability and demonstrates urban resilience (Angelidou, 2017). In fact, it has been concluded that smart cities cannot be evaluated separately from sustainability, nor can sustainability be evaluated separately from urban resilience (Arafah et al., 2018). The Sustainable Smart Cities idea represents an innovative approach to the integration and discourse surrounding the application

of ICT in daily urban living. It assists in addressing escalating urbanization trends, including minimizing urban expenditures, controlling urban complications, enhancing quality of life, and augmenting energy efficiency. A smart city aims to improve environmental, social, and economic conditions. These constitute the fundamental foundations of sustainability. Consequently, it enhances sustainable urbanization. (Konbr, 2019).

This study has identified 26 key factors linking five infrastructure areas through the conceptualization of sustainable smart cities using a systems approach. These factors were identified and discussed through a literature review and focusing on the technological aspects that influence the incorporation of intelligent structures inside intelligent urban environments (Shahrabani and Apanavičienė, 2022).

2. Research Methodology

This study is primarily conceptual and theoretical, seeking to amalgamate existing knowledge and formulate a cohesive framework for comprehending sustainable smart cities. The principal methodology utilized is an exhaustive, critical literature review aimed at identifying, analyzing, and systematizing the essential technological factors that form the infrastructural foundation of sustainable smart cities. This method aligns with recognized academic standards for constructing conceptual models and theoretical frameworks in nascent, interdisciplinary domains like urban science and technology studies (Kitchin, 2014; Bibri, 2021). The research process was carried out in three methodical stages, detailed as follows and summarized: Collecting Literature, Defining the Scope, Thematic Analysis, Creating a Framework.

2.1. Scoping and Literature Collection

The first step was to figure out what the review would cover and find relevant scholarly work. To delineate the extensive intellectual landscape at the convergence of "smart cities" and "urban sustainability," with a particular emphasis on technological and infrastructural elements. A systematic search was conducted across major academic databases, including Scopus, Web of Science, and Google Scholar. The examine used Boolean operators with key term combinations like: ("smart city" OR "urban technology") AND ("sustainability" OR "sustainable development") AND ("infrastructure" OR "system"). The search was not limited by a strict start date, but it did focus on literature from the last twenty years to capture the evolution of the discourse. The review concentrated on peer-reviewed journal articles, foundational texts, and authoritative reports from international organizations. Key foundational works (e.g., Giffinger et al., 2007; Angelidou, 2017; Bibri & Krogstie, 2020) served as reference points to follow up on later research and find common themes.

2.2. Thematic Analysis and Finding Identification

During this analytical phase, the gathered literature was scrutinized to extract fundamental concepts and particular factors. A thematic analysis methodology was employed. This was an iterative process of closely reading, coding, and sorting the text data from the chosen sources. The first step was to tag passages that talked about technological solutions, infrastructure systems, and integration problems in the context of smart and sustainable cities. "Energy storage," "mobility-as-a-service," "water monitoring," and "integrated security" were some of the codes that came up the most. After that, these codes were put into larger, more coherent groups based on things they had in common and the functions they served. This inductive process naturally led to the emergence of five core infrastructural domains: Smart Energy,

Smart Mobility, Smart Water, Smart Security Systems, and Smart Waste Management. For each domain, specific, actionable technological factors were listed, which led to the discovery of the 26 key factors that are important to this study. This classification corresponds with the perspective of the city as a complex technological system consisting of interdependent subsystems (Hämäläinen & Tyrväinen, 2018; Shahrabani & Apanavičienė, 2022).

2.3. Framework Synthesis and Conceptualization

The last step was to put all the findings together into a clear conceptual model. The five domains and the 26 factors that make them up were put together to show how they are connected and how they all work together to make the city's "digital nervous system." This synthesis goes beyond just listing things. It suggests a systems-based framework where factors don't stand alone but work together within and across domains. The integrated conceptual framework shown in Figure 3 is the main result of this methodological process. This framework shows the sustainable smart city as a technological system, with the five infrastructure areas acting as pillars and the 26 key factors connecting them. It provides a structured way to look at all the technological aspects of urban sustainability. This method makes it clear and easy to go from looking at a lot of different sources to creating a specific, factor-based conceptual framework. This meets the study's goal of evaluating sustainable smart cities by figuring out what their most important technological parts are.

3. Key Factors of Sustainable Smart Cities

A sustainable smart city requires adopting a systems perspective that addresses environmental, social, and economic variables as a city's long-term goal. In this study, the concept of a smart city is approached as a system based on establishing an organic connection between all components and factors of the complex urban system. The city is conceptualized as an urban ecosystem that integrates physical, institutional, and digital domains by revealing aspects such as interconnection, feedback, self-organization, and adaptation to enable the understanding of spontaneous growth, functioning, and evolution. This systems approach aims to help cities and their stakeholders implement robust smart city initiatives and develop sustainable smart city ecosystem designs (Hämäläinen and Tyrväinen, 2018). In this study, the sustainable smart city is conceptualized as a technological system, and this approach strengthens the link between new technological developments and increasing responsibility (Kitchin, 2014).

With the conceptualization of sustainable smart cities as technological systems, the study identified 26 key factors affecting the integration of smart buildings into smart cities across five fundamental infrastructure areas (Shahrabani and Apanavičiene, 2022). The impact factors identified for the integration of smart buildings into smart cities are presented and discussed with a focus on the following key infrastructure areas:

- Smart energy
- Smart mobility
- Smart water
- Smart security systems
- Smart waste management

These five infrastructure areas form the five pillars of the city's digital nervous system.

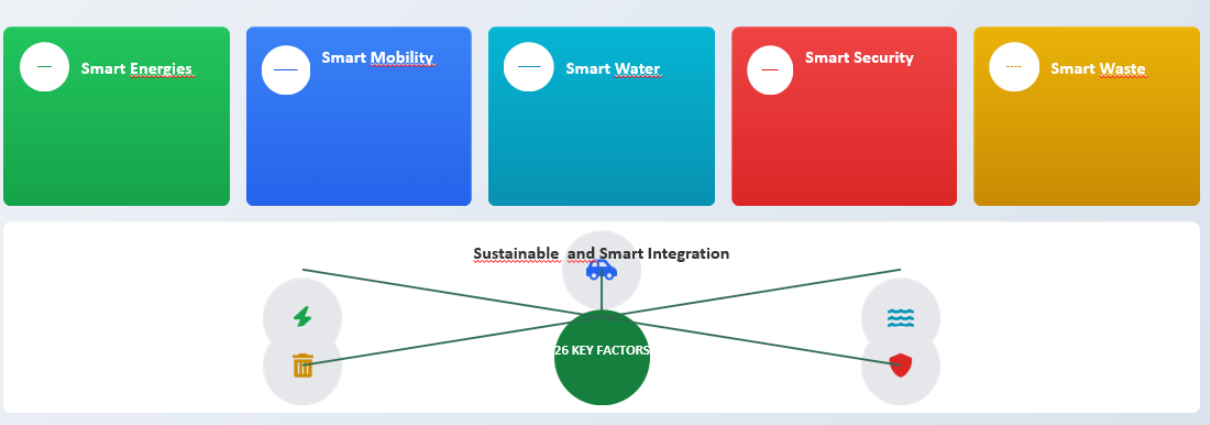


Figure 3. Conceptualized using a systems approach, sustainable smart cities form an integrated structure with 26 key factors connecting these five infrastructure areas.

3.1. Smart energy systems

Smart energy systems emphasize energy efficiency, automation, and the use of sustainable energy sources. Smart energy systems aim to save energy, reduce CO^2 emissions through lower energy consumption, and increase renewable energy sources (Tan et al., 2021). To reach energy resilience and decarbonization goals on a citywide level, these systems need to work together. For example, modern smart grids use advanced metering infrastructure (AMI) and real-time data analytics to dynamically balance supply and demand. They also include distributed energy resources like rooftop solar panels and community battery storage (Zhou et al., 2023). The Peña Station NEXT development in Denver, Colorado, USA, is a well-known example. It is a microgrid that combines solar generation, battery storage, and smart building controls to achieve net-zero energy performance and provide grid services. This shows how a localized smart energy ecosystem can work and be useful in a larger urban setting (Smith & Brown, 2022).

1. Electrical energy storage (battery)
2. Sharing electrical energy storage
3. Ability to work off-grid (renewable energy source: solar wind)
4. Energy use monitoring and control, demand-side management
5. Smart heating, cooling, and hot water preparation
6. Thermal energy storage
7. Sharing thermal energy storage

3.2. Smart mobility

The smart mobility component supports ICT-enabled transportation systems and is related to urban logistics and infrastructure. Smart mobility is designed to reduce traffic congestion, promote sustainable mobility, and increase the accessibility of public transportation (Zapolskyte et al., 2020). This field is quickly moving away from static management and toward Mobility-as-a-Service (MaaS) ecosystems. These ecosystems bring together different types of transportation (public transit, ride-sharing, bike-sharing, and e-scooters) into one user-friendly digital platform. These kinds of platforms use real-time data, IoT sensors, and AI-driven

analytics to find the best routes, predict demand, and make multimodal trips easier, which means people don't have to rely on their own cars as much (Jittrapirom et al., 2022). The "Whim" app in Helsinki, Finland, is one of the best real-world examples. It lets users plan, book, and pay for all types of urban transportation with just one monthly subscription or pay-as-you-go model. This system shows how data-driven integration can change how people use transportation to make it more efficient and environmentally friendly. It sets a standard for smart mobility integration around the world (Helsinki Region Transport, 2023).

- Smart Electric Vehicles (EV) charging
- Carpooling–ride sharing
- Smart parking management system (E-parking)
- Sharing parking space
- Online video surveillance
- Last mile driving

3.3. Smart water management

The field of water management focuses on optimizing resource consumption and ensuring environmental sustainability. Smart water management purpose to use efficient water resources, wastewater management, and environmental protection (Oberascher et al., 2022). This is becoming more and more important because of climate change and the stress on urban water supplies. Modern systems use a network of smart sensors, IoT devices, and predictive analytics to keep an eye on water quality in real time, find leaks in the distribution network before they happen, and improve irrigation and consumption patterns (Mukhopadhyay & Suryadevara, 2023). The "CityTaps" smart prepaid water meter system in Niamey, Niger, is a groundbreaking example. This solution uses hardware (IoT meters), software, and mobile payment to give low-income households access to clean water 24 hours a day, seven days a week. It also helps the utility reduce non-revenue water (NRW) by finding leaks quickly and collecting more money. This case shows how smart water technology can help with sustainability, fairness, and utility operational efficiency all at the same time in a difficult urban setting (CityTaps, 2022).

- Smart water mixtures
- Smart water monitoring and shutoff
- Smart water irrigation system
- Smart water meter
- Greywater recycling
- Rainwater collection (harvesting) and reuse

3.4. Smart security systems

Smart security systems cover individual security, public safety, and security. Smart security systems point to maximize services for city users while also controlling security (Khairuddin et al., 2021). The growth in this domain is marked by a shift from disconnected monitoring to connected, anticipatory security ecosystems. These environmental systems leverage AI-powered video analytics, bullets identification sensors, crowdsourced data from citizens, and

cooperation with emergency reply platforms to enable proactive threat detection, real-time situational awareness, and faster incoming resolution (Kumar et al., 2023).

The "Safe City" project in Singapore is a good example of a full implementation. It connects more than 110,000 police cameras to data analytics platforms, drone surveillance, and mobile apps that let citizens report crimes. This system utilizes video analytics for gather monitoring and identifying anomalies, and connects effortlessly with emergency services, creating a multi-layered, data-driven security infrastructure which boosts both proactive policing and public trust (Singapore Police Force, 2023).

- Smart monitoring and data analytics of the surrounding environment
- Smart fire management
- Disaster event communication management
- Smart security lightning
- Integrated sensors solutions

3.5. Smart waste management

Smart waste management aims to ensure the sustainable management of natural resources and reduce pollution and effective waste management (Shukla and Hait, 2022). It marks a big change from traditional collection systems that are based on schedules to ones that are based on data and respond to demand. Cities can save a lot of money, gas, and greenhouse gas emissions by using smart bins with fill-level sensors, vehicles with GPS, and AI-powered route optimization software. These systems make it possible to change collection routes on the fly, stop bins from overflowing, and give useful information for planning ways to reduce waste and improve recycling rates (Zaman & Lehmann, 2023). The system used in Seoul, South Korea, is a good example of a large-scale implementation. The city has put in thousands of smart bins in public places. These bins automatically compact trash and send real-time fill status to a central management platform. This information is used to make truck dispatch more efficient, which can cut down on collection frequency by up to 40% in some areas and make the city's waste management operations much more efficient and environmentally friendly (Seoul Metropolitan Government, 2023).

- Smart waste containers
- Automated and robotic waste collection

These core component are not only engineering projects but also architectural and design elements that directly shape the urban experience.

4. Conclusion

This study was designed to evaluate the essential infrastructural aspects of sustainable smart cities via a methodical integration of existing literature. The study sought to unify the frequently disparate discussions surrounding smart urban technologies and long-term urban sustainability by conceptualizing the city as an integrated technological system, thereby offering a structured framework for comprehending their intersection.

The main result of this in-depth study is the identification and grouping of 26 key technological factors into five key infrastructure areas: Smart Energy, Smart Mobility, Smart Water, Smart Security Systems, and Smart Waste Management. These fields work together to make up the

operational backbone, or "digital nervous system," of a smart city that will last. The framework shows that individual innovations, like smart grids, charging stations for electric cars, intelligent water meters, and automated waste collection, should not be seen as separate things but as parts of a whole that work together to make cities more efficient, resilient, and environmentally friendly. This focused analysis also delineates a clear boundary: the framework is predominantly concerned with technological and infrastructural factors. This makes governance, social equity, citizen participation, and financial models stand out as important areas that need to be integrated with the framework for comprehensive urban development.

The results provide substantial dual contributions. In theory, this work brings together bits of information into a single model, directly filling the gap in the literature about how to combine smart and sustainable city ideas. In practice, the derived framework is an important diagnostic tool and strategic plan for people who work in cities. It gives policymakers and planners a list of things to check to make sure that all technologies are covered and that their plans are in line with sustainability goals. It stresses the need for technology developers and urban planners to make solutions that work together in this larger, interconnected urban ecosystem. This will help them build cities that can meet the needs of a growing urban population.

It is essential to recognize the constraints inherent in the scope and methodology of this study. First, as stated, the framework is deliberately focused on technology, providing a comprehensive overview of infrastructural elements while neglecting the equally significant socio-economic, cultural, and governance factors that influence the success and fairness of smart city projects.

Second, the study offers a conceptual framework developed from literature synthesis; it does not provide a ready-to-use assessment methodology with specified metrics or weightings, nor does it empirically validate the relative significance or interdependence of the identified factors through case-specific analysis.

These constraints delineate a definitive agenda for forthcoming research. Future research should concentrate on the operationalization of this framework through the creation of precise assessment indicators and metrics. The next step is to test the framework's relevance and adaptability by using it in real-life situations in specific cities. Additionally, research needs to grow to include the non-technological parts of sustainability. It is important to use methods like Multi-Criteria Decision Making (MCDM) to look at the 26 factors' priorities, weightings, and cause-and-effect relationships.

Lastly, it is important to investigate the social acceptance, economic viability, and inclusive governance models needed to put these technological solutions into action. The successful realization of sustainable smart cities ultimately depends on a synchronized strategy that combines advanced technology with robust governance and inclusive design. This study offers a foundational overview of the technological landscape, seeking to facilitate more cohesive and efficient strategies for developing resilient and sustainable urban futures.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Angelidou, M. (2017). Shortcomings to smart city planning and development. *Tema*, 10 (1), 77–93.

Arafah, Y., Winarso, H., & Suroso, D. S. A. (2018). Towards smart and resilient city: A conceptual model. *IOP Conference Series: Earth and Environmental Science*, 158 (1), Article 012045. https://doi.org/10.1088/1755-1315/158/1/012045

Ateş, M. (2024). Akıllı şehir, kentsel direnç ve sürdürülebilirlik arasındaki ilişki: kentsel planlama için çıkarımlar. *Journal of Planning, Architecture and Design,* 2(1-2), 1–19.

Bibri, S. E., & Krogstie, J. (2020). Environmentally data-driven smart sustainable cities: Applied innovative solutions for energy efficiency, pollution reduction, and urban metabolism. *Energy Informatics*, 3, Article 29. https://doi.org/10.1186/s42162-020-00130-8

Bibri, S. E. (2021). Data-driven smart sustainable cities of the future: New conceptions of and approaches to the spatial scaling of urban form. *Future Cities and Environment,* 7(1), Article 4. https://doi.org/10.5334/fce.120

CityTaps. (2022). *Impact Report: Smart Water for Sustainable Cities*. CityTaps SAS. Retrieved from https://www.citytaps.org/reports

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., & Meijers, E. (2007). Smart cities: Ranking of European medium-sized cities. Centre of Regional Science, Vienna University of Technology. http://www.smart-cities.eu/download/smart_cities_final_report.pdf

Hämäläinen, M., & Tyrväinen, P. (2018). Improving smart city design: A conceptual model for governing complex smart city ecosystems. Proceedings of the 51st Hawaii International Conference on System Sciences. https://doi.org/10.24251/HICSS.2018.642

Javidroozi, V., Carter, C., Grace, M., & Shah, H. (2023). Smart, sustainable, green cities: A state-of-the-art review. *Sustainability,* 15(6), 5353. https://doi.org/10.3390/su15065353

Jittrapirom, P., Marchau, V., & van der Heijden, R. (2022). The future of Mobility-as-a-Service: A Delphi study identifying key uncertainties and research needs. *Transportation Research Part A: Policy and Practice, 165*, 1-18. https://doi.org/10.1016/j.tra.2022.08.001

Helsinki Region Transport (HSL). (2023). *Mobility as a Service (MaaS) – The Helsinki Region Model*. Retrieved from https://www.hsl.fi/en/about-us/mobility-service-maas

Khairuddin, M., Shahbudin, S., & Kassim, M. A. (2021). Smart building security system with intelligent face detection and recognition. *IOP Conference Series: Materials Science and Engineering,* 1088 (1), Article 012004. https://doi.org/10.1088/1757-899X/1088/1/012004

Kitchin, R. (2014). Making sense of smart cities: Addressing present shortcomings. Cambridge Journal of Regions, Economy and Society, 8 (1), 131–136. https://doi.org/10.1093/cjres/rsu027

Konbr, U. (2019). Smart sustainable cities—Vision and reality. In M. N. AbouElsoud & I. M. Elrayies (Eds.), Towards green cities in developing countries (Vol. 2, pp. 101–127). International Experts for Research Enrichment and Knowledge Exchange (IEREK).

Kramers, A., Höjer, M., Lövehagen, N., & Wangel, J. (2014). Smart sustainable cities: Exploring ICT solutions for reduced energy use in cities. *Environmental Modelling & Software,* 56, 52–62. https://doi.org/10.1016/j.envsoft.2013.12.019

Kumar, A., Goyal, S., & Singh, P. (2023). AI and IoT-driven frameworks for proactive urban security in smart cities: A systematic review. *Sustainable Cities and Society, 91*, 104468. https://doi.org/10.1016/j.scs.2023.104468

Mukhopadhyay, S. C., & Suryadevara, N. K. (2023). Internet of Things for sustainable water management: Architectures, protocols, and applications. *IEEE Internet of Things Journal, 10*(5), 4321-4335. https://doi.org/10.1109/JIOT.2022.3223456

Oberascher, M., Rauch, W., & Sitzenfrei, R. (2022). Towards a smart water city: A comprehensive review of applications, data requirements, and communication technologies for integrated management. *Sustainable Cities and Society*, 76, 103442. https://doi.org/10.1016/j.scs.2021.103442

Seoul Metropolitan Government. (2023). *Smart Seoul: Waste Management Innovation Report*. Retrieved from https://smart.seoul.go.kr/en/

Shahrabani, M. M. N., & Apanavičienė, R. (2022). Towards integration of smart and resilient city: Literature review. *IOP Conference Series: Earth and Environmental Science,* 1101(6), Article 062010. https://doi.org/10.1088/1755-1315/1101/6/062010

Shukla, S., & Hait, S. (2022). Smart waste management practices in smart cities: Current trends and future perspectives. *In Advanced Organic Waste Management* (pp. 407–424). Elsevier. https://doi.org/10.1016/B978-0-323-85792-5.00023-4

Singapore Police Force. (2023). *SPF Annual Report 2022: Harnessing Technology for a Safer Singapore*. Singapore Police Force. Retrieved from https://www.police.gov.sg/News-Room/Annual-Reports

Smith, J. A., & Brown, K. L. (2022). Peña Station NEXT: A case study in net-zero energy district development and smart grid integration. *Sustainable Cities and Society, 76*, 103521. https://doi.org/10.1016/j.scs.2021.103521

Tan, K. M., Babu, T. S., Ramachandaramurthy, V. K., Kasinathan, P., Solanki, S. G., & Raveendran, S. K. (2021). Empowering smart grid: A comprehensive review of energy storage technology and application with renewable energy integration. *Journal of Energy Storage*, 39, 102591. https://doi.org/10.1016/j.est.2021.102591

Toli, A. M., & Murtagh, N. (2020). The concept of sustainability in smart city definitions. *Frontiers in Built Environment,* 6, Article 77. https://doi.org/10.3389/fbuil.2020.00077

Zaman, A., & Lehmann, S. (2023). The Internet of Things (IoT) for smart waste management: A comprehensive review of technologies, benefits, and challenges. *Waste Management, 162*, 1-12. https://doi.org/10.1016/j.wasman.2023.02.017

Zapolskyte, S., Burinskiene, M., & Trépanier, M. (2020). Evaluation criteria of smart city mobility system using MCDM method. *The Baltic Journal of Road and Bridge Engineering,* 15(4), 196–224. https://doi.org/10.7250/bjrbe.2020-15.496

Zhou, Y., Wang, L., & McCalley, J. D. (2023). The role of smart grids in integrating renewable energy: A comprehensive review of technologies and frameworks. *Renewable and Sustainable Energy Reviews, 178*, 113245. https://doi.org/10.1016/j.rser.2023.113245

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Child-Friendly Street Designs in Urban Areas

Habibe ATAK[1]*

ORCID 1: 0009-0001-0744-470X
[1] Master's student, Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, Niğde-Türkiye
habibe.atakk@gmail.com

Gülbin ÇETİNKALE DEMİRKAN [2]

ORCID 2: 0000-0003-2283-3460
[2] Assoc. Dr., Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, Niğde-Türkiye
gcetinkaledemirkan@ohu.edu.tr (Corresponding author)

Abstract

Child-friendly streets are defined as accessible public spaces where children can safely walk around, play, and explore their surroundings. The spatial functionality and accessibility of streets determine children's interaction with the city. In child-centered urban approaches, elements such as child development, child participation, safety, accessibility, and the right to play are important. Insufficient play areas and traffic problems, along with dense urbanization, keep children away from outdoor spaces. This situation negatively affects children's development. Streets, which are heavily used by children in the context of public spaces and also serve as alternative play areas, form the focus of this study. Studies have been conducted on the role of street use in child development and the qualities that child-friendly streets should possess. The main objective of the study is to evaluate child-friendly streets at the national and international levels, examining them in terms of their compliance with child-friendly street criteria and assessing the effects of different planning and design approaches. In this context, the study outlines "child-friendly street" design criteria and provides visualizations based on these criteria.

Keywords: Child friendly city, urban area, design

1. Introduction

The increasing traffic problem associated with urbanization has led to the creation of unsafe spaces for movement on the streets that constitute children's living environments. The decline in green areas and the increase in concrete surfaces, which prevent children from establishing games that would allow them to socialize with their peers and contribute to their sensory, cognitive, and physical development, have over time weakened the child-city relationship and accelerated their dependence on the virtual world. This situation has revealed how crucial it is for children to have spaces within the city where they can socialize with their peers without leaving their immediate living environments. At this point, the concept of child-friendly cities has emerged, advocating for urban spaces that enable children to be more active in the city and contain areas that support their physical, social, and mental development. The concept of a child-friendly city aims to plan and create spaces in children's living environments and immediate surroundings where they can feel safe, play freely, and engage in activities that support their development (Churchman, 2003). Considering that the most frequently used spaces by children are homes, their immediate surroundings, schools, and playgrounds, the spaces children use and spend time in significantly influence their individuation process and behavioral psychology (Tandoğan, 2014; Karakuzu & Aksu, 2022). Therefore, designing or redesigning streets that can play an effective and healthy role in children's development according to their needs and desires is of great importance, and the emphasis on the concept of child-friendly streets needs to increase. With the growing awareness of the child-friendly street concept worldwide, it is possible to make the city more usable for children every day. In many countries, measures such as traffic restrictions and speed limits on streets have been

implemented. The primary goals of such applications are to develop play and exploration areas for children and to ensure that a significant portion of children's time is spent in safe, enjoyable, playful, and relaxing environments (Tandoğan, 2014; Collarte, 2014; Turan, 2020). The concept of child-friendly streets, which first appeared as "play streets" in 1938, was legalized by the United Kingdom and later adopted by Australia. It continues to be implemented in many cities in the USA as well (Sauer, 2024) (Figure 1).



Figure 1. Early Examples of Play Streets (URL-1, URL-2)

Based on the concept of play streets, these areas were created and began to proliferate in the 1970s with the support of neighborhood associations, aiming to preserve a social neighborhood culture while serving children and adolescents. Their numbers increased, particularly in densely populated areas, with the support of local institutions and organizations.

This study aims to provide information on the concept of child-friendly streets, highlight the importance of the topic, and raise awareness. In line with this objective, both domestic and international applications related to the subject are presented.

2. Child Friendly City

The creation of child-friendly environments is of paramount importance for enhancing urban resilience and supporting sustainability. However, as urbanization in our cities increases uncontrollably, the needs for children also rise, leading to imbalances between supply and demand in urban areas. This density in urban spaces has gradually reduced the interaction between humans and nature, weakening their connection. Simultaneously, due to technological advancements, environments have emerged that distance children from traditional forms of entertainment, restrict their movement spaces, reduce their physical activities, and negatively impact their physical and mental development (Engler et al., 2015; Witten et al., 2015; Bringolf-Isler et al., 2018; Chu et al., 2025). Furthermore, focusing solely on children's mental and academic development while neglecting behavioral patterns and psychological health has led to an increase in behavioral disorders. In the long term, this negatively affects learning processes, personal development, and character formation, pushing children towards antisocial behavior (Dong et al., 2025; Zhang et al., 2025).

Creating child-friendly urban areas is critically important for healthy child development. Due to the effects of rapid urbanization, primary spaces for children's activities, such as streets and pathways, are gradually disappearing. This situation highlights the urgency of improving urban planning to address children's needs in high-density areas. Recently, with a child-friendly approach, there has been a growing focus on regulating physical environmental factors of streets—such as walkability, traffic safety, green space levels, and infrastructure—to influence

children's travel behavior and safety perceptions. Thus, safe, healthy, and play-conducive environments will be created in streets and their immediate surroundings, positively impacting children's well-being. However, various limitations remain, such as the lack of children's inclusion in the planning process and the micro-scale nature of these efforts.

As stated in UNICEF's Convention on the Rights of the Child, the child-friendly city approach advocates for cities to be built without discrimination, prioritizing children's best interests, offering the right to life and optimal development, and respecting and considering their views and opinions. Therefore, it can be said that child-friendly cities adopt a governance approach based on children's rights (Riggio, 2002). The significance of this issue is also evident when health data is examined. Health data indicates an increase in childhood heart diseases, diabetes, and obesity (Hills et al., 2007; Mavrovouniotis, 2012). Consequently, urban planning policies and urban design guidelines should prioritize healthy and child-friendly urban environments.

3. Child-Friendly Street

The concept of child-friendly streets first gained attention with a street redesign implemented in the Netherlands in 1960. Known as "Woonerf," this intervention involved reducing vehicular traffic, creating a pedestrian-friendly, walkable environment, and encompassed everything from street furniture to overall road use to foster child-friendly spaces (Tandoğan, 2014; Aydoğan & Dilek, 2024). Following this example, various other applications have emerged in different regions worldwide.

In the United Kingdom, the concept was implemented under the name "Home Zone," based on the Woonerf system. Home Zones primarily focused on fostering socialization within the street, aiming to enhance the quality of life not only for children but for all users. Vehicle speeds were reduced to 10 km/h, and green spaces and areas for activities were allocated in front of residences, thereby enabling a wide range of activities and expanding the user base.

In Australia, this approach, initiated as "Shared Zones," is characterized as a street design focused on sharing and interaction, encompassing both pedestrians and vehicles (Figure 2).



Figure 2. Child-Friendly Street Example (a: Woonerf – URL-3; b: Home Zone - URL-4; c: Shared Zone – URL-5)

In Turkey, the child-friendly street approach has also been implemented, with designed streets present in many provinces such as Kocaeli, Sakarya, Bursa, and Tekirdağ. In some arrangements, traffic is completely closed off and the space is dedicated to children, while in others, streets are closed to traffic during specific hours (Figure 3).



Figure 3. Child-Friendly Street Implementations in Turkey (URL-6)

In child-friendly street designs, basic needs must be prioritized. By ensuring streets are safe, accessible, and provided with adequate infrastructure, users should be offered secure spaces where they can interact, engage in physical activity, and relax. Applications should be incorporated that allow children to ride bicycles, enable families to socialize, promote walkability, and enhance interaction with nature—thereby shifting children's engagement, even if slightly, from the virtual world to interaction with the real world.

4. Conclusion and Recommendations

Today, the rapid evolution of cities towards high-density development models, a planning approach prioritizing motorized vehicle traffic, and lifestyle changes brought about by digitalization have emerged as primary factors threatening children's physical and mental health. Current urban strategies fail to adequately realize the potential to redefine streets beyond mere transportation corridors as social and inclusive public spaces. This situation restricts children's freedom of active mobility, promotes sedentary lifestyles, and consequently paves the way for health issues such as obesity and respiratory diseases. Research demonstrates that child-friendly street design is not merely a matter of urban aesthetics; rather, it is of vital importance for children's physical activity, mental well-being, social development, and the construction of a sense of independence.

Children, who will be the adults of the future, will make a meaningful contribution to raising socially, cognitively, mentally, psychologically, and physically healthier individuals by connecting with the physical environment and nature, through the creation of safe public spaces, familiar environments that promote social cohesion, and pedestrian-friendly streets that support active transportation. To guide policies aimed at promoting walkable and child-friendly cities, a swift transition to spatial interventions targeting children's health and well-being is necessary for policymakers, and children must be included in the planning and design process. Greater emphasis must be placed on the issues of children's inadequate play in open and nearby spaces and social isolation. In the face of increasing urbanization, new urban arrangements must be implemented that also take children into account.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Bringolf-Isler, B., De Hoogh, K., Schindler, C., Kayser, B., Suggs, L.S., Dössegger, A., Probst-Hensch, N., Group, S.S. (2018). Sedentary behaviour in Swiss children and adolescents: Disentangling associations with the perceived and objectively measured environment. *Int. J. Environ. Res. Public Health* 15, 918.

Chu, M., Fang, Z., Lee, C.-Y., Shang-Kuan, C.-H., Mao, L., Chiang, Y.-C. (2025). Building a child-friendly social environment from the perspective of children in China based on focus group interviews. *Curr. Psychol*. 44, 2001–2017.

Churchman, A. (2003) "Is There a Place for Children in the City?", *Journal of Urban Design,* Vol. 8 No. 2, pp. 99111, June 2003. 11.

Collarte, N. (2012) The Woonerf Concept "Rethinking a Residential Street in Somerville", Master of Arts in Urban and Environmental Policy and Planning, Tufts University, Cambridge.

Dong, W., Liu, Y., Bai, R., Zhang, L., Zhou, M. (2025). The prevalence and associated disability burden of mental disorders in children and adolescents in China: A systematic analysis of data from the Global Burden of Disease Study. *Lancet Reg. Health–West. Pac.* 55, 101486.

Ergler, C., Smith, K., Kotsanas, C., Hutchinson, C. (2015). What makes a good city in pre-schoolers' eyes? Findings from participatory planning projects in Australia and New Zealand. *J. Urban Des.* 20, 461–478.

Hills, A.P., King, N.A., Armstrong, T.P., (2007). The contribution of physical activity and sedentary behaviours to the growth and development of children and adolescents. *Sports Medicine,* 37 (6), 533–545.

Karakuzu, E., Aksu, G., A., (2022). Çocuk Dostu Kent Kavramının Çocuk – Oyun – Mekan İlişkileri ve Paydaşlar Çerçevesinde Değerlendirilmesi. *Journal of Technology and Applied Sciences* 4(2), 147-156

Mavrovouniotis, F., (2012). Inactivity in childhood and adolescence: a modern lifestyle associated with adverse health consequences. *Sport Science Review*, 21 (3–4), 75.

Riggio, E. (2002). *Child Friendly Cities: Good Governance in the Best Interests of the Child*. *Environment&Urbanization,14*(2). http://www.bvsde.paho.org/bvsacd/cd26/enurb/v14n2/45.pdf Access date: [07.03.2018]

Sauer, M. (2024). Children are stuck indoors. Play Streets could get them back outside. The Washington Post, Opinion. Access date: https://www.washingtonpost.com/opinions/2024/01/08/play-streets-children-safety-outdoors/ Access date: 04.04.2024.

Tandoğan, O. (2014). Çocuk için daha yaşanılır bir kentsel mekân: Dünyada gerçekleştirilen uygulamalar. *Megaron Dergisi*, 9(1), 19–33.

Turan, E. (2020). Çocuk dostu kent açısından Çanakkale Belediyesi uygulamalarının değerlendirilmesi (Yüksek Lisans Tezi). Çanakkale Onsekiz Mart Üniversitesi, Türkiye.

Witten, K., Kearns, R. (2015). Carroll, P. Urban inclusion as wellbeing: Exploring children's accounts of confronting diversity on inner city streets. *Soc. Sci. Med*. 133, 349–357.

Zhang, M., Nie, Q., Ye, W., Wang, Y., Yang, Z., Teng, Z. (2025). Longitudinal dynamic relationships between videogame use and symptoms of gaming disorder and depression among Chinese children and adolescents. *J. Youth Adolesc.* 54, 426–438.

URL-1. https://welovelb.org/2020/03/03/the-birth-of-play-streets/ (Access date: 15.10.2025)

URL-2. https://pedestrianliberation.org/2012/07/25/play-streets/ (Access date: 15.10.2025)

URL-3. https://ithacating.com/2014/05/06/news-tidbits-5614-inhs-wants-woonerfs/ (Access date: 20.10.2025)

URL-4. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://nacto.org/wp-content/uploads/home_zones_department_transport.pdf (Access date: 20.10.2025)

URL-5. Shared Zone https://www.vta.org/cdt/street-design-home-page/shared-street-woonerf (Access date 20.10.2025)

URL-6. https://www.arkitera.com/haber/sokaklar-cocuklar-icin-donusuyor/#goog_rewarded (Access date: 20.10.2025)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Healing Garden Designs as Supportive Elements in Oncology Hospitals

İpek İPEKLİ [1]

ORCID 1: 0009-0009-8583-180X
[1] Master's student, Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, Niğde-Türkiye
ipek63ipekli@gmail.com

Gülbin ÇETİNKALE DEMİRKAN [2]

ORCID 2: 0000-0003-2283-3460
[2] Assoc. Dr., Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, Niğde-Türkiye
gcetinkaledemirkan@ohu.edu.tr (Corresponding author)

Abstract

Healing gardens are areas that strengthen communication between the individual and nature, feature natural elements prominently, contribute to the reduction of stress, and enhance the quality of life. User groups are among the most important guiding factors in the design of healing gardens, which have a history extending from the Middle Ages to the present day. In areas where the user group specifically consists of hospital users, gardens designed with the aim of contributing to the recovery process can support individuals' psychological and spiritual well-being by distancing users from environmental stress. In this context, the physical environment in which cancer patients, who are in most need of psychological support during treatment, find themselves due to the ailment they are exposed to, is highly significant for them. Their adaptation to the hospital and feeling well in their environment can lead to progress in the recovery process in psychological, social, and physical terms. Within this scope, a healing garden design was developed in the study for the open and green space of an oncology hospital, based on the area's users. The study aimed to reveal the importance of hospital gardens for oncology patients and to develop a design that includes healing garden design criteria for oncology hospitals, which can meet the spiritual, physical, and social needs of the users. At the oncology hospital studied, interviews were conducted with hospital users, and based on their expectations, needs, and requests, recommendations to support the psychological recovery process were developed, guiding the designs. In the study, 2-dimensional designs were prepared using the Autocad 2022 program, and 3-dimensional modeling was performed using Sketchup 2023 and Lumion 2025 programs, and the final reports were shared with the hospital administration.

Keywords: Healing garden, oncology hospital, landscape design, Diyarbakır

1.Introduction

The concept of "healing" refers to positive changes and improvements in an individual's health condition. This process is a state where the person feels well both spiritually and physically. Throughout history, people have continued to benefit from nature. Therapeutic gardens, which are reported to have started with monastery gardens used for functions similar to hospitals, have a deep-rooted history based on Roman, Greek, and Asian cultures (Akpınar Külekçi & Sezen, 2020; Akpınar Külekçi & Yazıcı, 2021). It can be argued that gardens support recovery processes and shorten treatment times due to their many features. Being in contact with nature or in environments reminiscent of nature, benefiting from sunlight, seeing plants, listening to animal sounds, and being aware of natural elements in the garden can create stress-reducing effects on patients and contribute to the healing process (Lani Alaine Gerity, 1998; Akın, 2006; Hussein, 2010; Demirel & Pouya, 2017; Çetinkale Demirkan, 2019).

Considering that humans have benefited from the possibilities of nature since their existence, it is evident that therapeutic gardens have a deep-rooted past. Looking at Turkish history, it is known that courtyards were surrounded by plants, and patients were treated in rooms within

them, while music was also used for therapeutic purposes. Furthermore, in history, Far Eastern gardens, used for meditation to relax, have been shown to be effective in solving many spiritual problems. It is also known that Zen gardens have positive effects in alleviating depression (Akpınar Külekçi & Sezen, 2020; Akpınar Külekçi & Yazıcı, 2021). In this regard, it is possible to speak of the healing properties of gardens created for different purposes.

When examining approaches to therapeutic garden design, different theories stand out: Kaplan's Theory, which states that designs should be based on criteria such as complexity, coherence, legibility, and mystery, allowing users to understand the environment, as well as escape, size, attractiveness, and compatibility; Marcus and Barnes' Theory, which suggests that gardens should offer elements such as privacy, socialization, the allure of nature, activity, sun-shade areas, walking opportunities, accessibility, comfort, and recognition to provide emotional support to users; and Ulrich's Theory, which advocates for creating natural environments that reduce stress and are psychologically, behaviorally, and physiologically beneficial. However, at the core of all approaches, it is emphasized that therapeutic garden designs should include area diversity, spaces specific to user groups, density of green areas, opportunities for physical activity, stimuli that aid concentration, protection from external stimuli, and easily understandable, positive designs (Ulrich, 1984; Kaplan & Kaplan, 1990; Ulrich et al., 1991; Marcus & Barnes, 1999; Marcus, 2007).

Looking at therapeutic gardens in oncology hospitals, it is observed that a multifunctional and flexible design approach dominates. Courtyard gardens, window views dominating indoor spaces, habitats attracting wildlife, and a focus on relaxation and tranquility are prevalent (Figure 1, Figure 2). In these areas, which are used not only by patients but also by caregivers and staff, designs incorporate elements such as water features, dense green areas, unique landscapes, and natural sounds to utilize the curative power of nature in reducing anxiety and stress (Figure 3). It is notable that social spaces are created where users can socialize not only with their companions but also with other users, and area usage options are varied (Figure 4).



Figure 1. Upper Chesapeake Cancer Center (Url-1)



Figure 2. Upper Chesapeake Cancer Center (Url-2)



Figure 3. Yale New Haven Smilow Cancer Hospital (Url-3)



Figure 4. Garden areas for dementia and alzheimer patients (Url-4)

In addition to many other illnesses, the physical environment in which cancer patients find themselves is extremely important due to the condition they face. Because of the process they are undergoing, hospital gardens designed for them play a significant role in helping cancer patients adapt to the hospital, feel better, and experience social, psychological, and physical development.

This study aims to demonstrate the importance of hospital gardens for oncology patients and to develop a design that includes therapeutic garden design criteria for oncology hospitals, capable of meeting the mental, physical, and social needs of users.

In hospital garden design, the interaction of people with the space, aligned with their needs, holds particular importance. The most crucial feature that distinguishes hospital gardens from other gardens is that these areas are designed to support patients' treatment processes (Hussein, 2012). Therefore, when designing a hospital garden, planning and design have been guided to meet the needs of the area's users, based on the user profile of the cancer hospital.

2.Material and Methods

a. Material

The main subject of the study is the Dicle University Oncology Hospital located in Diyarbakır. Diyarbakır province is situated in the Middle Euphrates Section of the Southeastern Anatolia Region and is one of the region's significant settlement centers. Geographically, it is surrounded by Elâzığ to the north, Bingöl and Muş to the northeast, Batman to the east, Mardin to the southeast, and Şanlıurfa to the southwest. Due to this location, Diyarbakır serves as a transitional area between both the Eastern Anatolia and Southeastern Anatolia regions. The Dicle University Oncology Hospital, located within the boundaries of Dicle University in the Sur district of Diyarbakır province, is a major healthcare institution treating approximately 10,000 cancer patients annually in the fields of medical and radiation oncology (URL-5) (Figure 5).



Figure 5. Diyarbakır City and Diyarbakır General View of the Oncology Hospital (Url- 6; Google Earth, 2025)

b. Methods

In the initial phase of the study, a comprehensive literature review was conducted on therapeutic gardens for oncology patients. This review examined the historical development, design principles, and international examples of therapeutic gardens. Furthermore, field observations were carried out in the study area, the Dicle University Oncology Hospital in Diyarbakır. After gathering detailed information about the study area, interviews were conducted with hospital users at the oncology hospital in question. Based on their expectations, needs, and desires, recommendations were developed to support the psychological recovery process, guiding the design proposals accordingly. In the study, 2D designs were prepared using AutoCAD 2022 software, and 3D modeling was performed using SketchUp 2023 and Lumion 2025 software. Through the proposed designs, the aim is to enhance the quality of life and the sense of well-being within the hospital and its surroundings.

3.Research Findings

The foundation of the study was to establish, within the therapeutic garden designed for oncology patients and other hospital users in the garden of Dicle University Diyarbakır

Oncology Hospital, not only a physical environmental arrangement but also a design that supports psychological, social, and emotional recovery. This aimed to highlight the importance of garden use for hospital users and to meet their mental, physical, and social needs (Figure 6).

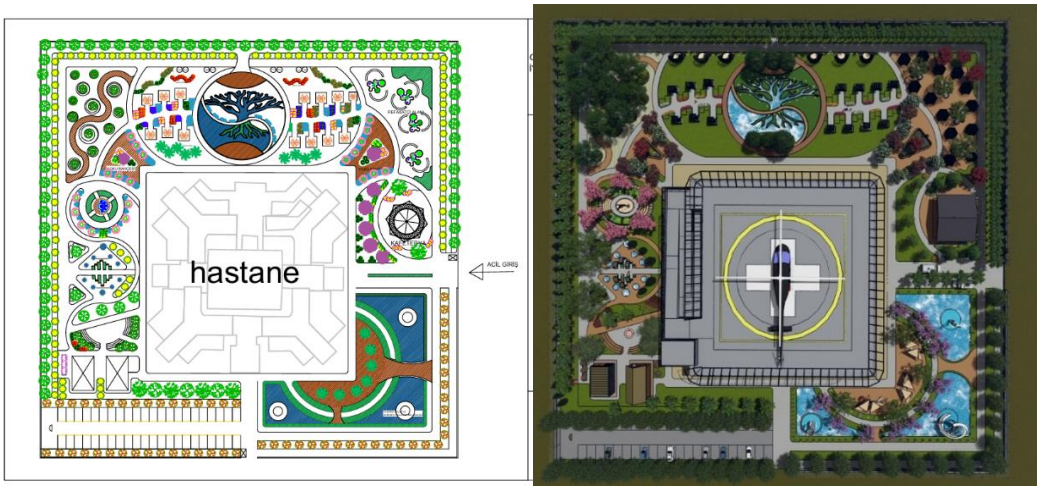


Figure 6. Views of the Therapeutic Garden Design for Diyarbakır Oncology Hospital (Produced by the authors, 2025)

In the designed area, two main entrances were arranged on the southern and eastern facades, with the eastern entrance designated for emergency access. To facilitate convenient transportation for hospital users, a 1,500 m² parking area was planned to the west of the southern entrance, surrounded by green space arrangements. To provide shade in these green areas, black locust (*Robinia pseudoacacia*) trees were selected (Figure 7).



Figure 7. 3D Views of The Hospital Garden's Parking and Entrance Areas (Produced by The Authors, 2025)

The focal point of the design is formed by a 2,500 m² grand plaza located to the north of the project, inspired by the concepts of the Yin-Yang symbol and the "Tree of Life". The Yin-Yang figure represents the balance of opposing forces in nature, while the Tree of Life, symbolizing the continuity of life and hope, has been incorporated into the project (Figure 8). The use of green space in one part of the plaza and a water feature in the other enhances the sense of integration with nature and contributes to patients' morale and motivation processes. Thus, the

design acquires the function of a space that serves not only as an aesthetic element but also as an environment fostering psychological balance and mental recovery.



Figure 8. 3D View of The Hospital Garden's Plaza (Produced by the Authors, 2025)

A cafeteria has been designed in a 435 m² area to the north of the project's eastern entrance. In the northeast of the project, a 745 m² area has been arranged with pergolas and planting islands placed on a wooden deck for caregivers and visitors. In the planting islands, linden tree (*Tilia tomentosa*) is surrounded by lavender (*Lavandula angustifolia*), rose (*Rosa* sp.), and chamomile (*Matricaria* sp.) (Figure 9).



Figure 9. 3D Views of The Hospital Garden's Cafeteria and Relaxation Area (Produced by The Authors, 2025)

To the west of the cafeteria area, within a 270 m² hardscape, a fragrance garden has been created in the integrated green spaces, designed to evoke the sensory experience of nature's seasonal transitions. In the fragrance garden, aromatherapeutic plants—lavender (*Lavandula angustifolia*), rosemary (*Rosmarinus officinalis*), thyme (*Thymus* sp.), and Japanese maple (*Acer palmatum*) were selected to stimulate users' sensory perceptions and provide mental relaxation. Along the edges of the fragrance garden's paths, pink and white-flowering crape myrtles (*Lagerstroemia indica*) were used as defining elements (Figure 10).



Figure 10. 3D View of The Fragrance Garden in The Hospital Garden (Produced by the Authors, 2025)

In the upper western section of the project, a 750 m² resting area has been planned for patients undergoing chemotherapy. In this area, shade zones have been created with plane trees (*Platanus orientalis),* surrounded by seating units (Figure 11). The reason for selecting the plane tree is its cultural association with the concepts of "family" and "trust," as well as its ability to foster a sense of psychological support in patients.



Figure 11. 3D View of The Hospital Garden's Resting Area (Produced by the Authors, 2025)

To the east of the resting area, green spaces have been incorporated within a 215 m² zone, where another fragrance garden is also located. In this garden, aromatherapeutic plants—lavender (*Lavandula angustifolia*), rosemary (*Rosmarinus officinalis*), thyme (*Thymus* sp.), and Japanese maple (*Acer palmatum*) have been selected. Along the paths of the fragrance garden, pink and white-flowering crape myrtles (*Lagerstroemia indica*) were used as border elements (Figure 12). The aim for users of this area is to stimulate their sensory perceptions and provide mental relaxation. On the southern side, a 160 m² plaza containing seating units has been designed (Figure 13).



Figure 12. 3D View of The Hospital Garden's Plaza Area (Produced by the Authors, 2025)



Figure 13. 3D View of The Fragrance Garden in the Hospital Garden's Plaza Area (Produced by the Authors, 2025)

In the eastern section of the southern entrance, a 2,086 m² area features a reflection pool, dynamic water sculptures, planting pits within hardscape, and seating areas. This space has been designed to function as a therapeutic environment, utilizing the visual and auditory effects of water to contribute to user relaxation. Integrated with lawn areas and wooden seating platforms, this section constitutes a stress-reducing open space arrangement (Figure 14).



Figure 14. 3D View of The Hospital Garden's Ornamental Pool and Seating Areas (Produced by the Authors, 2025)

In the southwestern corner of the project, art and sculpture studios have been designed in a 410 m² area, along with a 227 m² exhibition space. Thus, a social interaction area has been created where patients can express their creativity, demonstrate their productivity, and share their

works. This approach supports individual and communal healing in line with art therapy principles (Figure 15).



Figure 15. 3D View of The Hospital Garden's Performance Area and Art Studios (Produced by the Authors, 2025)

In the upper section, 230 m² of individual seating areas have been designed, surrounded by lavender (*Lavandula angustifolia*) shrubs to provide visual and auditory isolation. These areas offer patients the opportunity to spend time alone with nature (Figure 16).



Figure 16. 3D View of The Hospital Garden's Seating Area (Produced by the Authors, 2025)

The walking paths within the hospital garden are not only designed for recreational purposes but are also of a width suitable for wheelchair access and stretcher transport. Lighting elements have been placed on both sides of the paths, maintaining a clear path width of 2 m, and site furniture has been positioned in a way that does not reduce this clear width (Figure 17).



Figure 17. 3D View of The Hospital Garden's Walking Paths and Site Furnishings (Produced by the Authors, 2025)

Throughout the design of the hospital garden, created with a therapeutic garden approach, sharp corners have been avoided; a holistic aesthetic has been adopted through soft transitions and the use of natural materials. At the same time, requirements such as parking, emergency access,

and other technical infrastructure have also been considered. Across the entire area, designs have been incorporated to provide users with psychological and physical support, aimed at reducing stress and anxiety. Enriched with elements of nature, art, and social interaction, this design aims to support the emotional and physical healing processes of oncology patients. With this project, the intention is to present a garden arrangement that is compliant with therapeutic landscape design principles, accessible, user-centered, and multifunctional.

4.Conclusion and Recommendations

The positive effects of nature on human health have led to the emergence of therapeutic gardens in various forms throughout history. Therapeutic gardens are open and green spaces that support physical, sensory, and mental health, aim to enhance quality of life, and seek to reconnect users with nature by distancing them from stress. They are restorative and enabling gardens focused on improving psychological health by providing a peaceful and calming environment that helps reduce stress, anxiety, and mental fatigue. Based on this understanding, this study employed elements such as green vegetation, water features, natural materials, and ergonomic seating areas.

In our country, sufficient importance must be given to the gardens of healthcare institutions, and adequate budgets should be allocated. It is believed that well-designed therapeutic gardens, by supporting the recovery process of hospital users, will also contribute to reducing the burden on healthcare facilities through the positive effects they create. The adoption and widespread implementation of the therapeutic garden approach in the design of healthcare institution gardens, collaboration with interdisciplinary experts, and an increase in studies on this topic will also foster awareness regarding this subject. Consequently, landscape design in oncology hospitals should be considered not merely as an aesthetic element but also as a "therapeutic tool" that supports the treatment process.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Akın, Z. Ş. (2006). Çocuklar için iyileştirme bahçeleri. Ankara Üniversitesi. Fen Bilimleri Enstitüsü, Basılmamış Yüksek Lisans Tezi, Ankara.

Akpınar Külekçi, E., & Sezen, I. (2020). Peyzaj tasarım sürecinde iyileştirme bahçeleri. Bursa *Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, 34(Özel Sayı), 337-350.

Akpınar Külekçi, E., & Yazıcı, M. E. (2021). Design Features and Modern West Integrations of Zen Gardens. International Congress on the Phenomenological Aspects of Civil Engineering, 20-23 June 2021.

Çetinkale Demirkan, G. (2019). İyileştirici bahçeler ve tasarım kriterlerinin değerlendirilmesi. *Turkish Journal of Agriculture - Food Science and Technology*, 7(1): 148-151.

Demirel, Ö., Pouya, S. (2017). Engelli çocuklar için iyileştirme bahçeleri. *Plant Dergisi Peyzaz ve Süs Bitkiciliği Dergisi*, No: 22

Google Earth, 2025. https://earth.google.com/web/ (Access Date: 10.09.2025)

Hussein, H. (2010). Sensory gardens: Assessing their design and use, *Intelligent Buildings International,* 2:2, 116-123.

Kaplan R, Kaplan S (1990). Restorative experience: The healing power of nearby nature. In The meaning of gardens, ed. Francis M, Hester R T, 238-244. Cambridge, MA: MIT Press.

Lani Alaine Gerity, D.A., A.T.R-B.C. (1998). The healing garden; Art and nature. *Canadian Art Therapy Association Journal,* 12(1): 2-10.

Marcus, C. C. (2007). Healing gardens in hospitals. I*DRP Interdisciplinary Design and Research e-Journal* .27 http://www.idrp.wsu.edu/ Volume I, Issue I: Design and Health, January.

Marcus, C. C. & Barnes, M. (1999). Healing Gardens: Therapeutic Benefits and Design Recommendations. John Willey & Sons, New York.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science,* 224(4647), 420-421. https://doi.org/10.1126/science.6143402

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology,* 11, 201-230.

URL-1. https://www.mahanrykiel.com/portfolio/upper-chesapeake-cancer-center/ (Access date: 05.09.2025)

URL-2. https://www.garden-terracotta.com/en/therapeutic-healing-garden-psychological-physical-well-being.asp (Access date: 5.09.2025)

URL-3. https://www.ynhh.org/smilow/services/support-services/healing-garden (Access date: 10.09.2025)

URL-4. https://www.pinterest.com/pin/2181499814111520/ (Access date: 12.09.2025)

URL-5.https://hastane.dicle.edu.tr/index.php/boeluemlerimiz/onkoloji-hastanesi (Access date: 12.09.2025)

URL-6. Diyarbakır İli Genel Görünüşü https://crh.wikipedia.org/wiki/Diyarbak%C4%B1r_%28il%29#/media/Fayl:Diyarbakir_in_Turkey.svg (Access date: 10.09.2025)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Evaluation of the Conservation History, Archaeological Findings, and the "Heritage for the Future" Project of the Church of St. Nicholas

Ebru Fatma FINDIK

ORCID: 0000-0001-9150-0884
Assoc. Prof. Dr. Department of Art History, Faculty of Arts and Sciences, Hatay Mustafa Kemal University, Hatay, Türkiye
effindik@mku.edu.tr

Abstract

This study evaluates the conservation history, archaeological findings, and excavation activities conducted within the framework of the "Heritage for the Future Project" at the Church of St. Nicholas during 2024–2025.[1] The final phase of the church, believed to house the tomb of St. Nicholas, corresponds to a domed basilica plan dated to the 8th–10th centuries. The building, known to have functioned as a monastery during the Medieval period, is surrounded by two-story annex structures. Excavations and sondages carried out in these annexes under the "Heritage for the Future Project" revealed significant architectural and stratigraphic evidence. A Lycian-type variant sarcophagus identified in the lower floor of the E Structure demonstrates that the area was used as a burial site even prior to the Byzantine period, and the stratigraphic data attest to the long-term functional continuity of the space. The C Structure is considered to have been associated with pilgrimage accommodation and healing (incubation) activities. Upper-floor remains from the Ottoman and early Modern periods indicate that the church complex continued to serve diverse functions in later centuries. These findings highlight the importance of ongoing archaeological research and excavation at the site and demonstrate the potential for these studies to contribute significantly to a deeper understanding of the historical development of Myra.

Keywords: Church of St. Nicholas, Myra, Byzantine, Ottoman, "heritage for the future project"

Introduction

History of Myra and the Church of Saint Nicholas

Ancient Myra was located in the Lycian region, between the Alaca Mountains and the Mediterranean Sea, on the banks of the Myros River. This strategic location made the city accessible via land and sea routes, establishing it as a center of commercial and cultural interaction in antiquity. In the ancient period, it is estimated that the cults of Artemis Eleuteria and Apollo were influential in the region.[2] The harbor settlement of Andriake presents a concentrated urban layout including a granarium, agora, baths, shops, workshops, and early basilicas. Jewish communities in the area can be traced through the synagogue at the harbor.[3]

The arrival of Christianity in Myra is considered to be connected with the missionary activities of Saint Paul in 57 CE.[4] The appointment of Nicholas of Patara as bishop of Myra in the 4th century played a decisive role in shaping the city's religious identity. Nicholas's participation in the Council of Nicaea in 325 indicates that Orthodox doctrine was adopted in the region in the early period.[5] Hagiographic sources dating from the 6th to 14th centuries (Praxis de Stratelatis, *Vita Nicolai Sionitae*, *Vita per Michaëlem*, *Enkomium Methodii*) confirm that Nicholas served as bishop during the reign of Constantine I, that his tomb was located in Myra,

[1] I would like to express my sincere gratitude to the Ministry of Culture and Tourism of the Republic of Türkiye for its valuable support provided within the scope of the *Heritage for the Future Project*.
[2] Strabo, 1917-33; Foss, 1994, 1-52; Neumann, 2007, 21; Bean, 1998; Tekinalp, 2000; Marksteiner, 2013, 281-290
[3]Tekinalp, 2000, 289-310; Çevik & Bulut, 2022, 21.
[4] Bennett, 2015, 28, vd; The Holy Bible, New Testament, Acts 27:5-6. (English Standard Version). (2001); Crossway Bibles; The Acts of Paul, http://www.earlychristianwritings.com/text/actspaul.html Access: 10.11.2025.
[5] Ott, 1907; Poulos, 1992; Jones, 1978.

and that the cult of the saint had gained an institutionalized structure.[6] In particular, the *Vita Nicolai Sionitae* (565 CE) is of special importance as one of the earliest and most significant texts documenting that Nicholas's tomb was located in the city and that a martyrion existed there.[7]

During the reign of Theodosius II (408–450 CE), with the strengthening of Christianity's status as the official religion within the empire, religious visits to Myra and its harbor, Andriake, appear to have increased. This development can also be traced archaeologically from the 5th century onward, particularly through the basilical structures constructed around Andriake. These architectural data clearly demonstrate Myra's religious significance as an episcopal center and its position as the metropolis of the Lycian province.[8]

Throughout the Middle Ages, Myra was regarded as an important pilgrimage center in the Eastern Mediterranean due to the belief that the tomb of Saint Nicholas was located there. The belief that sacred oil, known as "myron," seeped from his tomb and possessed healing properties was a decisive factor in the increase of pilgrimage visits to the city.[9] The miraculous healing power attributed to Nicholas and his adoption as the protector of sailors reinforced Myra's sacred identity; these beliefs resulted in the tomb structure becoming a regional religious center visited for healing and protection.[10]

The Church of Saint Nicholas developed over the area believed to house the tomb of Nicholas, bishop of Myra. Following his death, a monumental structure (martyrion) was erected over his tomb in the late 4th century. During the reign of Theodosius II (408–450 CE), Myra's status as the metropolis of the Lycian province further emphasized the religious significance of the structure.[11] According to U. Peschlow, the building, repaired by Justinian I after the earthquake of 529, was probably transformed into a basilica around 530 CE. Previous studies date this first basilical-plan structure to the 6th century. Arab raids and earthquakes in the 7th–8th centuries affected the building, which was reconstructed as a domed basilica in the late 8th–early 9th centuries. After the Abbasid attack of 808, repairs and reinforcements were carried out in the early 9th century.[12] Excavations conducted in 2022 have revealed that the church's earliest phase extends to the 5th century and earlier.[13]

In the 10th–11th centuries, liturgical and iconographic renovations were carried out in the inner narthex, featuring council scenes; following the pirate attack in 1034, additions to the north, wall paintings, and opus sectile pavements completed the third architectural phase of the structure.[14] A stone inscription dated 1042 serves as an important document indicating that the building was renovated by Constantine IX Monomachos and his wife Zoe.[15] The Burial

[6] Anrich, 1913, I, 113-139; Michael the Archimandrite. (2014). *St. Nicholas of Myra: Life (Vita per Michaelem)* (J. Quinn & B. Sewell, Trans.). In *Bibliotheca Hagiographica Graeca* 1348. (Original work written ca. 9th-10th c.). https://www.roger-pearse.com/weblog/wp-content/uploads/2015/03/vita-per-Michaelem.pdf Erişim: 09.11.2025; *The Real St. Nicholas.* https://www.ewtn.com/catholicism/library/real-st-nicholas-5783 Erişim: 09.11.2025.
[7] Ševčenko & Ševčenko, 1984.
[8] Darrouzès, 1981, 143; Foss 1994, 14; Hellenkemper-Hild, 2004, 344.
[9] Hayes, 2016, 492-512.
[10] Anrich, 1913, I, 34-36; Peschlow, 1975, 303-359; Peschlow, 1990, 207-258; Maguire, 1996, 147, 169, 194; Ötüken, 2006, 523-536.
[11] Darrouzès, 1981, 143.
[12] Peschlow, 1975, 303-359; Peschlow, 1990, 207-258.
[13] Fındık, 2023, 1-23.
[14] Feld, 1975, 360-428.
[15] Peschlow, 1996/1997, 75-78; Ötüken, 2001, II, 405, Çiz. 5.

Chamber, constructed in the 12th century, along with chapels located in the southeastern part of the building, is notable for its burial spaces and wall paintings. The arcosolium in the courtyard, with a 1118 inscription on its wall paintings, is significant as evidence that the structure functioned as a monastic church during the Middle Ages.[16]

Metropolitans of Myra are recorded in documents between 1143 and 1161, and from 1207 onward, the settlement continued under Turkish administration. However, flooding in the 13th century, which altered the course of the Myros River, affected the city's topography; during the 14th–15th centuries, various attacks and sieges from Cyprus and Rhodes led to the city's devastation.[17] Although Myra remained an episcopal center in the 17th century, ecclesiastical administration had moved to the island of Kastellorizo (Meis/Megisti) off the coast of Kaş.[18]

19th-Century Excavation and Restoration Activities

Mid-19th-century Russian interventions at the Church of Saint Nicholas played a decisive role in shaping the architectural character of the structure that has survived to the present day. Institutional interest by the Russians was formalized in 1853 with the purchase of the building and its surrounding area on behalf of Princess Anna Golitsyna; subsequent extensive restoration works were carried out between 1858 and 1860 under the direction of architect A. Salzmann.[19] During this process, the western courtyard of the building was completely cleared, the outer narthex was reconstructed, the gallery floors were repaired, and the coverings of the southern nave and apse were renewed. The second phase of restoration, carried out in 1862–63, involved the renewal of the outer narthex and the main nave. Inscriptions documenting these interventions remain preserved on the structure today. Arches identified as belonging to a Russian-period funerary structure stand out among the original architectural contributions on the gallery floor.[20] Epigraphic and archival records from 1876 indicate that monastic buildings, administrative units, and water facilities were repaired, and a bell tower was constructed. The bronze bell from 1876, associated with this bell tower, is exhibited today at the Museum of Lycian Civilizations as tangible evidence of the Russian restoration activities.[21]

While these extensive restorations aimed to secure the structural integrity of the building, they also added a significant 19th-century intervention phase to the church's architectural layers. The recognition of the church within the scholarly community was facilitated by travelers visiting the region during the 19th century; in particular, architects, archaeologists, art historians, and researchers examining epigraphic data introduced Myra and the Church of Saint Nicholas into the academic literature.[22] Drawings, measurements, and documents produced during this period ensured that the architectural structure and early-period traces of the church became subjects of modern scientific study.

20th–21st Century Excavation and Restoration Activities

Early excavation and restoration works at the church have largely been overlooked until now. Excavations conducted by the Antalya Museum of Archaeology between 1953 and 1963 made significant contributions to the architectural and archaeological documentation of the

[16] Çorağan, 1998; Karakaya, 2005, 288-309.
[17] Doğan & Fındık (Eds.), 2018a, 38.
[18] Harrison 1963, 124.
[19] Rott, 1908, 326.
[20] Feld 1975, 368 vd.; Peschlow, 1990, 255.
[21] Doğan (Ed.) 2014, 33-47.
[22] Bulgurlu, 2010, 273-291.

structure.[23] Following the church's return to a state of neglect, the Antalya Museum of Archaeology carried out cleaning and restoration works in the southern and eastern areas of the building in 1963/64 and 1966/67.[24] In 1964–65, Y. Demiriz documented the opus sectile floor panels on the plan.[25]

In 1965, within the scope of the Myra Project, the church was studied comprehensively for the first time by U. Peschlow and O. Feld.[26] In 1968, the South Burial Chamber and the 2nd–3rd Southeast Chapels were protected with a tiled roof with the support of the Dumbarton Oaks Research Institute; in the 1980s, the construction of an iron-structured roof ensured long-term protection of the building.[27] Excavations conducted between 1989 and 2009 under the direction of Prof. Dr. S.Y. Ötüken uncovered architectural remains of the monastery and various finds around the church.[28] Following works conducted under the Antalya Museum Directorate between 2012 and 2014, excavations led by Prof. Dr. S. Doğan continued from 2014 to 2021; these studies focused on the western entrance of the church courtyard and additional structures. During this period, a new Deesis wall painting and a figure of Nicholas were revealed.[29]

Since 2017, excavation leadership and the conservation, restoration, and landscaping works have been carried out under the coordination of the Republic of Turkey Ministry of Culture and Tourism, with interventions implemented between 2021 and 2022.

2022 Sondage Studies

The sondages conducted in 2022 in the naos of the Church of Saint Nicholas provided significant findings regarding the early phases of the structure. The sondages revealed that the church was built over an earlier complex of buildings covered with mosaic floors executed in the opus tessellatum technique. These earlier structures were likely destroyed following a major earthquake, and in their place, the first basilica, dated to the 5th century and featuring floors in the opus sectile technique, was constructed. Only the mortar beds and traces of the coverings of the opus sectile floors have been identified.[30]

It was determined that the geometric composition of the floors corresponds to the arrangement of the mosaics in situ in the Southeast chapels of the church. The opus tessellatum floors were found to extend over a wide area beneath the naos and the annexes of the church. The sondages revealed five different construction and repair phases in the naos, thereby documenting for the first time the floors of the first basilica and the type of the early ambo arrangement.[31]

"Heritage for the Future Project" 2024–2028

Between 2024 and 2028, within the scope of the "Heritage for the Future Project" carried out by the Ministry of Culture and Tourism, sondages and minor restoration works were planned at the Church of Saint Nicholas for the purpose of preserving and documenting its historical and cultural values.

[23] Psalty, 1952, 27-28.
[24] Mellink, 1965, 241-251.
[25] Demiriz, 1966, 13-34.
[26] Peschlow, 1975, 303-359; Feld, 1975, 360-428.
[27] Doğan & Fındık (Eds.) 2018a, 49-52.
[28] Doğan & Fındık (Eds.), 2018a, 63-137.
[29] Doğan, Fındık & Bulgurlu, 2018b, 365-380.
[30] Fındık, 2023, 17-19.
[31] Fındık, 2023, 1-23.

Excavation Works in the C Structure

In 2024–2025, within the scope of the "Legacy for the Future Project," excavations and minor restoration works were planned in the northeastern annexes of the Church of Saint Nicholas (C Structures). The C Structures consist of a group of three annex rooms located to the east of the northern nave, adjacent to the apse. The complex connects to the church in the west, to the A2 and A1 structures in the north, and opens directly to the exterior through four doors in the south. The C1 and C2 rooms were documented and detailed in the plan during excavations that began in 1989. Studies revealed that C2 is covered with a dome, while C1 is covered by a longitudinal barrel vault oriented along the east-west axis.

The architectural features of the C Structures—including the four doors opening in three directions, their connection to the sacred area of the church, and small finds—highlight the significance of the complex. Previous excavations suggest that C2 was most likely a funerary structure, whereas C1 may have served as an incubation space where pilgrims seeking healing stayed.[32]

Although the medieval levels of C1 and C2 have been exposed, research on the early phases and architectural functions of these structures has not yet been completed. Considering the ancient significance of the area where the church was established, excavations are necessary to clarify the historical and architectural context of the building.

The C Structure opens to the C1 room through a passage-like doorway. The soil within the structure, which was entirely covered with alluvium due to a flood, was removed, revealing a vaulted space oriented along the north-south axis. A door opening in the northern wall, later blocked, was identified. Reused materials such as arch keystones, column capitals, and templon fragments were incorporated into the wall masonry. It is believed that this space acquired its current form, including the closure of the door, during the reconstruction of a pre-existing structure that had collapsed in a previous earthquake. A collapse caused by the flood was observed in the eastern wall of the building.

A conservation and implementation project has been prepared for the structure, and in the coming years, the architecture of the building will be fully exposed through excavations to determine its function and chronological phases. The architectural structure of the vault on the upper floor of the C Structure has been entirely revealed.

Excavation on the Upper Floor of the E Structure

The E Structure is a two-story architectural unit with a longitudinal rectangular plan, forming the southern boundary of the church courtyard. The upper floor originally featured a door opening to the courtyard, later blocked, and a staircase. Only the walls have survived to the present day; the upper covering has not been preserved. The building was constructed primarily of rubble stone, with limited use of spolia.

Excavations conducted in 2021 in the western section of the upper floor were partially completed, and the area was temporarily covered for protection. Two separate rooms, connected by a doorway, were revealed in this section.[33]

[32] Ötüken, 2006, 523-536.

[33] Doğan, Fındık, & Bulgurlu, 2022, 177-198.

In 2024, excavations continued in the eastern part of the upper floor. Surface soil and alluvial deposits were removed to a certain level, revealing wall remains from different periods. Wall remains from the Ottoman period, as well as ceramics and small finds from various phases, were recovered from the upper levels. These materials are understood to date to the Modern Period (after the 1923 population exchange), the Ottoman Period (17th–20th centuries), and the Early Ottoman Period (14th–15th centuries).

The findings indicate that the upper floor of the E Structure had a long period of use and was employed for different functions in various periods. In subsequent excavation phases, the functional and chronological context of these remains will be evaluated in greater detail.

Sondages on the Lower Floor of the E Structure

The lower floor of the E Structure is a rectangular space, 20 meters in length, oriented along the east–west axis and covered with a barrel vault. The lower floor consists of two rooms, each divided into three units by doorways. Apart from a round-arched doorway in the eastern wall, this section has no windows and is supported by arches and wall piers carrying the vault.

Between 2003 and 2009, the alluvial deposits filling the structure were removed, and the medieval layers were documented. The main aim of the sondages carried out in 2024 was to reveal the early phases of the building and to investigate whether the opus tessellatum pavement identified in the courtyard continued into the interior space.

During the excavation and sondages, a sarcophagus was revealed in the first two units of the first room, approximately 0.30 m. below the church floor level. The sarcophagus, made of limestone, is a simple type with a triangular pitched lid and semicircular projecting supports on its side faces. Due to the limited depth that could be reached within the room, the sarcophagus could not be fully exposed. Another reason is the presence of north–south wall remains built above the eastern part of the sarcophagus. This foundation wall, constructed in a later period along the north–south axis, indicates that the area was in use for a long and continuous period.

To the west of the sarcophagus, a rubble fill was identified, and to the south, another rubble-walled structure belonging to a later phase was revealed. The walls, overlapping at different levels, demonstrate that the room has a complex architectural stratigraphy. This complexity has prevented the complete exposure of the sarcophagus.

Typologically, this find shows affinities with Lycian-type sarcophagi and is considered to be related to the use of the area where the church stands as a burial site in antiquity. This provides archaeological evidence supporting historical sources that indicate Saint Nicholas was buried within the sacred precinct (temenos) of the city.

In 2025, excavations carried out in the third unit of the first room to expose a wall revealed that the wall was likely constructed over another grave dating to the Byzantine period at a higher level. The discovery of additional burials in the area further supports the hypothesis that this site functioned as the necropolis of the city of Myra.

Conclusion

Recent research conducted at the Church of Saint Nicholas has allowed for a reevaluation of the building's position within the settlement pattern of the Ancient and Medieval periods. The Lycian-type variant sarcophagus identified in the lower floor of the E Structure demonstrates that the area was used for burial purposes even before the Byzantine period, thereby establishing a direct link between archaeological evidence and written sources indicating that the saint's

tomb was located within the sacred precinct of Myra. The walls constructed over the sarcophagus in a later phase indicate that the space maintained functional continuity over an extended period and that the interwoven architectural phases created a complex stratigraphy. During the 2025 investigations, evidence suggesting the presence of a second burial along the same axis supports the idea that the site functioned as a selective necropolis based on a limited burial tradition.

The results of the excavations and sondages reveal that the early construction phases of the church extend to the 5th century and earlier. The opus tessellatum floorings found in at least ten different areas beneath the structure indicate the presence of a broader architectural complex. Wall remains from the Ottoman and early Modern periods identified on the upper floor of the E Structure provide important data regarding the building's use in the middle and late periods, showing that the area continued to serve different functions in later centuries.

These findings offer a new framework for understanding the multiple architectural phases of the Church of Saint Nicholas, demonstrating that the site had continuous use as a sacred precinct in antiquity, a pilgrimage center during the Byzantine period, and a repurposed architectural complex in subsequent centuries. Future excavation phases, particularly those focused on the architectural relationships surrounding the sarcophagus, are expected to provide more detailed data, contributing to a comprehensive reevaluation of the site's topographic and ritual organization.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Anrich, G. (1913–1917). *Hagios Nikolaos: Der heilige Nikolaos in der griechischen Kirche* (Vols. I–II, Texte und Untersuchungen). Leipzig-Berlin: Hinrichs.

Bean, G. (1998). *Eskiçağda Likya Bölgesi* (H. Kökten, Çev.). Arion Yayınevi.

Bennett, J. (2015). Christianity in Lycia: From its beginnings to the "Triumph of Orthodoxy." *Adalya, XVIII*, 1–29.

Bulgurlu, V. (2010). *Erken gezginlerin gözüyle Myra / Demre*. In N. Çevik (Ed.), *Arkeolojisinden doğasına Myra/Demre* (pp. 273–291). Antalya.

Çevik, N. & Bulut, S. (2022). Myra'nın limanı Andriake: Yeni veriler ışığında değerlendirmeler. *TARE: Türk Arkeoloji ve Kültürel Miras Enstitüsü Dergisi, 2*, 7–74.

Çorağan, N. (1998). Antalya'nın Demre ilçesindeki H. Nikolaos Kilisesi freskoları (Yayımlanmamış doktora tezi). Hacettepe Üniversitesi.

Darrouzès, J. (Ed.) (1981). *Notitiae Episcopatuum Ecclesiae Constantinopolitanae*. Paris: Institut Français d'Études Byzantines.

Demiriz, Y. (1966). Demre'deki Aziz Nikolaos Kilisesi. *Türkiye Arkeoloji Dergisi, XV*(I), 13–34.

Doğan, S. &Fındık, E. F., & Bulgurlu, V. (2022). *Aziz Nikolaos Kilisesi kazıları: 2019–2020 yılları çalışmaları* (pp. 177–198). In A. Özme (Ed.), *2019–2020 yılı kazı çalışmaları*

(Vol. 4). T.C. Kültür ve Turizm Bakanlığı, Kültür Varlıkları ve Müzeler Genel Müdürlüğü. Ankara.

Doğan, S. & Fındık, E. F. (Eds.) (2018a). *Aziz Nikolaos Kilisesi kazıları (1989–2009)*. İstanbul: Homer Yayınları.

Doğan, S., Fındık, E. F., & Bulgurlu, V. (2018b). *Demre/Myra Aziz Nikolaos Kilisesi kazı, koruma ve onarım çalışmaları – 2017*. In **4**0. Kazı Sonuçları Toplantısı (Vol. 3, pp. 365–380). T.C. Kültür ve Turizm Bakanlığı, Kültür Varlıkları ve Müzeler Genel Müdürlüğü. Ankara.

Doğan, S. (Ed.), Çorağan, N., Bulgurlu, V., Alas, Ç., Fındık, E., & Apaydın, E. (2014). *Demre-Myra Aziz Nikolaos Kilisesi*. Arkeoloji ve Sanat Yayınları.

Feld, O. (1975). Die Innenausstattung der Nikolaoskirche in Myra. In J. Borchardt (Ed.), *Myra. Eine lykische Metropole* (IstForsch 30, pp. 360–428).

Fındık, E. F. (2023). 2022 yılı Aziz Nikolaos Kilisesi naos sondaj çalışmalarının ön değerlendirmesi. *Arkhaia Anatolika, 6*, 1–23.

Foss, C. (1994). The Lycian Coast in the Byzantine Age. *Dumbarton Oaks Papers, 48*, 1–52.

Harrison, R. M. (1963). Churches and chapels of central Lycia. *Anatolian Studies, 13*, 117–151.

Hayes, D. M. (2016). The cult of St Nicholas of Myra in Norman Bari, c. 1071–c. 1111. *The Journal of Ecclesiastical History, 67*(3), 492–512.

Hellenkemper, H., & Hild, F. (2004). *Lykien und Pamphylien* (TIB 8). Berlin: De Gruyter.

Jones, C. W. (1978). *Saint Nicholas of Myra, Bari, and Manhattan: Biography of a legend.* Chicago: University of Chicago Press.

Maguire, H. (1996). *The icons of their bodies: Saints and their images in Byzantium*. Princeton University Press.

Marksteiner, T. (2013). Andriakè, un Port lycien. In K. Konuk, P. Brun, L. Cavalier, & F. Prost (Eds.), *Euploia: La Lycie et la Carie Antiques. Dynamiques des Territoires, échanges et Identités* (pp. 281–290). Bordeaux.

Mellink, M. J. (1965). Archaeology in Asia Minor. *American Journal of Archaeology, 69*(3), 241–251.

Neumann, G. (2007). *Glossar des Lykischen* (J. Tischler, rev. ed.). Wiesbaden: Harrassowitz Verlag. (Dresdner Beiträge zur Hethitologie, 21)

Ötüken, S. Y. (2006). Myra Demre Aziz Nikolaos Kilisesi içinde mimari değerlendirmeler. In K. Dörtlük & T. Kâhya (Eds.), *III. Uluslararası Likya Sempozyumu / III. International Lycia Symposium* (Cilt 1, ss. 523–536). Antalya: AKMED.

Ötüken, Y. (2001). 2000 Yılı Demre-Myra Aziz Nikolaos Kilisesi Kazısı ve Duvar Resimlerini Belgeleme Koruma-Onarım Çalışmaları. *23. KST II*, 401–414.

Peschlow, U. (1975). Die Architektur der Nikolaoskirche in Myra. In J. Borchardt (Ed.), *Myra. Eine lykische Metropole* (IstForsch 30, pp. 303–359).

Peschlow, U. (1990). Materialien zur Kirche des H. Nikolaos in Myra im Mittelalter. *Istanbuler Mitteilungen, 40*, 207–258.

Peschlow, U. (1996/1997). Die Byzantinische Kaiserinschrift aus Myra-Wiedergefunden. *Lykia, 3*, 75–78.

Psalty, F. (1952). Saint Nicolas Successeur de Neptune et Pere Noel. *T.T.O.K. Belleteni, 120*, 27–28.

Rott, H. (1908). *Kleinasiatische Denkmaeler aus Pisidien Pamphylien Kappadokien*.

Ševčenko, I., & Ševčenko, N. P. (1984). *The Life of Saint Nicholas of Sion*. Brookline, MA: Hellenic College Press.

Ševčenko, N. P. (1983). *The Life of Saint Nicholas in Byzantine Art*. [Yayınevi yok].

Strabo. (1917–1933). *Geography* (H. L. Jones, Trans.; Vol. 6, Books XIV–XVII). London: Heinemann. (Orginal. 7 CE)

St. Nicholas of Myra: Life (Vita per Michaelem) (J. Quinn & B. Sewell, Trans.). (n.d.). In *Bibliotheca Hagiographica Graeca 1348*. https://www.roger-pearse.com/weblog/wp-content/uploads/2015/03/vita-per-Michaelem.pdf Access: 15.11.2025.

Tekinalp, V. M. (2000). *Geç Antik Dönem Sonrasında ve Ortaçağ'da (MS 4.–14. yy) Andriake Kenti* (Yayımlanmamış doktora tezi). Hacettepe Üniversitesi, Sosyal Bilimler Enstitüsü.

The Holy Bible, New Testament, Acts 27:5-6. (English Standard Version). (2001). Crossway Bibles. https://www.earlychristianwritings.com/text/actspaul.html Access: 15.11.2025.

https://www.ewtn.com/catholicism/library/real-st-nicholas-5783 Access: 15.11.2025.

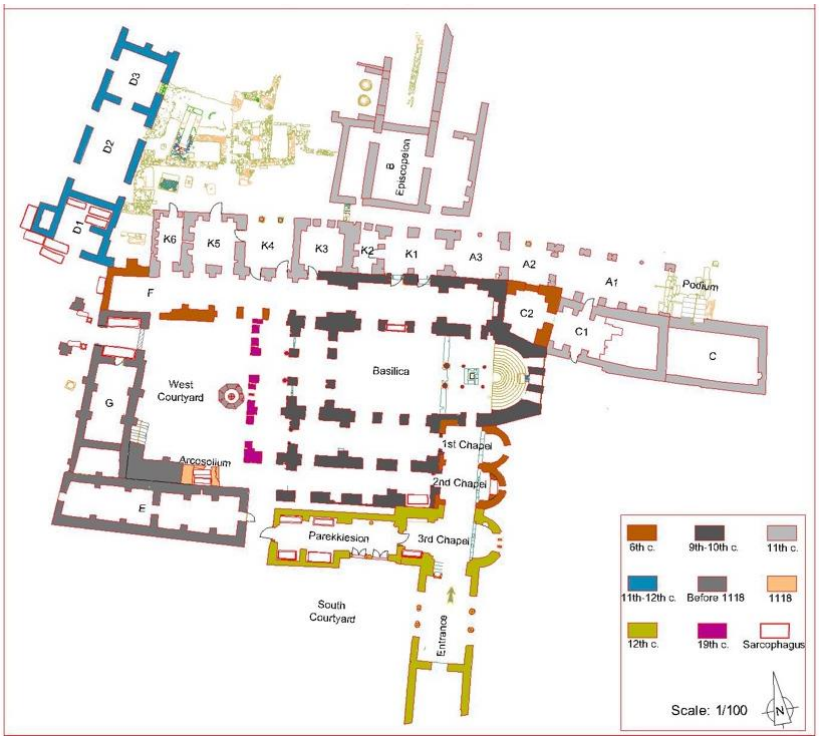


Figure 1. Plan of the spaces of the Church of Saint Nicholas (Doğan & Dertli, 2021)



Figure 2. Southern view of the Church of Saint Nicholas in Myra



Figure 3. The naos of the Church of Saint Nicholas



Figure 4. Sondage in the naos showing the mortar of the opus sectile floor and the opus tessellatum floor



Figure 5. Structures C on the northeast of the church

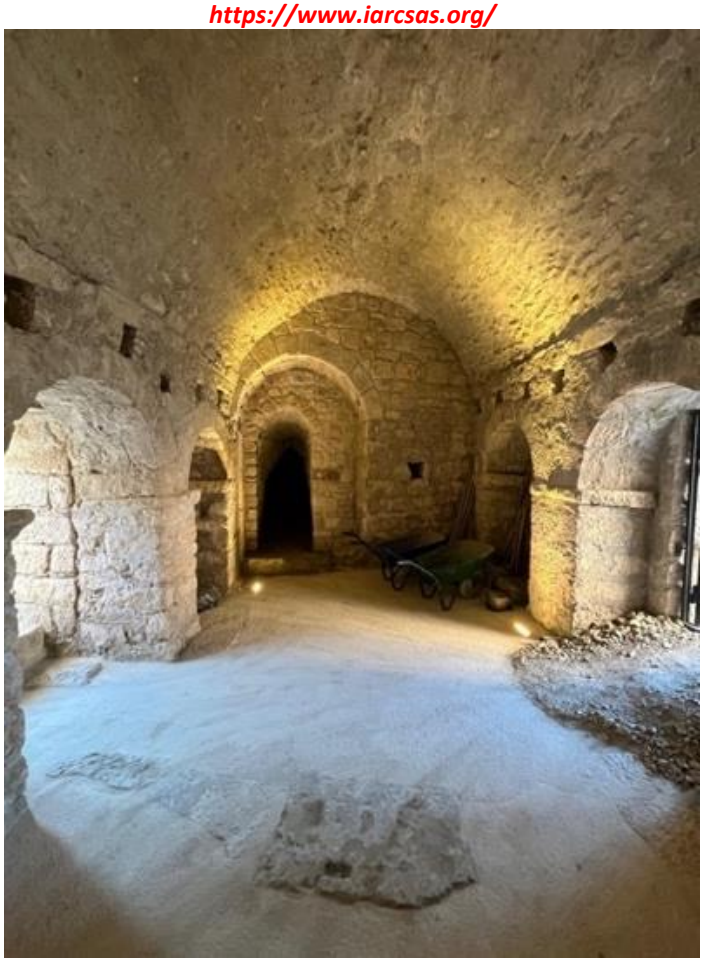


Figure 6. View from structure C1 toward structure C



Figure 7. North wall of Structure C interior after the alluvium was removed



Figure 8. Interior of the ground floor of Structure E



Figure 9. Door of the ground floor of Structure E



Figure 10. Discovery of the sarcophagus on the ground floor of Structure E

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Importance of Urban Green Areas in Demre (Antalya) in the Climate Change Adaptation Process, and Strategic Actions

Atila GÜL [1*]

ORCID 1: 0000-0001-9517-5388
[1]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
atilagul@sdu.edu.tr (Responsible Author)

Abstract

Urban open and green spaces provide ecological, environmental, physical, aesthetic, economic, social, psychological, and recreational services and contributions to the city and its inhabitants. On a global scale, the urgent actions envisioned for combating and adapting to climate change involve a significant economic cost. In particular, increasing and sustainably managing carbon sinks in urban areas is at the forefront of these urgent actions. In this context, natural areas (forests, protected areas, wetlands, etc.) and green areas (parks, gardens, recreation areas, children's and sports playgrounds, green roofs, wetlands, road medians and edges, etc.) are considered the most critical element in the urban planning, design, and sustainable management process. Demre District possesses great richness and diversity in terms of urban green areas and natural and cultural resource values. In Demre District, only 3 out of 17 neighborhoods have more than 10 m² of green space per capita, while the other 14 neighborhoods have less than 10 m², exhibiting an uneven and unbalanced ratio. However, the ratio of the total existing green areas in Demre District to the city's population is 12.41 m^2 of active green space per person. Generally, this meets the minimum green space standard of 10 m^2 defined in the legislation. Strategic actions have been made to maximize the benefits of urban green spaces (UGS) in mitigating climate change, addressing them under three different headings (Planning/Design and Implementation Process, Institutional, Legal and Administrative Process, Participation and Awareness Process).

Keywords: Urban green areas, Demre (Antalya), sustainability, climate change adaptation, strategic actions

Introduction

Globally, especially over the past 50 years, it is predicted that increased human activity and impact on natural resources have led to a significant increase in greenhouse gas and carbon emissions in the atmosphere. In this context, many negative consequences, such as damage to natural (ecological) systems, disruption of the natural balance, increased carbon emissions, increased environmental pollution, decreased biological diversity, and the adverse effects of climate change, have become a serious threat to humanity and all life. Climate change, in particular, has become a global problem requiring urgent action, beyond being a threat for the future.

Today, as urban populations and urbanization develop rapidly, especially horizontal and vertical construction activities, the excessive increase in impervious surfaces and production and consumption activities, improper land use, etc., negatively affect the urban ecosystem and face increasing environmental challenges (Nowak et al., 2002; McKinney, 2008; Pataki et al., 2011; Toy & Esringü, 2021).

However, heat waves, drought, fires, coastal flooding, urban flooding, and changing climate conditions significantly threaten the existence of urban systems that are vulnerable to natural disasters and cause ecological, economic, and social problems in cities.

Climate change, increased carbon emissions, and the effects of environmental degradation are manifesting themselves severely in cities. Urban areas are responsible for 80% of global production and 70% of total greenhouse gas emissions. In this context, cities are living spaces that are intensely exposed to the effects of climate change, such as heat waves, the urban heat

island effect, floods, water scarcity, rising sea levels, food crises, and environmental pollution (The Global Commission on the Economy and Climate, 2014).

Extreme weather events linked to climate change, increasing climate risks, and environmental problems will cause significant losses in urban areas, and it is clear that we must be prepared for these risks (UN-Habitat, 2020). In this context, the resilience of cities to potential risks and disasters and ensuring the environmental, social, and economic sustainability of urban systems are becoming increasingly important (Boland et al., 2021; Leichenko, 2011).

In Türkiye, the cities have a fragile structure in terms of climate change due to rapid growth and expansion. Urban areas are extremely important priority areas in combating and adapting to climate change (Akten & Gül, 2024). Cities are considered both the primary source of the problem and the target of climate disasters, while also being the most important actors in the solution (Balaban, 2017). As the places most affected by the negative impacts of climate change, cities are at the center of adaptation policies implemented to combat climate change.

Globally, the urgent actions required to combat and adapt to climate change involve significant economic costs. Among these urgent actions, increasing carbon sink areas in urban areas and ensuring their sustainable management are particularly important. In this context, natural areas (forests, protected areas, wetlands, etc.) and cultural green areas (parks, gardens, recreation areas, children's and sports playgrounds, green roofs, wetlands, road medians and verges, etc.) are considered the most critical elements in the urban planning, design, and sustainable management process. (Demuzere, et al., 2014; Gül et al., 2020; Türker & Gül, 2022).

Urban green spaces offer multifaceted ecological, social, and health benefits that can help mitigate the effects of climate change while improving the quality of life for city residents. Green and natural areas within and outside cities contribute to the sustainability of the urban ecosystem (improving air quality, carbon sequestration and storage, urban cooling effect, increasing biodiversity, etc.). In addition, urban green spaces are the most important component of the city, supporting people's physical, mental, and cognitive health and well-being, increasing social cohesion, increasing property values, providing tourism and recreation opportunities, and supporting local economies.

The purpose of this study is to emphasize the importance of urban green spaces in the climate change adaptation process and to propose strategic actions for urban and extra-urban green spaces aimed at reducing the climate change adaptation process and its potential negative effects, specifically in Demre.

The Relationship Between the Global Climate Change Adaptation Process and Urban Green Spaces

With the belief that climate change is primarily human-induced and that global adverse effects will occur if no action is taken, governments have signed international agreements to reduce greenhouse gas emissions, conduct research, collaborate on technology, and promote the protection of carbon sink areas. The most important of these are (Gül, 2024).

- 1992 - United Nations Framework Convention on Climate Change (UNFCCC)
- 1995 - COP 1, Berlin Summit, Germany
- 1996 - COP 2, Geneva, Switzerland
- 1997 - COP 3, Kyoto, Japan

- 1998 - COP 4, Buenos Aires
- 2013 - COP 19 Warsaw, Poland
- 2015 - COP 21 Paris, France
- 2021 - COP 26 Glasgow, Scotland
- 2022 COP27 Sharm El-Sheikh, Egypt
- 2023 COP 28 Dubai, United Arab Emirates
- 2024 COP 29 Baku, Azerbaijan
- 2025 COP30 Belém, Brazil (November 10-21)

According to the decisions made in these agreements, in order to ensure global zero carbon security and keep the temperature at 1.5°C, it is projected that emissions will be reduced by 43% by 2030 and 60% by 2035, reaching net zero by mid-century. Nature-based solutions are beginning to be seen as a tool for achieving the goals of the Paris Agreement, reducing climate change risks, and building climate-resilient societies (EC, 2022).

Nature-based solutions are a valuable tool used to strengthen the resilience of ecosystems, protect biodiversity, and address a wide range of societal challenges such as climate change adaptation and disaster risk reduction (IUCN, 2020). In addition, nature-based solutions, which have the flexibility to adapt to changing conditions, are effective and cost-efficient approaches compared to gray solutions (Feyen et al., 2020; Raymond et al., 2017).

Türkiye aims to reach its peak greenhouse gas emissions by 2038 at the latest, followed by a decline to achieve net-zero emissions by 2053. Türkiye aims to achieve this goal within the framework of the Long-Term (2024-2053) Development Strategy included in the Twelfth Development Plan. This strategy sets out a roadmap for maximizing the opportunities that the profound changes and transformation process anticipated worldwide can offer our country. To achieve the net-zero emissions target by 2053, the sustainable management of natural resources, energy transformation, green infrastructure and circular economy investments, environmental protection, and the widespread adoption of green technologies through domestic production are targeted (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2025).

Strategic Emergency Actions for the Global Climate Change Adaptation Process;

- ❑ Sustainable land use planning/management,
- ❑ Production of nature-based and ecologically focused solutions
- ❑ Landscape improvement works and increasing green space systems in urban and rural areas
- ❑ Applications that take into account carbon sequestration/storage functions
- ❑ Calculating the amount of carbon sequestered and monitoring changes in carbon stocks,
- ❑ Increasing the number of protected areas, etc.

Strategies for the Urban Sector within the Scope of the 2053 Climate Change Adaptation Targets have been determined as follows. (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2025).

Strategy 1. Adapting to climate change by increasing the resilience of cities

- ❑ In cities, improving areas at risk of flooding and determining appropriate transformation and protection zone models.
- ❑ Strengthen smart information systems on infrastructure capacities and heavy rainfall scenarios to increase the resilience of urban infrastructure against flood and inundation risks.
- ❑ Improving infrastructure by restructuring drainage systems, separating combined sewer systems (rainwater, wastewater), changing surface coatings, and increasing capacity where needed.
- ❑ Ensuring the effective use of location-specific materials will increase the resistance of building roofs and facades to severe weather events and prevent urban heat increase by determining standards.
- ❑ Identifying urban heat islands, green space needs, and wind corridors to create accessible and natural surfaces within urban fabrics with dense green spaces and ecological corridors.
- ❑ Rainwater management will be provided in urban areas and peripheral regions by creating rain gardens, sponge city details, rain ditches, and natural water surfaces; public spaces will be redesigned to collect water during heavy rainfall and transfer it to storage systems.
- ❑ Creating drought-resistant and aesthetically pleasing urban areas through drought-tolerant landscaping practices
- ❑ Changing water usage habits through education and awareness campaigns, promoting a culture of water efficiency, and adopting a water-efficient city approach

Strategy 2. Ensuring adaptation to climate change in spatial plans

- ❑ Spatial planning processes should be re-examined in the context of adaptation to climate change.
- ❑ Developing guiding manuals/guidelines that consider local climate data and address issues such as site selection, prevailing wind direction, passive ventilation and solar exposure, construction, and implementation, treating the urban landscape and urban greenery as an integrated system in spatial planning and urban design.
- ❑ Creating risk maps in urban areas using spatial data.
- ❑ Creating digital twins of cities and conducting risk analyses using this infrastructure.

Urban Green Spaces and Carbon Sequestration and Storage

Today, human-induced urbanization trends have altered the city's climatic processes as a result of settlements growing and changing in horizontal/vertical dimensions, increasing the urban heat island (UHI) effect and making urban daily life more negatively affected (Kazancı & Tezer, 2021; Gül & Gül, 2022). Cities consume 60-80% of the energy produced worldwide and generate carbon dioxide emissions roughly equivalent to this percentage. Population dynamics, income levels, and the physical and economic structure of cities play a key role in the increase of greenhouse gas emissions in cities. Urban open and green spaces are important for reducing CO_2 emissions and carbon storage in city centers.

The urban heat island effect, caused by factors such as reduced humidity and airflow due to the shielding effect of buildings, increased asphalt temperatures, increased traffic and air pollution, and insufficient vegetation cover reducing shade in residential areas and allowing more solar energy to be stored, contributes to global climate change. The development of urban canyons also alters wind patterns, preventing wind from entering and blowing through streets, causing heat to be trapped within the canyon. Thus, cities are warmer than the surrounding areas. Due to concrete construction and building density, cities are on average 5-6°C warmer than the surrounding rural areas. This is due to the Urban Heat Island effect, which arises from concrete construction and building density in cities. On sunny and hot days, city centers, with their high population density and tall buildings, are hotter than other surrounding areas, creating the urban heat island effect. Paved areas, especially during the hottest summer months, reach very high temperatures. Areas where plant communities have been destroyed and black surfaces are also among the causes of the heat island effect. The urban heat island effect is one of the factors contributing to global warming.

The urban heat island effect causes city centers to be warmer than their surroundings, leading to the intensive use of cooling systems, especially during the summer months. The increased energy demand for cooling due to rising temperatures in cities poses significant threats to the energy systems of countries (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2025).

Green space systems are defined as a network of interconnected natural, semi-natural, and cultural green spaces that provide and protect multifaceted ecosystem services and contributions (Benedict, 2000; European Commission, 2022). This network, consisting of segments (centers) and corridors, includes natural and semi-natural ecosystems (forests, scrublands, wetlands, river corridors, etc.) and cultural green spaces (parks, sports fields, schoolyards, private and institutional gardens, rooftop gardens, vertical/perpendicular gardens, zoos, botanical gardens, agricultural lands, cemeteries, landscaped pathways, etc.) (Gül et al., 2020).

Urban green spaces, both within and around the city, are a fundamental component that integrates and balances all land uses within the city through organic connections. The level of development of a city is directly proportional to the capacity of its green spaces in terms of quality and quantity, their balanced spatial distribution, and their accessibility to its inhabitants. Urban green spaces are public, semi-private, or private physical spaces that provide multifaceted services and contributions to the city's ecosystem and its inhabitants in biological, climatic, physical, social, psychological, economic, and aesthetic aspects, organized according to different green space typologies at the level of the urban unit they serve, and covered with natural and cultivated plants. Urban open and green spaces provide ecological and environmental, physical, aesthetic, economic, social, psychological, and recreational services and contributions to the city and its inhabitants (Gül & Küçük, 2001; Gezer & Gül, 2009; Gül et al., 2020).

The ecosystem services and contributions provided by green space systems vary according to factors such as the location, size, distribution, plant species, density and composition of the areas, and their organic connection with other green spaces (Gül, 2024).

The Earth's CO_2 storage or reserve areas are the atmosphere, oceans, and terrestrial biosphere. Natural areas (forests, protected areas, scrubland, etc.) and green spaces constitute a significant portion of the terrestrial biosphere. These areas enable the retention and storage of carbon in plants, litter, and soil. In terrestrial ecosystems worldwide, 19% of carbon is stored in plants

and 81% in soil. In forests, approximately 31% of carbon is stored in biomass and 69% in soil. In tropical forests, approximately 50% of carbon is stored in biomass and 50% in soil (IPCC, 2000).

The areas with the highest CO_2 emissions and large-scale energy consumption are urban areas with high population density. In city centers, urban trees and urban forests play an important role in reducing CO_2 emissions and sequestering carbon. In urban trees, the leaf biomass value is directly proportional to the tree's leaf ratio, canopy width, and age. An increase in a tree's biomass directly affects the amount of carbon it contains (Gül, 2024).

Urban green spaces can sequester between 1.2 and 1.6 tons of carbon per hectare per year, depending on the type of vegetation and management practices. The carbon dioxide storage capacity of urban trees is affected by tree species, height, age, leaf surface area, trunk diameter, tree density, existing canopy cover, and growing conditions, and can vary proportionally with their biomass.

As cities grow and face increasing environmental pressures, the need for resilient, sustainable, and livable urban environments is becoming more urgent.

Carbon pricing initiatives to mitigate climate change have become a multi-billion dollar industry. Quantitative measurements of carbon stocks are the fundamental basis for carbon trading and the carbon economy. An increase in a tree's leaf biomass directly impacts its carbon storage capacity. Leaf biomass is directly proportional to the tree's leafing rate, canopy width, and age. An increase in a tree's biomass directly affects the amount of carbon it holds (Gül et al., 2021).

Green spaces and green infrastructure are considered the most common and cost-effective actions to adapt to and become resilient to the effects of climate change. Urban green spaces (especially trees), which undertake the task of carbon capture and storage, as well as protected areas and natural systems within and outside cities, serve as an important resource.

In the context of combating global climate change, calculating and interpreting the carbon emissions and the amount of carbon sequestration and storage provided by urban trees/forests and green space systems, which serve as urban carbon sinks, will play a significant role in carbon pricing and in determining the services and contributions of urban ecosystems.

Integrating green spaces into urban structures not only addresses urgent environmental issues but also creates healthier and more equitable communities.

Despite the multifaceted services and contributions of urban green spaces (UGS), they face several significant challenges in mitigating the negative impacts of climate change.

- One of the most significant challenges is the prioritization of land use decisions in urban planning and management policies at the urban scale, particularly regarding construction, transportation, commerce, and industry, over green spaces, thus limiting the opportunity to create natural areas and green spaces.
- The high costs of creating and sustainably managing green spaces (maintenance, personnel, irrigation, repairs, machinery, equipment, security, etc.) can reduce the willingness to create green spaces due to insufficient local government budgets.
- The unequal and equitable distribution of urban green spaces in terms of quality and quantity at the neighborhood and city levels reduces the services and contributions of

green spaces. This inequality can exacerbate existing social inequalities, as individuals in underserved neighborhoods may have limited access to the health services provided by green spaces.

- The failure to use appropriate plant species in urban areas, the lack of suitable habitats for trees and shrubs, incorrect pruning practices, and the direct or indirect negative impacts of urban dwellers on urban green spaces and plants limit the services and contributions expected from green areas.

General information about the Demre District

Demre District is located within the borders of Antalya Province, on the Mediterranean coast, between 29° 20' - 32° 35' east longitudes and 36° 07'-37° 2' north latitudes and is a small rural-urban settlement 142 km from Antalya city center (Table 1).

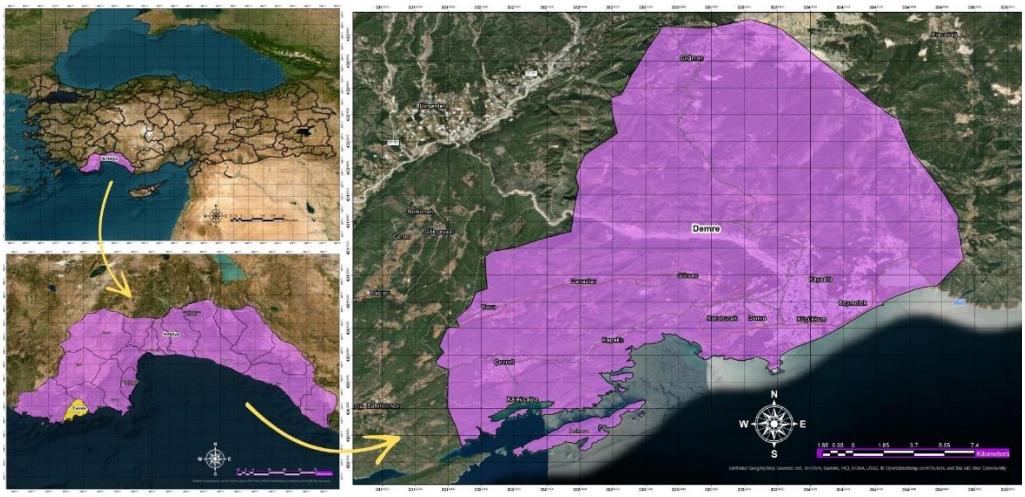


Figure 1. Demre District and its location

Agriculture and tourism are the driving forces in the city's economy. Housing construction and greenhouse farming play a significant role in urban development. Rivers originating in the northern mountains converge in the Myros Canyon (Demre River) before reaching the sea, and the current settlement is situated in the plain surrounding this river. Dalyan is located at the eastern end of this Demre plain, the famous port city of Andriake at the western end, and the ancient city of Myra at the northern end. Demre has a deep-rooted and significant cultural history dating back to the ancient Lycian period and is quite rich in natural and cultural heritage values. Spatially, Demre has fertile agricultural lands, and its wide plains, enriched by the alluvial soils brought by the Demre River, and its reddish-brown Mediterranean soils have a very favorable structure for agriculture (Western Mediterranean Development Agency (BAKA, 2021).

The region, which stands out in agricultural production with its intensive greenhouse activities and citrus fruit production (especially oranges and lemons), is known for its famous agricultural products such as "Demre pointed peppers". The diversity and quality of agricultural products ensure that the region has high potential in terms of agriculture-oriented tourism opportunities such as agrotourism, farm tourism and organic farming. Economically, Demre, which stands

out with its high-value aquaculture products such as blue crab and shrimp, makes significant contributions to the local economy thanks to its aquaculture resources.

The Demre district has a rich potential in terms of its historical and cultural architectural structures and ruins, as well as its unique natural heritage values. Furthermore, the presence of St. Nicholas, known as the birthplace of Demre and a significant figure in Christian history, and his church are considered significant identity assets (Dündar et al., 2024).

In order to evaluate the socio-cultural and socio-economic potentials of the Demre District, to protect cultural values, to protect rock tombs and protected areas and areas suitable for agriculture, to ensure the continuity of agricultural production, to plan tourism activities to be spread throughout the year and thus to ensure a homogeneous distribution of socio-economic development in the region, the Antalya Demre Culture and Tourism Protection and Development Region was declared (Official Gazette Decision dated 26.07.2010 and numbered 27653) (Antalya Metropolitan Municipality, 2018).

In the 1/25000 Scale Zoning Plan Report for the Demre District of Antalya Province, the total area of planned open and green spaces within the district borders is 130.0 hectares. Of this area, 76.2 hectares are within the plan approval boundaries, while 53.8 hectares are outside the plan approval boundaries.

This report presents the status of open and green spaces according to approved plan decisions; Park and Green Space 34 Ha, Afforestation Area: 6.7 Ha, Recreational Area 9.5 Ha, Cemetery Area 3 Ha and Shore and Beach 23 Ha (Antalya Büyükşehir Belediyesi, 2018).

The per capita green space amounts (m^2) in Demre District, according to the neighborhood populations, show an uneven and unbalanced distribution. Per capita green space amounts by neighborhood in Demre District: Beymelek (23.00 m^2), Büyükkum (21.73 m^2), Küçükkum (11.76 m^2), Yavu (9.70 m^2), Çağman (8.20 m^2), Davazlar (7.32 m^2), Belören (6.91 m^2), Karabucak (5.39 m^2), Köşkerler (3.54 m^2), Çevreli (3.06 m^2), Kayaaltı (2.89 m^2), Kapaklı (2.40 m^2), Gökyazı (2.33 m^2), Yaylakaya (1.32 m^2), Alakent (1.17 m^2), Üçağız (0.45 m^2), and Gürses (0.00 m^2),

In Demre district, only 3 out of 17 neighborhoods have more than 10 m^2 of green space per capita, while the other 14 neighborhoods have less than 10 m^2, resulting in an uneven and unbalanced ratio. Gürses neighborhood, in particular, has 0 m^2 of green space per capita. However, the ratio of the total existing green areas in Demre district to the city's population is 12.41 m^2 of active green space per capita. Overall, this meets the minimum 10 m^2 green space standard defined in the legislation.

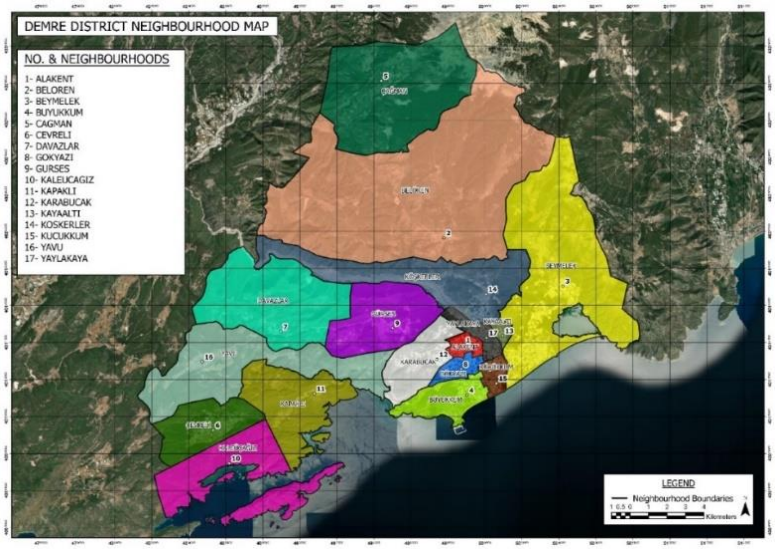


Figure 2. Neighborhoods of Demre District

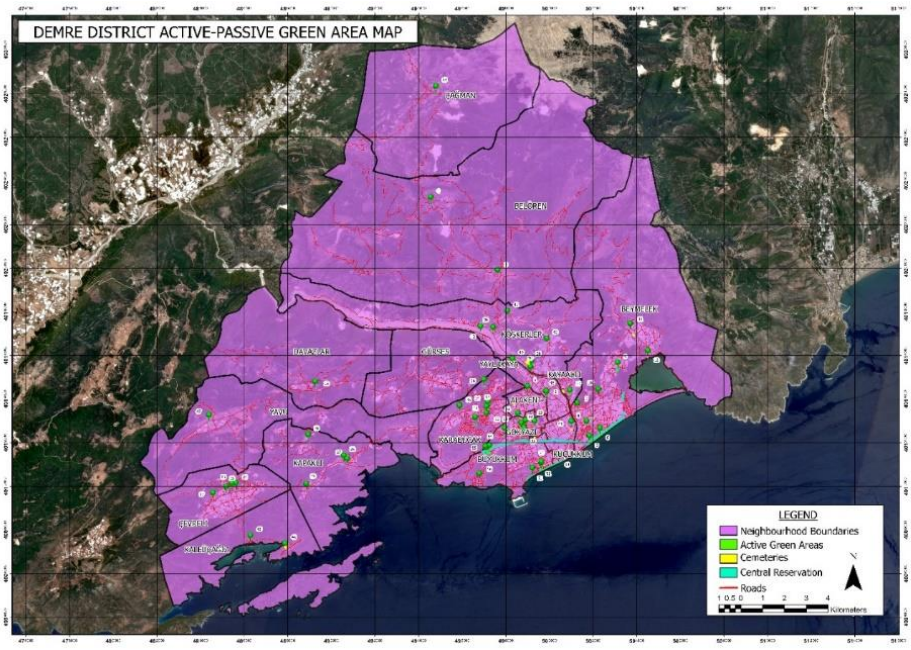


Figure 3. Active green areas of neighborhoods in Demre District

Table 2. Population, percentage of green space, and per capita green space (m^2) for the 17 neighborhoods of Demre District.

No.	Neighborhoods	Neighborhood Population (TÜİK, 2024)	Total Active Green Space Area (m^2)	Amount of Green Space per Person (m^2)
1	Alakent	1640	1931,75	1,17
2	Belören	496	3431,71	6,91
3	Beymelek	3686	84786,10	23,00
4	Büyükkum	2878	62556,72	21,73
5	Çağman	250	2051,35	8,20
6	Çevreli	786	2407,58	3,06

7	Davazlar	160	1171,23	7,32
8	Gökyazı	8129	18953,86	2,33
9	Gürses	402	0,00	0,00
10	Üçağız	502	228,82	0,45
11	Kapaklı	519	1249,17	2,40
12	Karabucak	2700	14576,19	5,39
13	Kayaaltı	404	1170,72	2,89
14	Köşkerler	2328	8245,90	3,54
15	Küçükkum	1344	15809,41	11,76
16	Yavu	411	3989,91	9,70
17	Yaylakaya	1179	1566,49	1,32
Total at Neighborhood Level		27814	224127	
Amount of Green Areas Per Person at the Urban Scale				12,41

Within the scope of urban green areas types, there are 55 in total, including 22 parks, 26 children's playgrounds, 4 sports fields, and 2 squares. Apart from urban active green areas, the total area of other passive green areas (Roadside and median green areas and Cemeteries) and the amount of green space per person is 8.10 m^2, and a total of 20.51 m^2 of green space per person is calculated

General Assessment of Demre City's Green Spaces

- The current amount of active green space per capita in Demre is 12.41 m², which can be considered sufficient.
- The distribution among neighborhoods is observed to be unequal and unbalanced.
- The ratio of green spaces to the neighborhood's total surface area is less than 1% in all neighborhoods.
- The areas covered by parks within the city are generally small.
- The largest area is Sahil Park, located within the boundaries of Beymelek, Büyükkum, and Küçükkum neighborhoods. It covers 94,332 m². There are four parks covering over 1 hectare. Other green spaces range from 2,000 m² to 250 m².
- The organic connection between parks within the city and with natural areas outside the city is insufficient.
- The variety of activities and facilities in children's and sports playgrounds is limited.

Strategic Actions for Spatial and Urban Green Spaces in Demre During the Climate Change Adaptation Process

Urban green spaces are a crucial component requiring a holistic approach to urban planning, urban design, and urban management. To maximize the benefits of urban green spaces (UGS) in mitigating climate change, key strategic goals and prioritizations in local government policies should be addressed under three main headings:

- Planning/Design and Implementation Process

- Institutional, Legal, and Administrative Process
- Participation and Awareness Process

a. Planning/Design and Implementation Process

- ❑ For the sustainability of Demre's resource values, establishing a balance between "conservation and use compatible with conservation" should be the fundamental goal in all spatial planning.
- ❑ Open and green space systems should be holistically linked and positioned in the city's Master Development Plans.
- ❑ Guiding guidelines/manuals should be developed that consider local climate data, addressing urban landscape and urban greenery as a holistic system in spatial planning and urban design, including issues such as site selection, prevailing wind direction, passive ventilation and sunlight, construction and implementation.
- ❑ The site selection, standards, functionality, and distribution of urban public open and green spaces should be mandatorily included in urban development planning decisions and should also be reflected in other sector planning and policies (housing, transportation, health, sustainability, biodiversity, etc.).
- ❑ In the urban master plan process, the inventory and analysis of green spaces should be considered as an important component of planning. For this purpose, in determining the typologies of green spaces at various scales (city, district, neighborhood), many factors should be taken into account, such as: user demands and trends for green spaces, ideal location selection for green spaces, size and form of green spaces, population analyses of the city, socio-economic dimensions of the city, relationship with urban local identity, accessibility, ecological relationship, plant species used, composition and analysis, landscape equipment and materials.
- ❑ In order to create livable, healthy and high-quality urban spaces, the open and green space system of the city should be considered in the urban planning process at the city, district and neighborhood scales in an equal, fair and sufficient size, with functional and equipped facilities that will provide multifaceted ecosystem services, and within a spatial, positional and functional hierarchy.
- ❑ Urban green spaces should be connected with natural green spaces within and around the city and should form a holistic green network system that provides continuity.
- ❑ Ecological bridges should be designed within the city and on intercity highways surrounding it.
- ❑ Urban heat islands, green space needs, and wind corridors should be identified, and accessible green areas with dense natural surfaces and ecological corridors should be created within the urban fabric.
- ❑ A "Urban Design Guide" should be created specifically for Demre.
- ❑ Conservation-Oriented Development Plans must be prepared for areas with conservation status both within and outside the city.

- A comprehensive green space inventory (type, tree diameter, crown width, height, etc.) should be compiled for carbon footprint calculations in urban trees and green areas, and digitized in a GIS environment.
- The primary goal in landscape structural and plant design projects should be to produce nature-based solutions for carbon sequestration and storage.
- Native species of the region should be preferred when selecting plant species to be used in green areas. Rainwater management should be implemented in urban and peripheral areas, creating rain gardens, sponge city details, rain ditches, and natural water surfaces. Public spaces should be transformed into designs that collect and transfer water to storage systems during heavy rainfall.
- Newly planned parks should be larger areas, designed as City Parks, National Gardens, and multi-purpose recreation areas.
- Complex children's and sports playgrounds should be located in urban green spaces, diversified to appeal to all age groups and suit their purpose.
- Empty and unused areas in and around the city should be transformed into green spaces or utilized as urban farming areas to contribute to the city's food needs. Green areas should be designed and implemented with sustainable and innovative drainage and infrastructure systems.
- A bicycle path network should be designed to increase accessibility from the city center to areas of tourist value (coastal area, ancient cities, Çayağzı, boat harbor, etc.) and to be linked to green areas.
- The Lycian Cultural Route, which passes through the Demre district, should be prioritized for spatial organization.
- New cultural routes should be created taking into account the city's historical, archaeological, and touristic points, landscape landmarks, green areas, etc.
- Parking lots should be provided in urban green areas to contribute to the city's transportation.
- Demre Çayağzı Boat Harbor and its surroundings are currently the most important attraction for boat tour tourism. However, it also has multifaceted problems in terms of spatial, recreational, environmental/ecological, transportation, economic, security, aesthetic, functional, and socio-cultural dimensions. A spatial improvement and development project should be carried out.

b. **Strategic Actions for Institutional, Legal and Administrative Processes**

- The municipality should be strengthened with technical staff and support personnel within its organizational unit to be effective and competent in the management of public green spaces for which it is responsible (planning/design, implementation, protection, maintenance, repair, etc.).
- A city council should be established, and voluntary participation should be ensured through various Working Groups.
- An "Aesthetics Board" should be established within the municipality.

- ❑ Landscape design application projects (Structural and Plant Projects) should be mandatory in the building permit approval process for construction projects in municipalities.
- ❑ Incentives and policies should be developed to promote green roofs and balcony gardening.
- ❑ A green space inventory should be integrated into the City Information System, which is mandatory for cities.
- ❑ Green roof and green facade applications should be encouraged, especially in high-density city centers where the supply of open spaces is limited.
- ❑ A green space network should be developed using concepts such as agrotourism, farm tourism, carbon farming, agroforestry, gastronomic tourism, and slow food, to integrate agricultural areas into tourism.
- ❑ Drought-resistant and aesthetically pleasing urban areas should be created through drought-tolerant landscape practices.
- ❑ A comprehensive strategic action plan should be developed for the Demre River (Myros River), and it should be surrounded by green corridors for conservation and recreational uses. Water storage can be ensured by constructing dams on the river.
- ❑ The city's rainwater drainage system management plan should be organized and linked to existing stream beds (especially the Demre River), and the water should be stored and made usable by creating a biological pond near the sea, rather than directly into it.
- ❑ Value-added products should be obtained from plant and organic waste and residues on an urban scale through recycling (e.g., producing compost fertilizer from plant residues, industrial product production, etc.). Risk maps should be created in urban areas using spatial data. Digital twins of cities should be created to enable risk analyses to be carried out through this infrastructure.
- ❑ An accessible city portal should be created within the municipality (WebMapService).
- ❑ Data sharing on tourism, recreation, green areas, transportation, cultural events, etc., should be done on the municipality's website.

c. Participation and Awareness Process

- ❑ Active participation of urban residents should be ensured in the planning and management of urban green spaces, and their demands and trends should be taken into account.
- ❑ Awareness activities should be carried out on topics such as nature and environmental protection, ornamental plant cultivation, gardening, fruit growing, etc. (Scientific events, festivals, cultural events, etc.)
- ❑ Public education and awareness campaigns should be conducted on urban agriculture and gardening.
- ❑ Changes should be made in water usage habits in urban areas, and education and awareness campaigns should be conducted to spread a culture of water efficiency.
- ❑

4. Conclusions and Recommendations

Within the framework of the Climate Change Adaptation Strategy, the goal is to increase climate resilience in all sectors through smarter, more systematic, faster, and international actions to achieve the 2050 zero-carbon target. It is emphasized that to achieve these goals, nature-based solutions should be utilized and investments in nature should be increased (European Commission, 2021).

In our country, Article 7-(4) of the "Climate Law" No. 7552, adopted on 2/7/2025 (Published in the Official Gazette: Date: 9/7/2025, Number: 32951), mandates the creation of a comprehensive plan in each province, taking into account the requirements for a just transition to reduce greenhouse gas emissions and adapt to climate change. Local governments need to integrate climate change into their urban planning and management activities to mitigate the negative impacts of climate change and to produce solutions for the adaptation process. Strengthening spatial relationships in cities and developing environmentally sensitive areas and ecosystems are important aspects of climate action planning.

Every city center needs to develop a database of existing conditions, including the provision of infrastructure and services, and details of environmental hazards and vulnerabilities. This process will go far beyond climate change adaptation, documenting and mapping other environmental hazards and who is most at risk, and providing important guidance on how best to respond (Akten & Gül, 2024).

Urban green spaces are an important part of public spaces. Therefore, public green spaces need to be easily accessible to all population groups, distributed equally and fairly at the urban and neighborhood scale, planned, designed, and sustainably managed to provide spatial size and functional services and contributions for green space typology purposes (WHO, 2017). In the specific case of Demre, the local government policy should prioritize the protection of existing green and natural areas and the sustainable management of newly created green spaces.

As cities continuously grow and continue to grow, the conscious integration of green spaces into urban planning and policies will be vital for creating resilient and sustainable environments. Prioritizing these areas will help cities effectively address the impacts of climate change, while promoting public health and social equity, and facilitating access to the benefits of green spaces for all residents.

Sufficient funding should be allocated for the maintenance and improvement of urban green spaces. Regular maintenance, including landscaping, irrigation, and waste management, is vital to keep these areas safe, attractive, and usable.

It will be possible to increase the climate resilience of cities by creating locally specific natural areas and green spaces (city parks, green corridors, stream corridors, rain gardens, roof gardens, etc.) that incorporate nature-based or hybrid solutions in urban areas to address the climate change, carbon emissions, and biodiversity crisis. Open and green spaces should have sufficient spatial capacity to be used as gathering and shelter areas for earthquakes, floods, and similar disasters.

Instead of a "Sustainable Development" approach, urban policies for combating climate change should prioritize a green economy approach that emphasizes ecology and nature conservation, social rights, fair working conditions, and increased employment. The organization and management of green spaces should actually be perceived as a public health and social investment, and having a long-term green city vision is a necessity for creating a holistic standard of living in Demre.

Demre has the potential to become a Cittaslow (Slow City), and the city planning and management process should be designed and organized according to this concept. Urban green spaces and natural green spaces should be considered within this concept.

The existence and quality of natural and cultural green spaces in Demre district should be considered as a factor supporting and developing urban tourism.

To create smart, healthy, resilient, and livable cities, green spaces should be designed in harmony and balance with the city. It should be understood that green spaces are not a luxury, but a smart form of conservation.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Akten, S., & Gül, A. (2024). The role of local governments in adapting cities to climate change. *Journal of Protected Areas Research*, *3*(1), 84–92. Retrieved from https://mimarlikbilimleri.com/ojs/index.php/journalofprotectedareasresearch/article/view/40

Antalya Büyükşehir Belediyesi (2018). Antalya İli Demre ilçesi 1 /25000 Ölçekli Nazım İmar Planı Raporu, Mayıs-2018. İmar ve Şehircilik Dairesi Başkanlığı Nazım Plan Şube Müdürlüğü. Antalya.

Balaban O. (2017). İklim değişikliği ve kentler. *ODTÜ'lüler Bülteni Dosya*, p 30. Temmuz-Ağustos 2017 https://www.odtumd.org.tr/odtubulten/2017/07082017/resources/_pdfs_/07082017__.pdf (Accessed on September, 12, 2025)

Batı Akdeniz Kalkınma Ajansı (BAKA) (2021). Antalya Demre Mevcut Durum Analizi Sorunlar ve Çözüm Önerileri. BAKA Yayın No: 2021/114, p 56.

Benedict, M. A. (2000) Green infrastructure: A strategic approach to land conservation. *American Planning Association PAS Memo*, October 2000.

Bilgili B.C., Çığ, A. & Şahin, K. (2011). Van Kenti kamusal yeşil alanlarının yeterliliğinin ulaşılabilirlik yönünden değerlendirilmesi. *YYÜ Tar. Bil. Derg. (YYu J. Agr. Sci.)* 2011, 21(2): 98-103.

Boland, B., Charchenko, E., Knupfer, S., Sahdev, S., Farhad, N., Garg, S., & Huxley, G., (2021). "Focused adaptation: A strategic approach to climate adaptation in cities, C40 Cities McKinsey Sustainability". Focused adaptation: A strategic approach to climate adaptation in cities.

Çevre, Şehircilik ve İklim Değişikliği Bakanlığı (2025). Türkiye'nin 2053 Uzun Dönemli İklim Stratejisi. https://iklim.gov.tr/db/turkce/dokumanlar/turkiyenin--8230-3143-20250210095501.pdf (Accessed on September, 12, 2025).

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management,* 146, 107-115.

Dündar, H. B. Aydemir, Ç., Gül, A. (2024). Ecotourism Potential of Demre (Antalya) Region. 5th International Urban Landscape and Art Congress October 25-27, 2024 / p.560-579. Paris, France. ISBN: 978-625-367-954-5. ISSUED: November 27, 2024. DOI: https://doi.org/10.5281/zenodo.14229713. https://www.iksadkongre.com/urban

European Commission, (EC), (2021). *Forging a climate-resilient Europe- the new EU Strategy on Adaptation to Climate Change*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN (Accessed on 17 May 2022).

European Commission, (EC), (2022). *Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN (Accessed on 17 May 2022).

Feyen L., Ciscar M., Carlos, J., Simon, G., Ruiz Dolores, I., Ramirez A.S., Alessandro, D., Gustavo, N., Simone, S., Giuseppe, F., Giovanni, Girardello, M., Spinoni, J., Mentaschi, L., Bisselink, B., (2020). "Climate change impacts and adaptation in Europe". *JRC PESETA IV final report*, *JRC Research Reports JRC119178*, Joint Research Centre (Seville site).

Gezer, A. & Gül, A. Eds. (2009). Kent Ormancılığı (Kavramsal-Teknik ve Kültürel Boyutu). SDU Orman Fakültesi, Kitap Yayın No: 86, s: 01-246. Isparta. 2009. (ISBN: 978-9944-452-30-4) SDU Basım evi- Isparta. https://www.researchgate.net/profile/Atila-Gul/publication/348522666_KENT_ORMANCILIGI_Kavramsal_teknik_ve_Kulturel_Yaklasimlar/links/600216b445851553a049292f/KENT-ORMANCILIGI-Kavramsal-teknik-ve-Kueltuerel-Yaklasimlar.pdf

Gül, A. & Küçük, V. (2001). Kentsel açık-yeşil alanlar ve Isparta Kenti örneğinde irdelenmesi. *Süleyman Demirel Üniversitesi, Orman Fakültesi Dergisi*, A (2), 27-48.

Gül, A., Dinç, G., Akın, T. & Koçak, A. İ. (2020). Kentsel açık ve yeşil alanların mevcut yasal durumu ve uygulamadaki sorunlar. *Journal of Urban Studies İdeal Kent, Kentleşme ve Ekonomi Özel Sayısı*, Cilt Volume 11, Yıl Year 2020-3, 1281-1312, ISSN: 1307-9905 E-ISSN: 2602-2133DOI:10.31198/idealkent.650461

Gül, H. E. & Gül, A. (2022). Nature-Based Solutions For the Design of The Built environment in The Framework of Climate Change Adaptation. 3rd International Mountain and Ecology Congress Within The Framework of Sustainable Development. (MEDESU2022) Proceedings Book, p 512-523. October 20–21, 2022/Trabzon-Türkiye. Issued: 05.12.2022, ISBN: 978-625-6380-31-8.

Gül, A. (2024). Karbon Fiyatlama Yaklaşımları ve Yeşil Alan İlişkisi. İnce, K. (Ed.) Kentsel Yeşil Alanların Sürdürülebilir Yönetimi. (Haziran, 2024), Bölüm 6, 176-210. ISBN: 978-625-367-746-6. Iksad Publications. DOI: https://dx.doi.org/10.5281/zenodo.12698808

IPCC, (2000). Emissions Scenarios. A Special Report of IPCC Working Group III (Accessed on September 20, 2025). https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf

IUCN, (2020). "IUCN Global standard for nature-based solutions: A user-friendly framework for the verification, design and scaling up of NBS", *International Union for Conservation of Nature,* Gland, Switzerland.

Kazancı, G. & Tezer, A. (2021). Spatial planning in the climate change adaptation and Turkey in the framework of smart governance. *Planlama,* 2021;31(2):302–320. doi: 10.14744/planlama.2021.87487

Leichenko, R., (2011). "Climate change and urban resilience", *Current Opinion in Environmental Sustainability,* 3 (2011), 164-168.

McKinney, M. L. (2008). Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystems*, 11(2), 161-176.

Nowak, D. J., Stevens, J. C., Sisinni, S. M., and Luley, C. J. (2002). Effects of urban tree management and species selection on atmospheric carbon dioxide. *Arboriculture & Urban Forestry (AUF)*, *28*(3), 113-122.

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., and Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*, 9(1), 27-36.

Raymond, M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita , M. R. Geneletti, D., Calfapietra, C., (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy* Volume 77, November 2017, Pages 15-24.

The Global Commission on the Economy and Climate, (2014). Better Growth, Better Climate: The New Climate Economy Report the Synthesis Report IMF-WB Annual meetings, 8 October 2014. https://sustainabledevelopment.un.org/content/documents/1595TheNewClimateEconomyReport.pdf

Toy, S., & Eren, Z. (2023). Suggestions for the parametrization of urban characteristics to increase the climate – resilience of cities in Türkiye. *Çevre, Şehir ve İklim Dergisi.* 2(4), 324-347.

Toy, S., & Esringü, A. (2021). Erzurum'da Kent Kanyonu Alanlarının gelişimi ve peyzaj imarlığı açısından alınabilecek Tedbirler. *ATA Planlama ve Tasarım Dergisi, 5*(2), 89-96. 10.54864/ataplanlamavetasarim.1038118

Türker, B. H., & Gül, A. (2022). Kentsel açık ve yeşil alanlarının niceliksel analizi ve irdelenmesi: Uşak Kent Merkezi örneği, *Kent Akademisi Dergisi,* 15(4):2088-2109. https://doi.org/10.35674/kent.999451

Turizm Proje Dergisi, (2021). Antalya Turizm Sezonunu Uzatıyor: İlk 9 Ayda 14 Milyon Ziyaretçi. https://www.turizmprojedergisi.com/haber-detay/antalya-turizm-sezonunu-uzatiyor-ilk-9-ayda-14-milyon-ziyaretci/5801#:~:text=Toplam%20Ziyaret%C3%A7i%3A%202025%20y%C4

%B1l%C4%B1n%C4%B1n%20ilk,milyon%2091%20bin%20318%20ki%C5%9Fi). (Accessed on June 17 2025).

WHO, (2017). Urban Green Spaces: A Brief for Action. p 11. https://www.euro.who.int/en

UN-Habitat, (2020). *World Cities Report 2020 The Value of Sustainable Urbanization*. ISBN 978-92-1-132872-1

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Classification of Kinetic Building Components in Contemporary Architecture

Hatice Eda GÜL[1]*

ORCID 1: 0000-0001-5203-1739
[1]Master's Student, Dokuz Eylül University, Department of Architecture, Doğuş Çaddesi, Buca- Izmir, Türkiye
haticedagul@gmail.com (Responsible Author)

Nazire Tuğçe YENİCE[2]

ORCID 2: 0009-0008-7167-1385
[2]Master's Student, Dokuz Eylül University, Department of Architecture, Doğuş Çaddesi, Buca- Izmir, Türkiye
naziretugcee.yenice@gmail.com

Yenal AKGÜN[3]

ORCID 3: 0000-0001-5595-9153
[3] Prof. Dr., Dokuz Eylül University, Department of Architecture, Doğuş Çaddesi, Buca- Izmir, Türkiye
yenal.akgun@deu.edu.tr

Abstract

Recent technological developments in architecture, engineering, and materials science have accelerated the incorporation of kinetic systems in contemporary buildings, enabling them to adapt dynamically to environmental functional, and social demands. While existing studies often examine individual examples or typologies, there remains a need for comprehensive classification framework to reveal the full potential of kinetic design. This study presents a comprehensive taxonomy divided into four main categories: (1) Structural systems that demonstrate large scale adaptability such as bridges, transformable structures and deployable temporary systems. (2) Kinetic Façade Systems, which directly affect energy performance, climate control, and aesthetic expression: (3) Kinetic Roof Systems, capable of managing large spans and react to environmental conditions while preserving structural integrity and functionality. (4) Building Components, which include interactive elements, interior adaptability and kinetic urban furniture that emphasize user experience and spatial flexibility. By positioning these diverse systems within a unified framework, the study demonstrates how kinetic architecture enhances building performance through increased energy efficiency, environmental responsiveness, and user comfort, while also enhancing architectural experience through adaptability, diversity, and interaction. The study frames kinetic design as a multifaceted design language that shapes the smart, adaptable cities of the future.

Keywords: Kinetic systems, contemporary architecture, smart buildings, adaptive design

1.Introduction

The fields of architecture and structural engineering are evolving rapidly to meet the demands of the era and the ever-changing needs of users. This evolution has led to the design and implementation of smart and adaptable building systems that can reconfigure spatial arrangements in response to immediate demands incorporating movable interior walls, variable façades, and multipurpose furniture (Akgün et al., 2013). The dynamic potential of buildings with moving components has been maintained as a dynamic possibility through the concept of kinetic architecture, first defined in the 1970s, contrasting with the static nature of traditional buildings. During the rapid technological developments of the early 20th century, this concept began to express artistic, political, and philosophical discourses as well as aesthetics and functionality (Fouad, 2012).

The origins of kinetic systems in architecture date back to the earliest periods of architectural history. These systems have undergone significant evolution, progressing from manually

operated mechanisms to highly sophisticated mechanical and electronic smart systems. Today, kinetic elements appear in various forms as dynamic components of circulation schemes, functional elements of service systems, or most frequently, flexible building façades (Ramzy & Faye, 2011). Kinetic systems offer flexibility to buildings by enabling various configurations, from interior redesign to complete structural arrangements, and adaptation to users and environmental factors such as temperature or wind (Fouad, 2012). These systems serve both practical (safety and space optimization) and humanitarian purposes. Researchers and architects in this field are working to develop complex systems that can automatically correct structural deformations, dynamically adjust load-bearing capacity, or completely alter geometric configurations (Ramzy & Fayed, 2011). Such systems may also include structural components that fold, slide, expand, or transform in size and shape.

Although deployable and transformable systems, while possessing a similar capacity for movement and change, they differ significantly. Deployable structures expand by moving from a collapsed to an expanded position, having only two predefined states (closed/collapsed or open/deployed). On the other hand, transformable structures form a broader category; while also expandable, they are not limited to binary configurations. They can possess multiple states and change their shape, orientation, function, or size. In short, all deployable structures are transformable, but not all transformable structures are deployable (Maden et al., 2019).

This study examines four primary architectural components commonly used in kinetic architectural applications: structures, façades, roofs, and other architectural elements. Portable, relocatable, and demountable systems are outside the scope of this study. Deployable and transformable systems encompass all these categories. Despite the increasing number of kinetic systems applied in contemporary architecture, literature still lacks a clear and comprehensive framework that unifies these systems under a single structure. Existing studies generally focus on isolated examples or narrow typologies, leading to a fragmented understanding of the field and making holistic comparison or evaluation of kinetic systems difficult. To address this gap, the study aims to propose an inclusive and systematic classification that organizes kinetic systems according to their fundamental architectural components. By examining structures, façades, roofs, and building elements as an integrated taxonomy, the study aims to clarify their roles, performance potentials, and architectural implications, and establishes a more consistent terminology and a logical classification system.

2.Materials and Methods

This study employs systematic literature review as its primary research methodology. The main objective is to develop a new classification of kinetic systems under four main groups. The methodological framework consists of three interrelated phases: (i) reviewing existing classification systems, (ii) collecting and analyzing relevant data, and (iii) identifying deficiencies and limitations within current classification approaches.

To assess the current state of research, the first phase begins with a systematic review of literature that focuses on kinetic structure of classifications. To follow the development of the main classification frameworks in kinetic architecture, the reviewed studies are arranged chronologically. Search using terms such as “kinetic,” “deployable,” “transformable,” “changeable,” “material-based,” “structural typology,” “geometric configuration,” “function-based,” and “movement-based” are used in an organized keyword search to find relevant publications. These keywords allow a thorough analysis of the criteria used in current

classification systems, the methodological coherence of the reviewed studies, and the theoretical basis of kinetic structures.

The study examines existing current general classification frameworks and synthesizes them into four main groups. A comprehensive and novel classification system is proposed based on this synthesis. The inclusion of completed example projects supports the validity applicability of the proposed classification, highlighting its significance for both theoretical research and architectural practice.

3.Findings and Discussion

Over the years, various researchers have conducted numerous studies on the classification of kinetic architecture and kinetic structures. These classification techniques are based on each author's area of expertise and the scientific framework they apply in their approach to the subject. Classification is based on technical observations about the structural and mechanical functioning of buildings, as well as evaluations of their final application and results related to movement mechanisms. This dual approach reveals the depth and diversity of the field (Megahed, 2016).

3.1. Evaluation and Review of Existing Classifications

Table 1 summarizes current kinetic structure classification techniques and emphasizes the standards each author applied. Although structural type and movement type are the main focus of many classifications, this comparative analysis demonstrates significant variation in the inclusion of other crucial features such as material, function, and geometry. For instance, Merchan (1987), Otto & Burkhardt (1972), Mollaert (1996), and Schumacher et al. (2010), for example, concentrate on movement type, which describes how a kinetic structure functions, and structural type, which describes its fundamental form. The principle of movement is further developed by Otto & Burkhardt (1972), and Mollaert (1996), while Merchan (1987) and Schumacher et al. (2010) incorporate additional criteria, such as material, to this fundamental framework. This approach exemplifies a commonly used technique that seeks to describe a structure in terms of both its motion mechanisms and its static state.

Function and structural type are the primary focus of Del Grosso & Basso (2013), Gantes (1991), Escrig (1996), and Hanaour & Levy (2001). For these researchers, prioritize the structure's basic form and function over other aspects related to movement. Direction of movement is additionally employed by Escrig (1996) and by Hanaour & Levy (2001). The main criteria in the classifications put forth by Pellegrino (2001) and Lee (2012) are also function and structural type. However, Temmerman (2007) and Adrover (2015) classify systems based only on their basic form, concentrating almost entirely on structural type. Temmerman (2007) also incorporates movement direction as an additional criterion. In contrast to other classifications, Adrover's (2015) classification is based on particular examples rather than movement or function. Stevenson (2011) offers a simple method that categorizes structures only based on the kind of movement. Instead of emphasizing the structure's physical layout, this framework concentrates on its dynamic properties.

The most comprehensive set of criteria, which includes material, function, structural type, movement direction, and geometry, was utilized by Korkmaz (2004) and Asefi (2010). Their work provides one of the most comprehensive classifications in the field by examining kinetic structures from a variety of perspectives: shape, movement, purpose, and physical characteristics.

Table 1. Evaluation of existing classifications (Atlamaz & Akgün, 2023)

Classification methods								
Author	**Year**	**Classification**	**Material**	**Function**	**Structural type**	**Movement type**	**Movement direction**	**Geometry**
Merchan	**1987**	Deployable Structures	✓		✓	✓		✓
Otto & Burkhardt	**1972**	Deployable/ Transformable Membranes			✓	✓	✓	
Otto & Burkhardt	**1972**	Retractable Roofs			✓	✓	✓	
Gantes	**1991**	Terrestrial Applications		✓	✓	✓		
Escrig	**1996**	Deployable Structures		✓	✓			
Mollaert	**1996**	Deployable Membranes			✓	✓		✓
Pellegrino	**2001**	Deployable Structures		✓	✓			
Hanaour & Levy	**2001**	Deployable Structures		✓	✓			✓
Korkmaz	**2004**	Kinetic Architecture	✓	✓	✓			✓
Temmerman	**2007**	Deployable Structures			✓			
Schumacher et al.	**2010**	Deployable Structures	✓		✓	✓		
Asefi	**2010**	Transformable Structures	✓	✓	✓			✓
Stevenson	**2011**	Kinetic Architecture				✓		
Lee	**2012**	Changeable Structures		✓	✓			
Del Grosso & Basso	**2013**	Deployable Structures		✓	✓			
Adrover	**2015**	Deployable Structures			✓			

3.2. Proposed Classification for Kinetic Building Components

Depending on the primary system type used, the proposed classification depicted in Figure 1 divides kinetic building components into four main categories: structure, roof, facade, and building components.

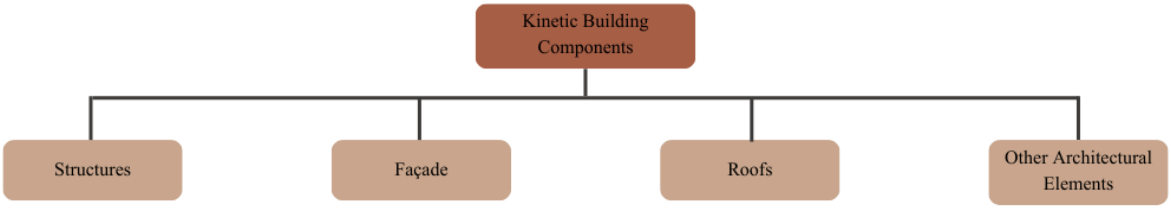


Figure 1. General Classification of Kinetic Building Components

Based on the fundamental modifiers, kinetic systems are classified into two main categories: deployable and transformable. Within each category, motion groups are used to further classify the systems. These two main categories can be divided into three main types of movement: responsive, sliding, and rotating (Figure 2)

Responsive systems are highly convertible systems that can withstand the effects of changing requirements and dynamic needs, switching between more than two variations to create more flexible alternatives (Abdallah et al., 2020).

Deployable structures that can be folded for transport or storage. The fundamental contradiction between deployable and transformable structures definitions are often used interchangeably. Deployable structures can independently make changes between their major configuration changes (Werner, 2013).

Depicted in Figure 2 rotating mechanisms are divided into two categories: folding/scissor and radial/fan expansion. They distribute the load by moving around hinges or axes (URL 1, 2). Telescopic/nested extension, coolable/stem telescopic systems, and linear sliding deployable spans, which offer planar extension, are examples of sliding systems based on the linear movement of components relative to each other (URL 3, 4, 5). Lastly, responsive deployable systems are examined in more detail under the subheadings of morphing deployable trusses, active tensegrity morphing systems, smart material-based deployable, and electro responsive deployable, which can change form through active or passive control (URL 6, 7).

Conversely, transformable structures can rapidly and controllably acquire new shapes, forms, functions, or properties through changes in external and/or internal surfaces connected by articulated joints. Convertible projects generally focus on meeting the functional requirements of the project rather than aesthetic effects (Werner, 2013).

Depicted in Figure 2, Rotating, sliding, and responsive mechanisms are used to analyze these systems methodically. Rotating transformable systems utilize radial/fan expansion, fold/articulated rotation through jointed movements, and scale/single-axis rotation to alter their structural form (URL 8, 9, 10). Linear translation, which provides retractability, and Curvilinear/Rolling Path principles, which alter form along curvilinear paths, are two examples of sliding mechanisms that exhibit linear translational motion (URL 11, 12). On the other hand, responsive transformable systems provide the capacity to align with operational principle control strategies and interact with environmental demands, such as light, heat, wind, and user input. These systems are classified into two fundamental strategies: Material-based adaptation,

which depends on the material's own response, and actively controlled structural adaptation, which depends on external control (URL 13).

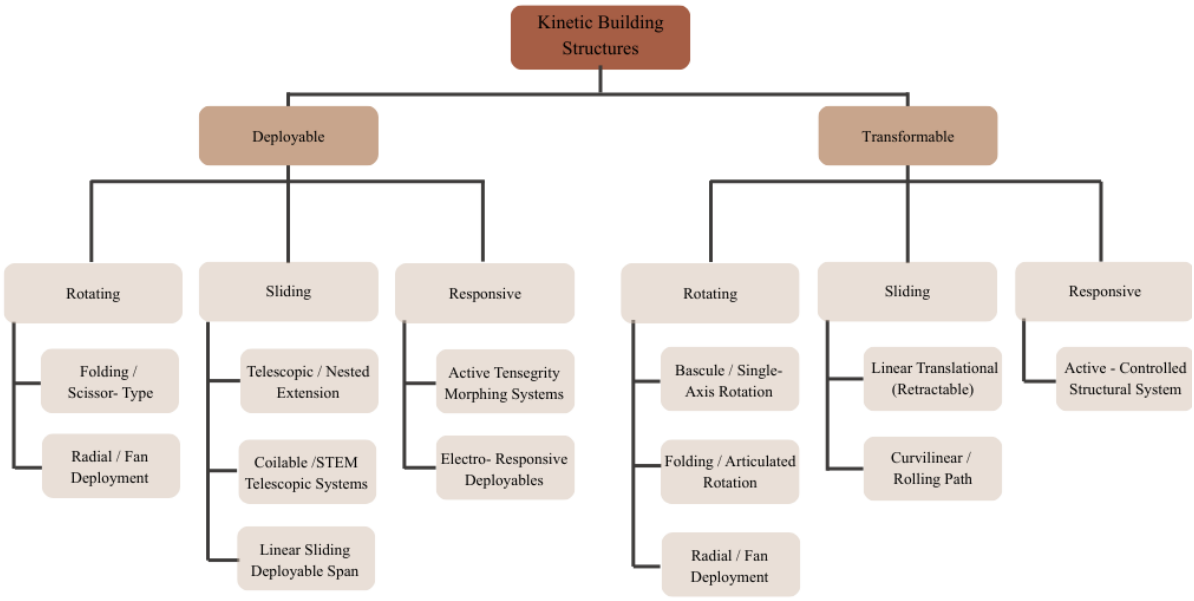


Figure 2. Classification of Kinetic Building Structures

Kinetic facades involve movements or deformations that occur through geometric transformations in space without disrupting the overall structural integrity of building facades. As a result of these movements, the condition of the building's facades, material properties, or physical structure are affected. The applications of kinetic facades aim to enhance aesthetic qualities as well as create sustainable and user-responsive systems that respond to changing environmental conditions, fulfilling functions that would be impossible for static facades (Sharaidin, 2014).

Two basic movement mechanisms, sliding and folding, are used to examine these systems (Figure 3). The single-axis movement type, in which façade elements move in a single plane or along a single axis, is a model of sliding mechanisms (URL 14). Folding systems, which include articulated/bi-fold movement type, rely on folding façade components with hinged links (URL 15).

Transformable façade systems typically change their shape, size, or optical properties to fulfill a continuous operational need. Four primary mechanisms, rotating, scaling, responsive deforming, and hybrid, are used to categorize these systems (Figure 3). Rotating façade systems offer distribution through rotation around axes; classified as single-axis rotation (vertical or horizontal) and multi-axis rotation for complex movements. One-axis rotation involves movement around a single fixed axis, vertical rotation refers to situations where façade elements rotate only around the vertical axis, and multi-axis rotation describes complex movement (URL 16, 17, 18). There are two types of scaling mechanisms: translation-based scaling and 2D scaling based on 2D rotation. These mechanisms change the coverage ratio or façade surface size (URL 19, 20).

Facades that can adapt to changes in environmental conditions and respond to these changes by making typological changes or altering their overall form are defined as responsive. This can

be applied to improve daylight quality and thermal performance in interior spaces by affecting the physical structure or material properties of the building facade. This adaptation can reflect environmental conditions while maintaining overall structural integrity (Sharaidin, 2014).

Responsive deformation systems bend or deform the form to adapt. The findings are categorized into two groups: deformation/physical properties and deformation/visual properties (URL 21, 22). Lastly, among hybrid systems that include various types of movement, the square tic, which features sliding and retracting movement, is found (URL 23).

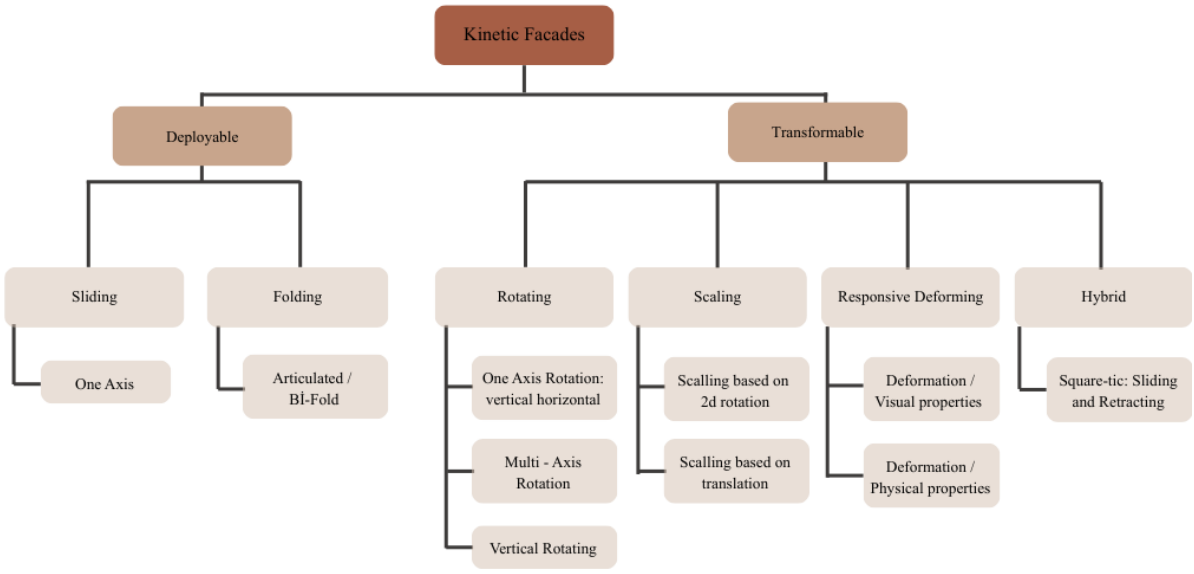


Figure 3. Classification of Kinetic Facades

According to Atlamaz & Akgün (2023), kinetic roof structures are divided into three main categories according to the primary systems used: membrane, rigid bar, and rigid panel. Membrane kinetic roof structures are primarily classified according to the type and size of movement. Rigid bar kinetic roof structures are classified only by the type of movement because the direction of any movement is difficult to determine due to the multifaceted nature of the system. Finally, rigid panel kinetic roof systems are classified according to the type of movement, appearance, and whether there is an overlap condition.

Lightweight deployable roofs are commonly used in various applications to provide weather or environmental protection. For example, sport facilities are often designed with retractable roofs so they can be used to open in good weather and covered in bad weather. Quickly constructed roofs can also be used to seasonally cover athletics fields or swimming pools, allowing for year-round use (Wolfe, 2013).

Depending on the structural component used, deployable roof systems are categorized into three main types, aiming to provide flexibility in both storage and deployment (Figure 4). Folding and bunching movements, such as horizontal folding/bunching (horizontal to the center), horizontal folding/bunching (horizontal to the perimeter), and horizontal parallel folding/bunching (horizontal to the parallel), as well as general folding/bunching systems, are typical of membrane kinetic roof structures (URL 24, 25, 26). The movement of rigid components is the foundation of rigid bar deployable roofs, which can rotate or combine folding/bunching with rotating movements (URL 27, 28, 29). Rigid panel deployable roofs, on

the other hand, are deployed by the movement of the panels; the sliding category comprises movable panels overlapping and sliding onto static part types, while the rotating classification comprises horizontally and vertically rotating panels (URL 30, 31).

Transformable roof systems that can rapidly and controllably acquire new shapes, forms, functions, or characteristics because of changes to the building, exterior, and/or interior surfaces. They are generally structural applications that focus on improving the functional requirements of a project rather than aesthetic effects, addressing environmental impacts (e.g., rain protection for various sporting events or allowing sunlight in). Examples include outdoor projects such as stadiums and pavilions with retractable roofs (Lee, 2012).

There are two main structural types of transformable roof systems, which typically aim to provide continuous functional change or adaptation (Figure 4). Rigid bar transformable roofs include rotating mechanisms (single axis) and multidirectional kinematics, which involve complex movements and rely on the motion control of rigid bar elements (URL 32, 33). Rigid panel transformable roofs consist of rigid panels and are kinetic roof systems in which the roof geometry is transformed over time through the opening, closing, or movement of these panels by means of mechanical systems (URL 34).

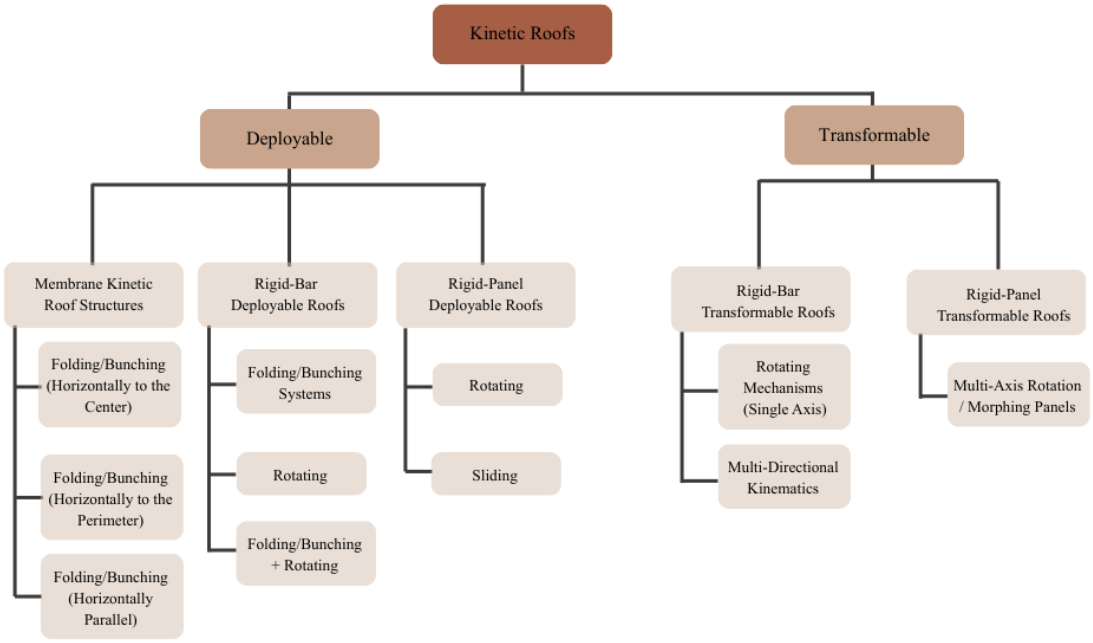


Figure 4. Classification of Kinetic Roofs

Other deployable building elements are classified into three main groups based on their movement mechanisms, and these systems can be efficiently opened and closed according to functional requirements (Figure 5). The potential uses for components with sliding mechanisms are diverse, encompassing areas such as furniture, doors, windows, stairs, walls and partitions (URL 35, 36, 37, 38, 39). The rotating mechanism can also be used to deploy these same types of components such as partitions/ walls, doors, windows (URL 40, 41, 42). The third mechanism, the folding/scissor type, provides quick deployment and small storage for furniture, doors, windows, stairs, walls and partitions (URL 43, 44, 45, 46).

Systems that can be changed from one configuration to another, typically for space optimization or multifunctionality, are known as transformable building components (Figure 5). Similar to deployable systems, a sliding mechanism can alter the shape and purpose of essential elements, such as walls and partitions, furniture, doors, windows, and stairs (URL 47, 48, 49). For the same component types, a rotating mechanism also offers transformability (URL 50, 51, 52). Lastly, building components such as walls, partitions, furniture, doors, windows, and stairs can be transformed using a folding/scissor mechanism, providing flexibility and spatial efficiency (URL 53, 54, 55, 56, 57).

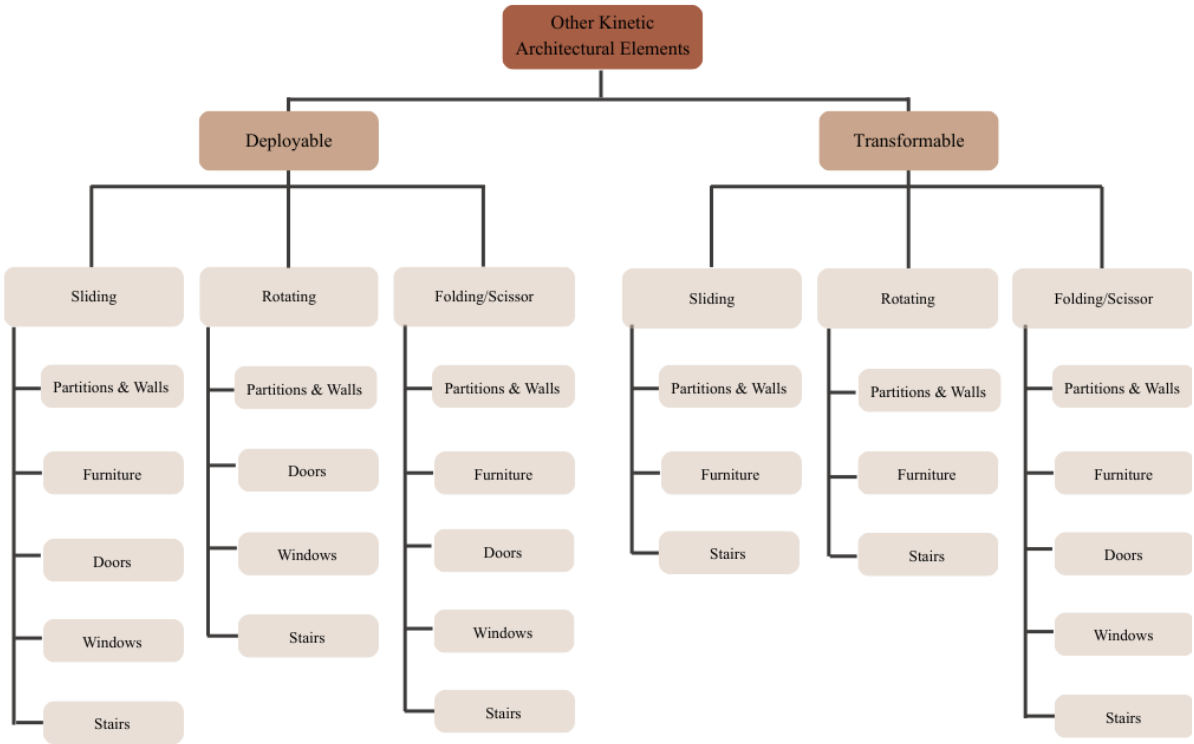


Figure 5. Classification of Other Kinetic Architectural Elements

3.Conclusion and Recommendations

The architectural literature offers a wide variety of classification schemes for kinetic structures and systems, each emphasizing different criteria such as movement mechanism, functional purpose, or environmental responsiveness. While these classifications share certain fundamental principles they remain fragmented due to variations in scope, level of detail, and the criteria used. This inconsistency makes it challenging to evaluate kinetic architectural applications within a unified framework.

This study addresses this gap by proposing a comprehensive classification system organized under four primary categories: structural systems, façade systems, roof systems, and other building elements. By examining deployable and transformable systems across these categories, the study offers an integrated framework that combines principles of movement with architectural scale, performance objectives, and functional adaptability. This approach not only brings together previously scattered classification methods but also provides a coherent

reference that can guide future research, design strategies, and technological innovation in kinetic architecture.

The proposed classification contributes to the literature by establishing a clear and systematic basis for understanding kinetic systems at both macro and micro levels. It enables designers and researchers to compare different movement mechanisms, evaluate performance potential, and develop more holistic design frameworks for smart and adaptive buildings. Future studies may expand this classification by incorporating computational control systems, responsive material technologies, and real time environmental adaptation, further enhancing the architectural potential of kinetic systems.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. Artificial intelligence was used to assist in this study. All authors contributed to the article 1st Author %40, 2nd Author %40, 3rd Author %20 contributed.

References

Abdallah, M. R., Abdelazem, A. G., & Essa, H.Y. (2020). Application of kinetic systems technology in design. *Journal of Engineering and Applied Science*, 67(1),139-158.

Akgün, Y., Maden, F., & Korkmaz, K. (2013). Design of adaptive structures by kinematic synthesis of mechanisms. In J. Cruz (Ed.), *Structures and Architecture: Concepts, Applications and Challenges,* Taylor & Francis Group.

Atlamaz, B., & Akgün, Y. (2023). A critical review and novel classification proposal for kinetic roof structures. *Journal of Architectural Sciences and Applications*, 8(2), 84-105.

Fouad, S. M. A. E. (2012). *Design methodology: Kinetic architecture*. *(Master Thesis), Alexandria University, Egypt.* Accessed from database Access Address (10.11.2025)

Lee, J. (2012). *Adaptable, kinetic, responsive, and transformable architecture:* An alternative approach to sustainable design (M.Sc. thesis). Austin: The University of Texas at Austin.

Maden, F., Akgün, Y., Kiper, G., Gür, S., Yar, M. & Korkmaz, K. (2019). A critical review on classification and terminology of scissor structures. *Journal of the International Association for Shell and Spatial Structures*, 60(1), 47–64. https://doi.org/10.20898/j.iass.2019.199.029.

Megahed, N. A. (2016). Understanding kinetic architecture: Typology, classification, and design strategy. *Architectural Engineering and Design Management*, 13(2), 1–17. doi:10.1080/17452007.2016.1203676.

Ramzy, N, & Fayed, H. (2011). Kinetic systems in architecture: New approach for environmental control systems and context-sensitive buildings. *Sustainable Cities and Society* 1 (2011) 170–177

Sharaidin, K. (2014). Kinetic facades: towards design for environmental performance, PhD thesis, Architecture and Design, RMIT University, iv.

Werner, C. (2013). *Transformable and transportable architecture: Analysis of buildings components and strategies for project design.* Barcelona: Universidad Politécnica de Cataluña.

Wolfe, M. H. (2013). *Analysis of Deployable Strut Roof Structures* (Master Thesis, Massachusetts Institute of Technology).

URL to Examples of Kinetic Systems

URL 1: https://gordonhuether.com/news/gordon-huether-hoberman-arch-installed-salt-lake-city-airport/ (Accessed on: September 10, 2025)

URL 2: https://heatherwick.com/project/rolling-bridge/ (Accessed on: September 10, 2025)

URL 3: https://archello.com/project/wimbledon-centre-court (Accessed on: September 10, 2025)

URL 4: https://www.nasa.gov/centers-and-facilities/langley/deployable-composite-booms-dcb/ (Accessed on: September 10, 2025)

URL 5: https://inhabitat.com/origami-inspired-portable-bridge-gives-victims-of-natural-disasters-instant-access-to-supplies/mobile-bridge-version-4-0-hiroshima-university/ (Accessed on: September 10, 2025)

URL 6: https://icap.sustainability.illinois.edu/node/5808 (Accessed on: September 10, 2025)

URL 7: https://wyss.harvard.edu/news/self-actuating-materials/ (Accessed on: September 10, 2025)

URL 8: https://wilkinsoneyre.com/projects/gateshead-millennium-bridge (Accessed on: September 10, 2025)

URL 9: https://www.ingeni.ch/en/projects/jet-d-eau-mobile-walkway/ (Accessed on: September 10, 2025)

URL 10: https://www.knightarchitects.co.uk/bridges/merchant-square-footbridge (Accessed on: September 10, 2025)

URL 11: https://en.wikipedia.org/wiki/Vlotbrug (Accessed on: September 10, 2025)

URL 12: https://heatherwick.com/project/rolling-bridge/ (Accessed on: September 10, 2025)

URL 13: https://www.edenproject.com/mission/architecture (Accessed on: September 10, 2025)

URL 14: https://www.archdaily.com/625830/situla-housing-and-office-complex-bevk-perovic (Accessed on: September 10, 2025)

URL 15: https://www.e-architect.com/austria/biocatalysis-technical-university-graz (Accessed on: September 9, 2025)

URL 16: https://henninglarsen.com/projects/university-of-southern-denmark-campus-kolding (Accessed on: September 9, 2025)

URL 17: https://www.dezeen.com/2014/03/19/penumbra-kinestic-louvres-tyler-short-movie/ (Accessed on: September 9, 2025)

URL 18: https://www.archdaily.com/89270/kiefer-technic-showroom-ernst-giselbrecht-partner (Accessed on: September 9, 2025)

URL 19: https://www.archdaily.com/162101/ad-classics-institut-du-monde-arabe-jean-nouvel (Accessed on: September 9, 2025)

URL 20: https://www.ahr.co.uk/projects/al-bahr-towers (Accessed on: September 10, 2025)

URL 21: https://www.archdaily.com/49150/media-tic-enric-ruiz-geli (Accessed on: September 9, 2025)

URL 22: https://technologyinarchitecture.wordpress.com/2017/08/13/homeostatic-facade/ (Accessed on: September 9, 2025)

URL 23: https://www.archdaily.com/522344/sharifi-ha-house-nextoffice (Accessed on: September 9, 2025)

URL 24: https://www.str-ucture.com/en/projects/stureplan-pavilion (Accessed on: September 10, 2025)

URL 25: https://www.jeanprouve.com/en/fiche/1969 (Accessed on: September 10, 2025)

URL 26: http://wikimapia.org/3798730/Summer-Theatre (Accessed on: September 10, 2025)

URL 27: https://www.tensinet.com/index.php/component/tensinet/?view=project&id=4000 (Accessed on: September 10, 2025)

URL 28: https://calatrava.com/projects/emergency-services-centre-sankt-gallen.html?view_mode=gallery (Accessed on: September 10, 2025)

URL 29: https://smia-experimental.com/2013/04/23/deployable-stage-proposal-of-an-application-with-mobile-structures-2/ (Accessed on: September 10, 2025)

URL 30: https://www.klook.com/en-SG/activity/135264-fukuoka-softbank-hawks-baseball-game-ticket/ (Accessed on: September 10, 2025)

URL 31: https://torontosocietyofarchitects.ca/buildings/skydome-now-rogers-centre/ (Accessed on: September 10, 2025)

URL 32: https://mam.org/info/architecture/quadracci-pavilion/ (Accessed on: September 10, 2025)

URL 33: https://www.archdaily.com/429862/honoring-architecture-s-digital-pioneers?ad_medium=gallery (Accessed on: September 10, 2025)

URL 34: https://atlanta.curbed.com/2018/5/29/17403536/mercedes-benz-stadium-retractable-roof (Accessed on: September 10, 2025)

URL 35: https://shigerubanarchitects.com/works/timber-and-bamboo/naked-house/ (Accessed on: September 13, 2025)

URL 36: https://www.atimspa.com/en/prodotto/dinamico/ (Accessed on: September 13, 2025)

URL 37: https://www.archdaily.com/994084/what-is-a-pocket-door-maximizing-space-flexibility-and-style (Accessed on: September 13, 2025)

URL 38: https://www.archdaily.com/catalog/us/products/11061/insulated-sliding-doors-classic-sky-frame?ad_source=neufert&ad_medium=gallery&ad_name=close-gallery (Accessed on: September 13, 2025)

URL 39: https://weburbanist.com/2015/08/16/slide-hide-stealth-staircases-save-space-in-micro-suites/ (Accessed on: September 13, 2025)

URL 40: https://www.dezeen.com/2016/01/10/mje-house-pkmn-architectures-apartment-spain-rotating-walls/ (Accessed on: September 13, 2025)

URL 41: https://www.archdaily.com/778809/chicken-point-cabin-olson-kundig (Accessed on: September 13, 2025)

URL 42: https://www.dezeen.com/2016/02/29/liddicoat-goldhill-ancient-party-barn-conversion-kent-england/ (Accessed on: September 13, 2025)

URL 43: https://www.archdaily.com/1014623/movable-walls-the-transformative-effect-of-retractable-and-folding-partitions (Accessed on: September 13, 2025)

URL 44: https://www.designboom.com/design/flat-fabric-deployable-3d-furniture-cords-magnets-sewing-machine-sapna-tayal-04-24-2025/ (Accessed on: September 13, 2025)

URL 45: https://www.dezeen.com/2016/01/22/freshwest-rivershed-office-wales-uk-corrugated-metal-newcastle-emlyn-river-teifi/ (Accessed on: September 13, 2025)

URL 46: https://columbus.ch/index.php/holzklapptreppe/#holz (Accessed on: September 13, 2025)

URL 47:https://www.archdaily.com/566605/pkmn-architectures-builds-transformer-house-studio-in-madrid (Accessed on: September 13, 2025)

URL 48: https://www.designboom.com/design/the-ori-cloud-bed-transforms-into-home-office-06-10-2021/ (Accessed on: September 13, 2025)

URL 49: https://www.sesameaccess.com/lifts/thames-retracting-stair-lift (Accessed on: September 13, 2025)

URL 50: https://www.archdaily.com/104724/ad-classics-maison-bordeaux-oma (Accessed on: September 13, 2025)

URL 51: https://www.nevertoosmall.com/post/murphy-beds-and-where-to-hide-them (Accessed on: September 13, 2025)

URL 52: https://dornob.com/convertible-stair-ramp-home-accessibility-design-concept/ (Accessed on: September 13, 2025)

URL 53: https://design-milk.com/transformer-apartment-vlad-mishin/ (Accessed on: September 13, 2025)

URL 54: https://parametrichouse.com/transforming-furniture/ (Accessed on: September 13, 2025)

URL 55: https://www.archdaily.com/1017719/bi-folding-doors-for-transforming-flexible-spaces (Accessed on: September 13, 2025)

URL 56: https://dornob.com/pop-up-balcony-attic-window-transforms-into-outdoor-space/ (Accessed on: September 13, 2025)

URL 57: https://brainrichkids.com/products/transformable-indoor-climbing-set-for-toddler-swedishladder?srsltid=AfmBOorVc2ID6NhFeXzOIxUENlnFOnHNcyMPpEoezK504LjdDM7sfHmy (Accessed on: September 13, 2025)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Dwelling-Street Relations in Traditional Urban Fabrics: The Case of Famagusta Walled City

Hasan DOĞAN[1]*

ORCID 1: 0000-0002-9082-3275
[1]Dr., Harran University, Faculty of Fine Arts, Department of Architecture, Şanlıurfa-Türkiye
hasandogan@harran.edu.tr **(**Responsible Author)

Abstract

Traditional urban environments are characterised by strong spatial coherence, where private, semi-public, and public domains intersect to form a continuous and legible urban fabric. In such settlements, streets play a pivotal role as extensions of dwellings at the ground level, shaping both the physical and social quality of the built environment. This study examines the relationship between dwellings and streets in the traditional urban fabric of the Famagusta Walled City in North Cyprus, with particular attention to transitional spaces that mediate between private and public realms.

The research employs a combination of literature review, field observations, and architectural analysis. Spatial configurations, plans, and on-site illustrations are analysed to understand how traditional design elements such as courtyards, sundurme (verandas), arch houses, and narrow streets foster social interaction, privacy, and neighbourhood cohesion. Findings reveal that the physical characteristics of streets and transitional spaces not only facilitate circulation and connectivity but also sustain community identity by accommodating a variety of social and cultural activities.

By highlighting the significance of dwelling–street continuity, this study contributes to a deeper understanding of how traditional urban design strategies can inform contemporary approaches to livable and socially cohesive urban environments. The findings underscore the importance of maintaining spatial relationships between private and public domains in the conservation and revitalisation of historic urban fabrics.

Keywords: Dwelling-street relationship, transitional spaces, social interaction, community-based revitalisation, Famagusta Walled City

1. Introduction

Traditional urban environments have long been a subject of interdisciplinary inquiry, attracting the attention of architects, urban planners, anthropologists, sociologists, historians, art historians, and geographers. Over the past decades, numerous studies have examined the morphological, functional, and socio-cultural characteristics of these environments, generally following two primary lines of inquiry: one focusing on the traditional house as an architectural artefact and the other on the broader traditional settlement pattern. As Eyüce (2012) notes, “Architects are more inclined to decipher the morphological characteristics of the individual dwelling unit heir tendency is to see the traditional house as the end product of the traditional building.” The relationship between the private outdoor domain of the dwelling and the public outdoor urban domain has been recognised as central to the spatial and social organisation of traditional environments. These two domains intersect in various ways, creating dynamic social interactions. Oktay & Önal (1998) emphasise that “Social variables predominantly determine any function potentially occurring in both public and private outdoor space,” underscoring the importance of cultural and social norms in shaping the use of transitional and shared spaces. Traditional built environments are typically characterised by compact and dense settlement patterns, reflecting a high degree of interdependence between individual dwellings and the broader urban fabric. Rapoport (1989) highlights this spatial coherence by observing that “it is sometimes difficult to separate dwelling and settlements. Particularly in the case of communal

dwellings, where dwellings and settlement are one." This integration creates a strong sense of spatial continuity and collective identity within the urban form.

The duality between the house and the street, or the private and public realms, is also expressed in the phenomenology of "inside" and "outside." Tuan remarks that "Constructed form has the power to heighten the awareness and accentuate… the difference in emotional temperature between 'inside' and 'outside'," suggesting that architecture can both delineate and mediate these spheres (Tuan, 2001, p. 107). This distinction is further related to the concept of neighborhood, which, as Tuan (2001) argues, contributes significantly to the inhabitants' "larger place consciousness": "Houses and streets do not of themselves create a sense of place, but if they are distinctive this perceptual quality would greatly help the inhabitants to develop the larger place consciousness." The philosophical dimension of dwelling has also been explored. Heidegger argues that "the basic character of dwelling is to spare, to preserve… dwelling itself is always a staying with things," thereby framing dwelling as a practice deeply connected to existence and place (Heidegger, 1993, p. 351). Similarly, Oktay highlights the enduring historical and cultural significance of streets and open spaces, observing that "since the earliest urban settlements, there has been a fundamental human impulse to organise and shape streets and public areas—to make them more functional for daily and communal activities, and more aesthetically restorative for the urban community" (Oktay, 2002, p. 263).

Together, these studies demonstrate that traditional urban environments should not be perceived merely as physical assemblages of dwellings, streets, and public spaces. Rather, they embody complex socio-spatial systems in which architecture, settlement patterns, and cultural practices are deeply interwoven. These systems foster a strong sense of community identity and facilitate dynamic forms of social interaction, grounded in spatial continuity and everyday lived experience. By exploring the interplay between built form and social life, this study aims to contribute to a more nuanced understanding of the traditional urban fabric as a living cultural construct that continues to inform contemporary urbanism. The Famagusta Walled City presents a complex and multifaceted backdrop, shaped by influences from Ottoman, Venetian, and British colonial legacies. Numerous families have inhabited the Walled City for centuries, and their social customs—ranging from street-level interactions to the informal use of public and semi-public spaces—are deeply intertwined with the architectural landscape. Revitalisation efforts that ignore these living traditions jeopardise the community's sense of place, turning living history into a museum-like artefact devoid of social significance. Such an approach risks alienating residents, who may feel that their cultural heritage is being commodified rather than celebrated. To ensure the preservation of both the architecture and the vibrant community spirit, revitalisation initiatives must prioritise participatory methods by allowing residents to voice their needs and aspirations.

2. Materials and Methods

This study investigates the spatial continuity between dwellings and streets within the traditional urban fabric of the Walled City of Famagusta, North Cyprus. The research particularly focuses on the role of transitional spaces—such as thresholds, semi-open areas, and narrow passageways—in mediating the relationship between private and public realms. It aims to uncover how these spatial interfaces contribute to community cohesion, everyday social interaction, and the construction of collective identity.

To achieve this, a mixed-methods approach was employed, combining literature review, fieldwork, and case study analysis:

- Literature Review: A comprehensive review of interdisciplinary literature was conducted to build the theoretical foundation of the study. The review included works from architecture, urban sociology, human geography, and heritage studies, particularly focusing on the relationship between domestic architecture, public space, and social life in traditional urban contexts.

- Fieldwork and On-Site Documentation: Empirical research was carried out through site visits to selected locations within the Walled City. Photographic surveys, spatial mapping, and architectural sketching were employed to document and analyse the built environment. Special attention was given to intermediate spaces such as *sundurme*, courtyards, and shared thresholds that support everyday encounters and social use.

By integrating spatial analysis with community-based insight, this methodology enables a deeper understanding of how traditional urban environments operate as both physical and social infrastructures. It also provides a basis for future revitalisation strategies that respect both tangible heritage and living culture.

3. Findings and Discussion

3.1. Contextual Features of Traditional Urban Architecture

To understand the formation of traditional settlements in Cyprus, it is essential to provide a brief overview of the island's historical background. Due to its strategic location at the crossroads of the Eastern Mediterranean, Cyprus has historically been subjected to successive waves of control by various civilisations, including the Egyptians, Assyrians, Persians, Romans, Byzantines, Arabs, Venetians, Ottomans, and, most recently, the British. As a result, both the island's social structure and architectural character have undergone continuous transformation. Pulhan and Numan (2005) emphasise that "the multicultural accumulation of different sovereignties was reflected mainly in the urban areas of the built environment." Accordingly, the multi-dimensional identity of Cypriot society today is largely shaped by the layered coexistence of these diverse cultural influences.

Each ruling power in Cyprus contributed distinct architectural styles to the built environment. For instance, British, Ottoman, and Roman influences can be clearly identified in various urban and architectural forms. Over time, these styles collectively shaped the domestic urban fabric. A notable example is the Famagusta Walled City (Figure 1), which exhibits a layered architectural history — combining Ottoman and Medieval elements, enclosed by Venetian fortifications and structured according to a medieval street pattern that was later reshaped under Ottoman influence.

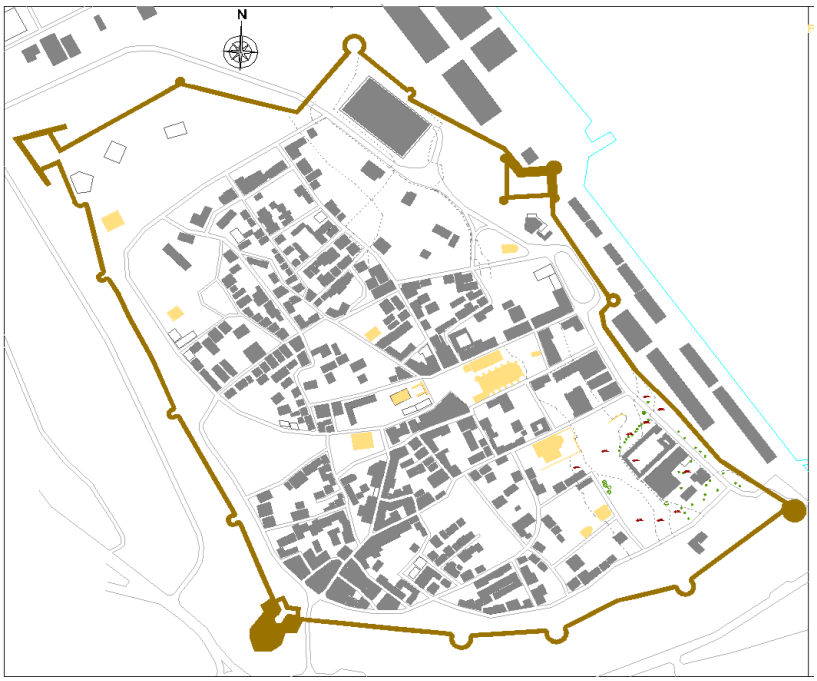


Figure 1. The traditional urban pattern of the Famagusta Walled City (reproduced by the author).

In general, traditional Turkish urban dwellings in Cyprus have been shaped by the interaction of various cultural influences over time. In other words, the traditional architectural character of Cyprus bears the imprint of multiple civilisations, resulting in a hybrid and layered urban form. As a result, traditional Turkish houses represent an amalgamation of different architectural traditions, both in terms of form and construction techniques. Commonly used methods include adobe and masonry systems, which reflect the adaptation of local materials and know-how. Pulhan and Numan (2005) describe Ottoman-era construction techniques in Cyprus as follows:

Techniques such as Bağdadi (wattle and daub or lath and plaster system) and Çatma (brick or stone nogged system) can be traced through the cracks on the plastered surfaces. The walls, often made of cut stone, and the masonry arches supported by columns, along with the building's mass and street-facing façades adorned with Gothic and Renaissance decorations, all point to Frankish and Venetian antecedents (Pulhan & Numan, 2005).

This synthesis of Ottoman and Western architectural elements—particularly Gothic and Renaissance motifs—demonstrates the multi-layered identity of traditional Cypriot dwellings, where imported forms were reinterpreted through local traditions and needs.

Despite similar geographic, topographic, and climatic conditions, the form and functions of urban dwellings differ significantly from those of rural dwellings in Cyprus. This difference primarily stems from the influence of dominant cultural patterns and associated lifestyles on the development of urban housing forms (Numan, Dinçyürek, & Pulhan, 2002). In other words, while house forms adapt to Cypriot environmental conditions, they also reflect cultural values that evolve across time and setting. Nevertheless, one architectural feature that remains consistent across both rural and urban communities on the island is the presence of transitional spaces. These spatial elements—such as courtyards and sundurme (verandas)—mediate

between the private and public domains and are fundamental to traditional domestic architecture.

As Rapoport argues, cultural factors play a central role in shaping traditional dwelling forms (Rapoport, The nature of the courtyard house: a conceptual analysis, 2007). In the case of Famagusta Walled City, elements such as family structure and attitudes toward privacy have guided the spatial organisation of homes. Thus, the development of the traditional urban environment in Cyprus, especially in Famagusta, can be seen as an inward–outward progression: beginning from the interior (private sphere) and extending toward the exterior (public spaces, such as the street). The courtyard and sundurma serve as key transitional modules that articulate this relationship, fostering both seclusion and community engagement.

The courtyard serves as one of the most essential spatial modules in the organisation of traditional urban fabrics. It functions as a transitional or intermediate space that mediates between the private domain of the dwelling and the public domain of the street. The term "intermediate space" is used to refer to the ambiguous zone between interior and exterior that does not strictly belong to either (Doğan, 2016). According to Rapoport, "the courtyard house itself can be seen partly in these terms. Thus, the form of the relation between the private and public domains—via a 'lock,' rather than without such a lock and with a permeable boundary—is more fundamental than the shape of the domains (let alone the materials used)" (Rapoport, The nature of the courtyard house: a conceptual analysis, 2007). This interpretation highlights the role of the courtyard as a buffer zone, controlling visual and physical permeability.

Pulhan and Numan reinforce this by describing the havlu as a central element of domestic life in Cypriot traditional dwellings: "Havlu is the outdoor space that is in the centre of private and public life in the dwelling... Most of the activities, particularly laundry and cooking, were held in the havlu" (Pulhan & Numan, 2005). Unlike the more romanticised vision of a garden courtyard, the havlu is a functional outdoor space, enclosed by building façades and additional boundary walls (Figure 2). In this context, the courtyard emerges as a spatial and cultural construct—simultaneously shaped by architectural forms and social practices. It exemplifies how traditional dwellings establish a nuanced balance between privacy, community, and daily life activities.

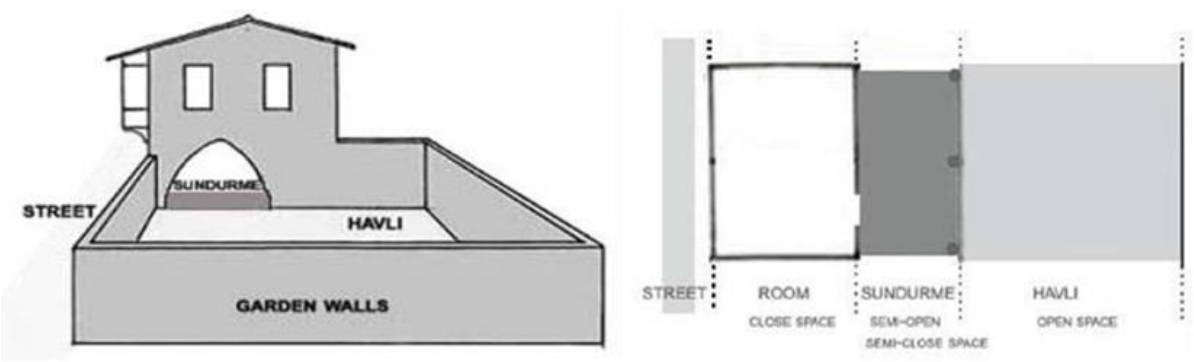


Figure 2. A Schematic Presentation of Traditional Turkish houses in Cyprus (Pulhan & Numan, 2005).

The sundurme is one of the principal spatial components of traditional urban dwellings in Cyprus. Serving as a transitional element, it functions as a semi-open passageway that connects interior rooms to outdoor spaces such as courtyards and streets, while preserving privacy and

ensuring spatial fluidity. Architecturally and culturally, the sundurme acts as a private circulation route embedded within the domestic layout, reinforcing the layered structure of public and private domains. Pulhan and Numan (2005) highlight the significance of the sundurme in shaping traditional architectural patterns:

It is the essential component that determines the spatial patterns and formal configurations in the traditional architecture of Cyprus. The interaction between public and private, people and environment, open and closed, inside and outside, and part and whole are important design criteria in traditional environments. This interaction and the indissoluble whole of the fabric—transitional space—described as the overlapping of the indoor and outdoor space, has great importance (Pulhan & Numan, 2005).

In this regard, the sundurme exemplifies the role of transitional spaces in mediating between opposing spatial and social domains—public/private, open/closed, and inside/outside. It not only shapes the architectural identity of the dwelling but also contributes to the experiential quality of urban life. As a spatial interface, the sundurme links street, room, and courtyard, generating continuity between the urban public realm and the domestic interior (Figure 2). Far beyond its structural function, it represents a culturally embedded response to the social and environmental context of Cypriot cities. Pulhan and Numan further note: “Sundurme is perceived as a semi-open space satisfying the needs of its physical and social contexts” (Pulhan & Numan, 2005).

Thus, within the broader urban fabric, the sundurme serves as a critical spatial mediator, articulating social boundaries, enabling interaction, and reinforcing the intimate relationship between inhabitants, architecture, and neighborhood life. At the building scale, it exemplifies how traditional design integrates functionality, privacy, and social cohesion. This spatial logic extends beyond the individual dwelling to shape the structure of the wider neighbourhood (mahalle), where physical and social dimensions are intricately interwoven.

Building upon this foundation, the following section explores the interdependence between spatial arrangements and communal life in traditional environments, particularly focusing on how architectural forms reflect and reinforce patterns of social interaction, collective identity, and neighbourhood cohesion.

3.2. Interdependence between Spatial and Communal Life.

In traditional urban environments, the mahalle (neighbourhood) functions not merely as a physical aggregation of buildings but as a vital socio-spatial unit where spatial arrangements and community life are deeply intertwined. Social cohesion in such settings arises from the interconnectedness of households and the shared use of semi-public spaces—alleys, courtyards, thresholds—which collectively sustain compact urban morphologies and nurture strong interpersonal relationships.

However, the nature of this spatial-social interdependence varies across cultural geographies. In many Islamic cities, for instance, urban form is shaped by religious and moral codes that emphasise privacy, neighbourly duty, and collective well-being. As Hakim and Rowe (1983) illustrate with examples from North African medinas such as Fez, Tunis, and Marrakesh, decisions made by a single household regarding built form often have tangible consequences for the surrounding community. This entanglement, rooted in Qur’anic guidance, reveals a spatial ethic of mutual respect and social accountability (Hakim & Rowe, 1983).

In the Cypriot context, these spatial codes have evolved into a hybrid urban tradition. While Islamic principles were dominant during the Ottoman period, they later became interwoven with Byzantine and Venetian architectural legacies and British colonial planning norms. As a result, the spatial fabric of towns such as Famagusta reflects a layered synthesis of cultural influences—religious, civic, and colonial—that inform the morphology of the neighbourhood and the nature of street–dwelling relations.

The Famagusta Walled City provides a rich case study for exploring these dynamics. The urban fabric is composed of a dense network of narrow streets, cul-de-sacs, and organic intersections that facilitate nuanced transitions between private and public domains. The Lynch analysis (Figure 3) identifies a coherent mental map structured around paths, nodes, edges, landmarks, and districts, suggesting a high degree of spatial legibility and cognitive engagement among residents. Multiple entrance points, especially those located along major traffic arteries, increase permeability and social connectivity between the historic core and peripheral zones (Figures 3 & 4). The traffic analysis (Figure 5) further reveals a functional hierarchy of circulation routes—from pedestrian-only streets to secondary vehicular paths—that balances mobility with human-scale urbanism. This configuration supports walkability and reinforces everyday social interaction in streets and transitional zones, particularly in narrow alleys and shaded courtyards.

The land use analysis (Figure 4) confirms the heterogeneous spatial composition of the walled city, where residential units coexist with shops, cafes, offices, schools, and cultural landmarks. This spatial mix fosters urban vitality, transforming the street into more than a circulation corridor; it becomes an extension of domestic life, a zone of interaction, negotiation, and sociability. The presence of flowerpots, chairs, and thresholds animated by daily routines blurs the boundary between private and public, creating semi-public spaces of encounter.

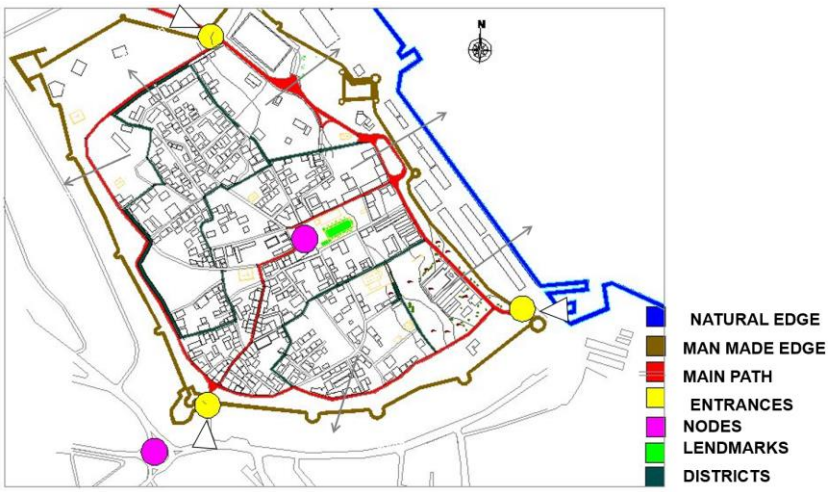


Figure 3. Lynch's analysis of the Walled City of Famagusta, highlighting key urban elements such as paths, edges, nodes, districts, and landmarks that structure both movement and cognitive mapping within the historical core.

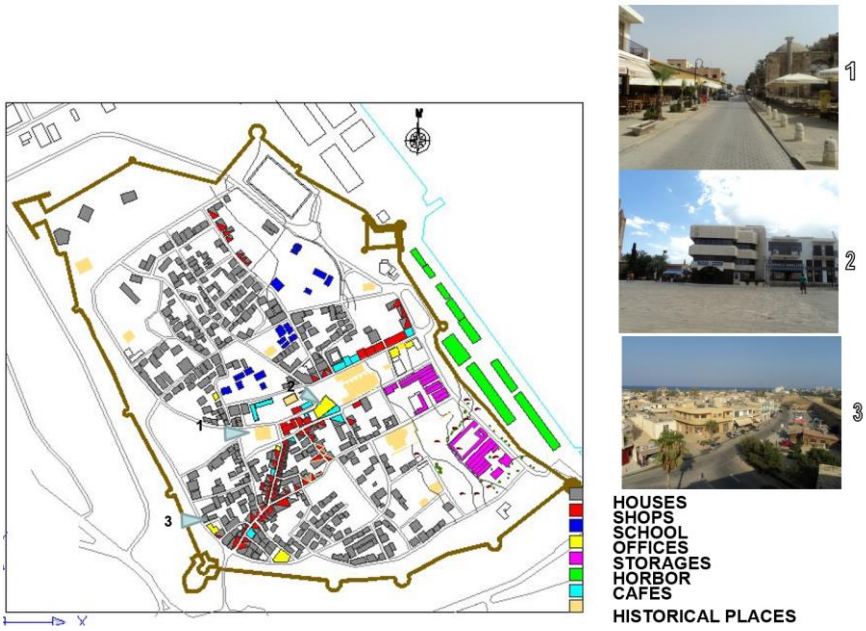


Figure 4. Land use distribution in the Walled City of Famagusta, showing the spatial integration of residential, commercial, educational, and cultural functions that promote urban vitality and mixed-use character.

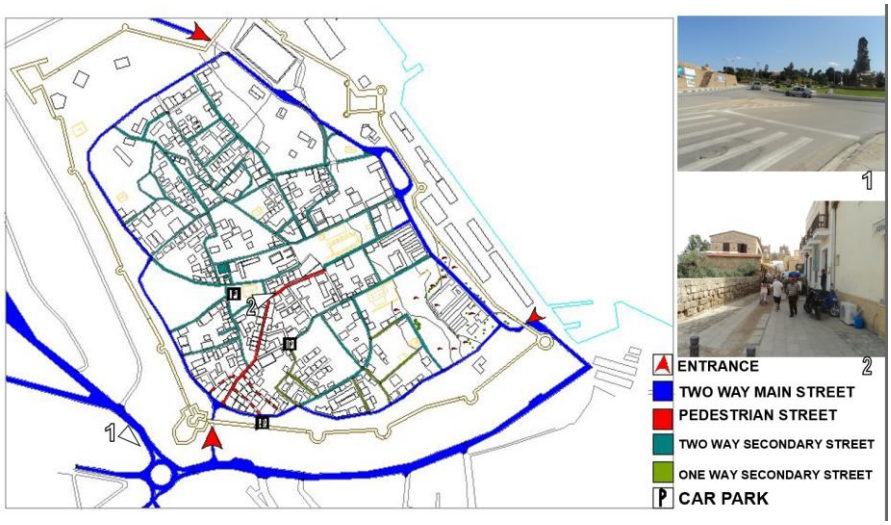


Figure 5. Traffic circulation analysis of the Walled City, illustrating the hierarchy of streets—from pedestrian-only alleys to secondary vehicular routes—that supports walkability and informal social interaction.

As Oktay and Önal (1998) note, in Cypriot towns, "the street is the most primitive intersection between private and public domains … almost an extension of the home." The streets of Famagusta function precisely in this way. Architectural elements such as passage houses (Figure 6) mediate movement and privacy, ensuring continuity within the spatial fabric while allowing for flexibility in communal life. These built forms exemplify the adaptability of traditional design to the demands of social interaction, climate, and cultural norms. Streets, therefore, operate as social infrastructures. As Moughtin (1992) argues, they are not only

physical connectors but also "social facts," influencing patterns of behaviour, collective memory, and identity formation. Lynch (1961) similarly emphasises that streets with distinctive characteristics enhance the imageability of the city and support the mental orientation of its inhabitants.



Figure 6. Passage houses in the Famagusta Walled City, Cyprus, illustrate how spatial continuity and social interaction are maintained through architectural design.

In this respect, the street–dwelling relationship in the Famagusta Walled City (Figures 7) embodies both spatial and cultural continuity. Dwellings frequently open directly onto the street, transforming it into a semi-private platform where daily life unfolds—children play, neighbours converse, and elders gather. These practices produce a lived space that is not strictly interior nor fully public but oscillates between domains, fostering intergenerational exchange and collective identity.



Figure 7. Street–dwelling interface in the Walled City of Famagusta, showing how semi-public thresholds such as doorfronts and alleys function as extensions of domestic space and sites of everyday sociability.

Recent scholarship echoes this insight. Yu et al. (2024) argue that street vitality in traditional urban settings emerges from both physical morphology and the continuity of social practices. Likewise, Cömert (2025) highlights the symbolic and functional role of streets in Northern Cyprus as carriers of collective memory and sites of solidarity. In light of these findings, preserving the spatial and social fabric of the Walled City is essential not only for architectural heritage but also for sustaining community life. The degradation of narrow streets and semi-public thresholds risks more than physical loss; it may lead to social disintegration and the erosion of place-based identity. Conservation efforts must therefore adopt a holistic approach, one that embraces both the tangible and intangible dimensions of urban space. Only then can the Famagusta Walled City endure as a living heritage, where history, culture, and everyday life remain meaningfully intertwined.

3.4. Community-Based Revitalisation Strategies in Famagusta

In recent years, approaches to revitalising historic environments have moved away from understandings that solely aim to preserve physical heritage and towards community-based and sociocultural sustainability strategies (Table 1). This new paradigm emphasises that the long-term sustainability of historical environments, like Famagusta's Walled City, depends not only on the restoration of the built environment but also on the preservation of the intangible cultural practices that give meaning to these spaces (Doratlı et al., 2007). Famagusta has a multi-layered historical fabric shaped by a rich cultural heritage from the Ottoman, Venetian, and British colonial periods. Many families have lived in the same neighbourhood for generations, and everyday spatial practices, such as street-level interactions and using courtyards and alleys, have become integral parts of this historical fabric. Therefore, community-based revitalisation strategies should aim to preserve not only physical structures but also this social fabric (Asbagh & Tümer, 2021; Philokyprou, 2024).

To achieve success in the revitalisation process, multi-scale approaches are necessary that treat space not just as an architectural object but as a carrier of social life. Intermediate spaces—for example, porches, alleys, and common streets—are not only physical transition areas; they are also spatial representations of neighbourhood relationships, privacy, and social solidarity (Yu et al., 2024).

The conservation of traditional urban fabric entails more than safeguarding historic buildings; it requires a nuanced understanding of the spatial and social dynamics that animate everyday life in heritage environments. In the case of the Walled City of Famagusta, revitalisation strategies must address the interplay between tangible architectural heritage and the intangible cultural practices embedded in the neighbourhood's daily routines.

A successful revitalisation model requires a multi-scalar approach that integrates top-down planning frameworks with bottom-up, community-driven initiatives. This includes aligning municipal policies with local needs, recognising both individual household concerns and broader neighbourhood values. Intermediate spatial elements—such as sundurme, courtyards, and shared streetscapes—are particularly important in this regard. These elements are not only architectural connectors but also social thresholds, shaping the vernacular experience of privacy, neighbourliness, and coexistence.

Table 1. Literature review on heritage conservation, community participation, and socio-spatial revitalisation.

Years	Authors	Title	Main Focus
2024	Babazadeh-Asbagh, Narmin	Adaptive Reuse of Abandoned Churches in the Walled City of Famagusta, North Cyprus	Adaptive reuse of abandoned church structures within the Walls of Famagusta—a case study in the context of conservation and revitalisation.
2024	Maria Philokyprou	Linking Teaching and Research in Conservation of the Built Environment	The connections between architectural education and conservation practices in the context of Cyprus. Methodological contribution to community-based approaches.
2023	Cam Kara and Aminreza Iranmanesh	Modelling and Assessing Sustainable Urban Regeneration: The Case of the Walled City of Famagusta	It compares the inner walls of Famagusta and Nicosia. It offers model suggestions in terms of social, economic, and environmental sustainability.
2024	Yu, Bing, Jing Sun, Zhaoxing Wang, and Sanfeng Jin.	Influencing Factors of Street Vitality in Historic Districts Based on Multisource Data: Evidence from China	It analyses the spatial and social factors influencing the vitality of streets in historical urban fabrics. It supports your "street-home-neighbourhood" focused section.
2025	Cömert, N. Z.	Historical–Geographical and Procedural Typological Approach in Urban Renewal: As a Case Louroujina, Northern Cyprus.	A methodological study on the evaluation of traditional settlements in Northern Cyprus.
2022	Narmin Babazadeh Asbagh and Ege Uluca Tümer	Cultural Heritage Interpretation: Proposals for Medieval Churches in Famagusta Walled City, North Cyprus	It contains suggestions for interpreting cultural heritage in historical settlements. It addresses the "intangible heritage" dimension in revitalisation strategies.

3.4.1. Revitalisation strategy

The conservation of traditional urban fabric involves more than the preservation of historical buildings; it requires a sensitive engagement with the spatial and social dynamics that shape everyday life in heritage settlements. In the case of the Walled City of Famagusta, efforts at

revitalisation must account for the complex interplay between tangible architectural heritage and the intangible communal practices embedded within the neighbourhood.

Conservation strategies that treat the built environment as a static artefact risk overlooking the evolving nature of social life in traditional quarters. Therefore, revitalisation should aim not only to restore the physical integrity of dwellings, streets, and courtyards but also to reactivate the communal interactions that define their meaning and use. As such, policies must prioritise inclusive participation, economic viability, and the adaptation of spaces to contemporary needs without disrupting the historical continuity of form and function.

Furthermore, successful revitalisation requires a multi-scalar approach—one that balances individual household needs with collective neighbourhood values, and aligns municipal planning with bottom-up community initiatives. In this regard, the preservation of intermediate spaces such as sundurme and shared streetscapes becomes central, as they embody the spatial logic of coexistence, privacy, and interdependence that characterises Cypriot vernacular urbanism. Therefore, community-based revitalisation in Famagusta should prioritise the following:

- Participatory Planning: Involving residents, local NGOs, and cultural associations in planning and decision-making processes ensures that interventions reflect the real needs and aspirations of the community. Participation also fosters a strong sense of ownership, which is essential for the long-term sustainability of conservation initiatives.

International conservation efforts in Famagusta's Walled City provide tangible examples of community-based approaches. The Historic Walled City of Famagusta project, initiated by the World Monuments Fund (WMF), has developed an inclusive conservation model that promotes collaboration among local stakeholders, universities, and civil society organisations. The project aims not only to preserve monumental structures but also to strengthen the social sustainability of the historic environment by encouraging the active participation of the local community.

WMF's approach establishes a holistic balance between physical preservation and social revitalisation, integrating cultural continuity with heritage management. By embedding community engagement at every stage of the conservation process, the project ensures that heritage protection becomes a shared social responsibility rather than a top-down technical exercise. In this respect, the WMF initiative not only safeguards the historical fabric of Famagusta but also sustains its regeneration within the conceptual framework of "living heritage" (Anon., 2012).

- Adaptive Reuse and Incremental Rehabilitation in Harmony with Local Knowledge: Instead of large-scale, top-down restorations that may displace long-term residents, small-scale, incremental upgrades—guided by local knowledge and practices—can improve safety, infrastructure, and living conditions while preserving authenticity and daily life (Asbagh & Tümer, 2021).

- Protection of Intermediate and Shared Spaces: As discussed in earlier sections, semi-open spaces such as the *sundurme*, passageways, and narrow streets play key roles in community life. These elements are not mere spatial connectors but serve as social thresholds and everyday meeting points; thus, they must be preserved and integrated sensitively into revitalisation efforts (Cömert, 2025; Yu, Sun, Wang, & Sun, 2024).

Yu et al. (2024) demonstrate that street vitality in traditional urban fabric is not solely dependent on morphological features but is also nourished by such social interfaces. Similarly, Cömert (2025) asserts that intermediate spaces in traditional settlements in Northern Cyprus serve as structural and social networks, ensuring the continuity of neighbourhood culture.

As seen in conservation efforts in Famagusta, the physical and functional continuity of these areas supports social cohesion at the neighbourhood level (WMF, 2012). The repurposing of intermediate spaces in a way that is sensitive to contemporary needs not only ensures historical continuity but also allows local people to continue their daily lives. Otherwise, the removal of these thresholds could lead to the weakening of social relationships and the anonymisation of public spaces. The preservation of neighbourhood culture in Famagusta stands as a vital endeavour, ensuring both physical and functional continuity that fosters social cohesion among its residents. By thoughtfully repurposing intermediate spaces to align with contemporary needs, the community not only safeguards its historical essence but also enriches the daily lives of its inhabitants. This careful stewardship of cultural heritage affirms that removing these elements could have detrimental effects, eroding social relationships and leading to the anonymisation of public spaces. Ultimately, the vibrant tapestry of Famagusta's neighbourhood culture is not merely a relic of the past but a living framework that supports community interaction and continuity in an ever-evolving urban landscape.

- Cultural and Educational Programming: Organising community-led events, intergenerational storytelling workshops, exhibitions, and heritage walks can promote the transmission of local knowledge, strengthen community identity, and foster culturally sensitive tourism (Philokyprou, 2024).

- Economic Empowerment through Heritage-Based Micro-Enterprises: Supporting traditional crafts, home-based production, local gastronomy, and eco-tourism initiatives can provide economic alternatives that align with conservation goals. Such approaches allow residents to see heritage as an asset rather than a burden (Kara & Iranmanesh, 2023).

Ultimately, community-based revitalisation strategies in Famagusta must aim to reconnect people with place by respecting historical continuities while responding to contemporary socio-economic needs. As the urban fabric continues to evolve, embedding local agency into conservation practice becomes essential—not only to protect buildings, but also to preserve the living culture they support.

4. Conclusion

This study investigates the spatial continuity between housing and streets within the traditional urban fabric of Famagusta Walled City, elucidating how these physical relationships foster social interactions, a sense of belonging, and urban identity. Through field studies, it was found that intermediate spaces (such as porches, passages, and narrow streets) not only serve as physical connections but also promote social interactions as social thresholds of daily life.

The research findings indicate that in multi-layered historical environments like Famagusta, it is of great importance not only to preserve the physical heritage but also to sustain the ongoing daily practices and social relationships in these areas. The effective use of these public-private intermediate spaces by diverse user groups, particularly children, women, and the elderly, underscores the vital importance of these areas for social sustainability.

In this context, conservation and revitalisation strategies must encompass not only monumental structures but also the social fabric and cultural continuity that have formed around them. Participatory planning processes will make it possible to benefit from the knowledge and experience of local people and to preserve these heritage sites not only as an aesthetic but also as a livable. In conclusion, approaches that focus on the reciprocal relationship between spatial continuity and social life in historical settlements, such as Famagusta Walled City, promote physical preservation and encourage a sustainable understanding of urbanisation in line with the concept of "living heritage." This approach forms the basis of a holistic conservation model that integrates the spatial wisdom of the past with the social needs of the present.

Thanks and Information Note

The article complies with national and international research and publication ethics. 1st Author %100 contributed. There is no conflict of interest.

References

Asbagh, N. B. (2024). Adaptive Reuse of Abandoned Churches in the Walled City of Famagusta, North Cyprus. *Journal of Mediterranean Cities, 4*(1), 130–155.

Asbagh, N. B., & Tümer, E. U. (2021). Cultural Heritage Interpretation: Proposals for Medieval Churches in Famagusta Walled City, North Cyprus. *Conservation and Management of Archaeological Sites, 23*(1-2), 61–101.

Cömert, N. Z. (2025). Historical–Geographical and Procedural Typological Approach in Urban Renewal: As a Case Louroujina, Northern Cyprus. In M. Hanzl, A. A. Kantarek , A. Zaguła , Ł. Musiaka, & T. Figlus, *Urban Morphology versus Urban Redevelopment and Revitalisation* (pp. 57-72). Cham: Springer.

Doğan, H. (2016). *The Interaction Between Public and Private Space in Traditional Environments: The Case of Kabaltı Houses in Urfa.* Eastern Mediterranean University. Famagusta: Unpublished Ms Diss.

Doratli, N., Hoşkara, Ö. S., Vehbi, O. B., & Fasli, M. (2007). Revitalizing a Declining Historic Urban Quarters: The Walled City of Famagusta, North Cyprus. *Journal of Architectural and Planning Research, 24*(1), 66-87.

Eyüce, A. (2012). Interdependence of Traditional House Form and Settlement Pattern. *Intercultural Understanding, 2*, 17-24.

Hakim, B. S., & Rowe, P. G. (1983). The Representation of Values in Traditional and Contemporary Islamic Cities. *Journal of Architectural Education, 36*(4), 22-28.

Heidegger, M. (1993). Building, Dwelling, Thinking.” In, edited by David Farrell Krell, 343–364. San Francisco: HarperSanFrancisco. In D. F. Krell (Ed.), *Basic Writings* (pp. 343–364). San Francisco: HarperSanFrancisco.

Kara, C., & Iranmanesh, A. (2023). Modelling and Assessing Sustainable Urban Regeneration for Historic Urban Quarters via Analytical Hierarchy Process. *Land, 21*(1), 72.

Lynch, K. (1961). *The Image of the City.* Cambridge: The M.I.T. Press.

Moughtin, C. (1992). *Urban Design: Street and Square.* Oxford: Butterworth-Heinemann.

Numan, I., Dinçyürek, Ö., & Pulhan, H. (2002). Multi-cultural influences on the development of the traditional urban fabric of Nicosia. In H. Turgut, & P. Kellett (Ed.), *IAPS-CSBE*, (pp. 425-430). Istanbul.

Oktay, D. (2002). The Quest for Urban Identity in the Changing Context of the City: Northern Cyprus Cities. *Cities, 19*(4), 261–271.

Oktay, D., & Önal, Ş. (1998). Analysis of Residential Outdoor Spaces in Cypriot Town. *Open House International, 23*(1), 22-31.

Philokyprou, M. (2024). Linking Teaching and Research in Conservation of the Built Environment: Case Studies from Courses of the University of Cyprus Graduate Programme on Conservation. *Studies in Conservation, 70*(5), 343–57.

Pulhan, H., & Numan, İ. (2005). The Transitional Space in the Traditional Urban Settlement of Cyprus. *Architectural and Planning Research, 22*(2), 160-178.

Rapoport, A. (1989). On the Attributes of Tradition. In J. P. Bourdier & N. AlSayyad (Eds.), *Dwellings, Settlements and Tradition Cross-Cultural Perspectives* (pp. 77-105). Lanhan: Univercıty Press of America.

Rapoport, A. (2007). The nature of the courtyard house: a conceptual analysis. *Traditional Dwellings and Settlements Review, 18*(2), 57-72.

Tuan, Y.-F. (2001). *Space and Place: The Perspective of Experience.* Minneapolis: University of Minnesota Press.

World Monuments Fund. (2012). Retrieved October 20, 2025, from Historic Walled City of Famagusta: https://www.wmf.org/projects/historic-walled-city-famagusta

Yu, B., Sun, J., Wang, Z., & Sun, J. (2024). Influencing Factors of Street Vitality in Historic Districts Based on Multisource Data: Evidence from China. *ISPRS International Journal of Geo-Information, 13*(8), 277.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Reflections of Designer Identity on Architecture: Analyses on Peter Zumthor and Kengo Kuma[1]

Pınar TASLI [1*]

ORCID 1: 0009-0009-7019-5599
[1]MSc. Architect, Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon-Türkiye
pnrtsl03@gmail.com (Responsible Author)

Hare KILIÇASLAN [2]

ORCID 2: 0000-0002-6113-7962
[2]Assoc. Prof, Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon-Türkiye
hkilicaslan@ktu.edu.tr

Abstract

Long before the profession of architecture existed, humanity had been striving to create living spaces that met their basic needs for shelter and protection, shaping these spaces sometimes for functional and sometimes for aesthetic purposes. The individual's identification with their living space, through which they reflect their own identity onto the space, is shaped by aesthetic concerns and functional requirements, becoming a factor that influences design decisions. The individual's personal desire to create, shaped by the knowledge they have acquired over time, forms their identity as a designer. This identity is reflected in the resulting work, ensuring its originality and distinction from others. In this regard, the aim of this study is to examine and comparatively evaluate the designer identities of Peter Zumthor and Kengo Kuma, who occupy an important place in the profession of architecture and are leading representatives of contemporary architecture. The projects selected through purposeful sampling are analysed using architectural data and the analysis model found in the source "Precedents in Architecture". As a result of these analyses, the criteria adopted by architects in their design production and their designer identities are sought to be determined. The findings are evaluated comparatively in terms of the commonalities between the two architects and the aesthetic approaches that distinguish them from each other. In conclusion, despite having grown up in different cultural and geographical contexts, Peter Zumthor and Kengo Kuma are found to be similar in their respect for nature and humanity and their use of natural materials and light as fundamental components of design, but there are distinct differences in their approaches to architecture and design decisions stemming from their personal designer identities.

Keywords: Designer identity, architectural approach, precedents in architecture, Peter Zumthor, Kengo Kuma

1.Introduction

The concept of identity creation in design became prominent during the modernism and subsequent post-modernism periods (Özçam, 2022). With the acceleration of industry in the early 20th century, identity creation in design began to be used by both designers and brands as a countermeasure to the standardisation of products (Upshaw, 1995). Today, designers are turning to branding with their own unique techniques. They produce designs that convey their own expression, style or signature and are easily distinguishable from others. World-renowned architects Zaha Hadid, Frank Gehry and Rem Koolhaas have identities that are easily distinguishable from their peers. Zaha Hadid uses futuristic vectors in her designs, Rem Koolhaas uses Cubist folds, and Frank Gehry uses Neo-Baroque curves (Foster, 2011). These

[1] This study was produced from the master's thesis titled "Decoding the Designer Identities of Architects: Peter Zumthor and Kengo Kuma" prepared by Pınar Taslı under the supervision of Assoc. Prof. Dr. Hare Kılıçaslan at the Graduate School of Natural and Applied Sciences, Karadeniz Technical University.

architects' designs reveal their identities through the techniques, forms, or materials they choose to use.

The analysis model created using analytical diagrams and coding methods enables the examination of the construction stages of all layers of the forms produced formally by the designer.

To understand or interpret the essence sought, the designer's stylistic choices, and the designer's formative decisions, it is necessary to analyse the codes within the design. The concept of code refers to the organisation or design that enables the understanding of the essence of the message to be conveyed or the relationships between units (Hatipoğlu & Koç, 2020). Codes also contain the stages of thought in the design formation process, user expectations, and reflections of the designer's identity. Therefore, revealing the designer's identity, getting to the essence of the design, and correctly reading the codes are possible.

The fundamental design principles that initiate the design creation process serve as a guide in the problem-solving process. While facilitating and initiating the design phase, they also play an important role in understanding, resolving, and evaluating the design (Civcir, 2015). The design principles that play a role in the creation and resolution of the design are addressed in different sources as different criteria. Within the scope of this thesis, the fundamental design principles are addressed under eight headings: balance, rhythm-repetition, contrast, harmony (suitability), proportion, unity (integrity), hierarchy, and dominance.

The number of elements in design is defined by Maitland Graves as seven components: direction, form, line, measure, texture, colour, and tone (Graves, 1951), while Hulusi Güngör adds the components of space, light-shadow, and movement to these in his book “Basic Design” (Güngör, 2005). Within the scope of this study, the Basic Design Elements are addressed under ten headings: Texture, Tone (Value), Colour, Line, Scale (Size), Direction, Spacing, Form, Light-Shadow, and Movement.

Within the scope of the study, fundamental design principles and elements are frequently referred to in the rethinking, resolution, evaluation and emergence of the design concept (Taslı, 2024).

2.Materials and Methods

In this study, an analytical evaluation model consisting of 11 criteria developed by Roger H. Clark and Michael Pause was used to conduct a detailed analysis of a sample group comprising five buildings by each architect. These criteria are: structural system, natural light, massing, plan-section-façade relationships, circulation and usage areas, from part to whole, repetition and originality, symmetry and balance, geometry, addition-subtraction, and hierarchy (Table 1).

Table 1. Analytical evaluation model assessment criteria (Clark & Pause, 2005)

Criteria	Description	Code
Structural system	In order for a structure to remain standing, it must be present in all architectural works. In this context, load-bearing elements such as columns, walls, and beams are evaluated in terms of repetition frequency, regularity, pattern, simplicity, randomness, and complexity.	• **Regular** • **Random**
The relationship of design	Balance, repetition, proportion, line, interval, direction, continuity	
Natural light	Factors such as where daylight is taken from play an important role in shaping the design. Light is an important design criterion in the perception of spaces. The size, position, shape and frequency of openings in walls and roofs present natural light as a design concept.	•**Active** •**Inactive**
The relationship of design	Repetition, texture, interval, shadow, movement, direction, form, scale, continuity	
Mass formation	It shapes the holistic perception of architecture. As a design concept, it can be examined in terms of the concept related to content, the coming together of the units that form the whole and the formation of patterns and singular masses, primary and secondary elements. It is an effective concept for defining, articulating and organising outdoor spaces and for the perception of architecture.	•**Pattern** •**Single**
The relationship of design	Interval, repetition, unity, harmony, colour, texture, tone, proximity, similarity, closure	
Plan-section-façade relationships	Plans are considered the creator of form, enabling the organisation of actions. Plans and sections facilitate a volumetric understanding of the structure. The relationships between plans, sections and elevations can influence each other's form through examinations of equality, balance, similarity, proportion, identity, differentiation and contrast.	•**Similarity** •**Contrast**
The relationship of design	Interval, proportion, direction, proximity, continuity, texture, tone, colour, harmony, form	
Circulation and areas of use	The focus of determining the design is the functional use of the space. Circulation facilitates the user's perception and recognition of the space. Circulation can be located at the centre or alongside functional areas, determining the placement of focal points.	•**Easily recognisable**
The relationship of design	Interval, proportion, continuity, movement, dominance, direction, form, measure	
From part to whole	A design may consist of a single unit or may be formed by the combination of units. The relationship between a unit and the whole structure constitutes an organisational and design strategy, while also revealing the concept of shaping the design. In this context, units are considered to be adjacent, separate, overlapping, or less than the whole.	**Overlapping** •**Separate**
The relationship of design	Form, proportion, proximity, closure, repetition, harmony, unity, scale, interval, direction	

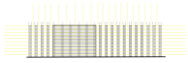
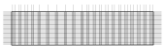
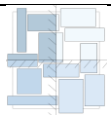
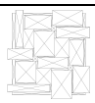
Originality through repetition	To highlight the distinctiveness of an element within a whole, it may be necessary to compare the elements within that group and identify their different characteristics. The concepts of size, shape, position, orientation, colour, material and texture can be evaluated to reveal the differences between repetition and originality.	**•Repetition** **•Originality**
The relationship of design	Direction, form, texture, repetition, colour, interval, proportion, scale, continuity, harmony, unity	
Symmetryan d balance	The balance of the units reveals that there is a relationship between them. The main characteristic of the relationship between the two must be determined. Symmetry can be achieved by repeating the same units on both sides of the determined axis of balance.	**•Symmetry** **•Balance** **•Asymmetry**
The relationship of design	Balance, repetition, harmony, proportion, unity, measure, direction	
Geometry	Geometry has been used as a design tool throughout architectural history. It is a characteristic concept most commonly used in buildings. The focus is on the concepts of dimension, shape, proportion and position. In the analysis, it is observed in terms of frequency, configuration, complexity, consistency and diversity.	**•Consistency** **•Diversity**
The relationship of design	Form, measure, ratio, direction, continuity, dominant, interval, similarity	
Addition-subtraction	Design is developed through processes such as adding, removing and assembling forms to the structure. In a design dominated by addition and removal, even if the omitted units and parts are defined separately, the removed parts of the architectural work can be perceived as a whole within the structure.	**•Addition** **•Subtraction**
The relationship of design	Form, proportion, measure, unity, movement, continuity	
Hierarchy	It can be defined as the ordering of one or more attributes. Hierarchy denotes the transition from one state to another. In hierarchy analysis, classification criteria can be evaluated using concepts such as large-small, open-closed, simple-complex, private-public.	**•Open** **•Closed**
The relationship of design	Continuity, interval, harmony, unity	

3. Analysis of Peter Zumthor's Buildings

Peter Zumthor's architectural approach focuses on human-space interaction and the use of materials. Zumthor's architecture has an effect that arouses curiosity, provides internal focus and stimulates users' spatial perceptions. The atmosphere he achieves in his designs stimulates users' sensory perceptions. Material choices shaped by the context in which the buildings are located and the way the materials are used reflect Zumthor's architectural approach. His unique design decisions, technique, and significant role in sensory architecture make Zumthor unique. Therefore, the five building examples included in the sample group created for the thesis study

are supportive in revealing Zumthor's design decisions, shaping ideas, and thus his identity as a designer.

Table 2. Swiss Pavilion evaluation table

Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The regularity is evident in the arrangement of the timber forming the structure, stacked at similar intervals and repeating in a linear orientation.	**Regular**
Natural light		The regular spacing between the timber elements demonstrates that natural light has been incorporated into the design and is an active element.	**Active**
Mass formation		The wooden planks are positioned perpendicular to each other in units at regular intervals, creating a permeable pattern.	**Pattern**
Plan-section-façade relationships		The spacing, similarity, and direction of the timber elements, among other design decisions, are reflected both in the layout and on the façade, demonstrating the concept of similarity.	**Similarity**
Circulation and areas of use		The timber stacks, arranged upright and in parallel groups, are positioned at varying distances within designated circulation areas, ensuring that circulation zones are easily identifiable.	**Recognisable**
From part to whole		The patterned wall system creates spaces and forms based on the principles of proximity and closure. The unit form transforms into a similar form within the structure and is overlapping.	**Overlapping**
Originality through repetition		The stacked multiple pieces of timber demonstrate that the concept of repetition prevails in terms of shape, texture, colour and continuity.	**Repetition**
Symmetry and balance		The units have different proportions and orientations when viewed on the horizontal and vertical axes. Therefore, asymmetry prevails.	**Asymmetry**
Geometry		All units, including the courtyard voids incorporated into the structure, are rectangular in form and consistent throughout the building.	**Consistency**
Addition-subtraction		Courtyard spaces have been left within the structure. These spaces are created by removing sections between the stacks.	**Subtraction**
Hierarchy		Although its environmental relationship is clear, there is an acoustic environment that aims to stimulate the senses and is desired to be achieved. For this reason, it is considered closed..	**Closed**

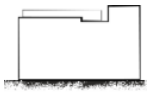
According to the evaluation in Table 2, the Swiss Pavilion effectively draws natural light into the interior thanks to its perforated design. The pattern created by the stacked timber in the façade design also characterises the visual identity of the structure. The harmony between the

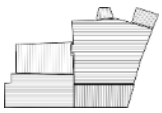
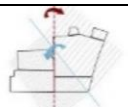
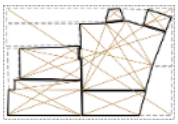
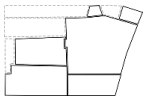
plan, section and elevations demonstrates consistency throughout the design. The open-plan structure of the circulation and usage areas facilitates transitions and connections within the interior space. The harmony between the parts and the whole, along with the repetition of material usage, maintains aesthetic and functional integrity. The perforated form and open-plan structure continue the relationship and continuity established with the exterior space.

In the design of the Swiss Pavilion, the structure's connection to natural environmental factors (lighting, ventilation) remains uninterrupted. The hollow structure of the stacked timber allows for this, while also serving as a restrictive and dividing wall. The perpendicular and hollow structure of the timber provides visual and auditory isolation. It offers a space for relaxation and rest, away from the noise of the city. In this regard, it incorporates a sound box feature that focuses on the acoustic experience. The use of timber ensures that sound is dispersed softly and naturally. This creates an acoustic atmosphere in the space.

The Swiss Pavilion highlights the strong connection between nature and architecture. The building's sound box features integrate with the sounds of nature (bird chirping, wind noise, etc.) and spread throughout the interior space. The open-plan structure allows sound to circulate within the interior space. In this way, while maintaining the structure's connection to nature and the environment, it offers an enclosed experience that focuses on the senses within the interior space.

Table 3. Kolumba Museum evaluation table

Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The structure is supported by columns to prevent load bearing on the remains of the Kolumba Church. The columns are arranged at regular intervals and in a radial pattern, demonstrating regularity.	**Regular**
Natural light		The use of natural light in accordance with design decisions and the effort to create dark rooms as needed also demonstrates that light is a factor in design.	**Active**
Mass formation		The towers rising at the corners are striking in this context. Their external seclusion, the dim atmosphere created inside, and their enormous size also emphasise the uniqueness of the structure as a whole.	**Single**
Plan-section-façade relationships		Similarities exist in the additions and removals reflected in the plan and section. When evaluated as a whole, there are similarities in terms of concepts such as material, harmony, additions and removals.	**Similarity**
Circulation and areas of use		The red bridge connects to the main circulation, offering not only a change in proximity to the works but also movement and different perspectives.	**Recognisable**
From part to whole		As there is no similarity or continuity between the units of the structure, which contains multiple forms at different angles and ratios, they are assessed separately.	**Separate**

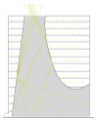
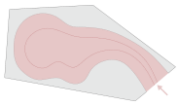
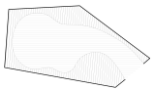
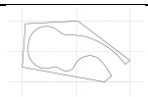
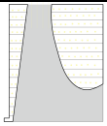
Originality through repetition		Due to the shape of the main exhibition area, the spaces are positioned at different angles. The combination of different shapes demonstrates the uniqueness of the structure.	**Originality**
Symmetry and balance		When examined along the vertical axis in the plane, it can be seen that there is no symmetry and that the axis of equilibrium is displaced.	**Asymmetry**
Geometry		When the structure geometry is completed in a rectangular form, it can be seen that the reduced areas do not form a regular geometric shape. The use of forms at different angles and proportions demonstrates diversity.	**Diversity**
Addition-subtraction		Additions and omissions are evident in the layout of the plan. The reductions in the plan layout are supported by the gaps between the towers on the façade, thereby reducing the monotony of the structure.	**Subtraction**
Hierarchy		The atmosphere captured indoors and the feeling of being protected like a fortress from the outside demonstrate that the concept of enclosure dominates the structure.	**Closed**

When all the criteria are in Table 3 are taken into account, the structural system of the Kolumba Museum is supported by columns placed at regular intervals and parallel to the existing walls. While the natural light entering the interior is limited, darkness prevails in some areas. Zumthor deliberately chose and incorporated dark spaces into the design to stimulate visitors' senses. The building's closed exterior, the towers rising from the corner points, and the singular mass form contribute to the building's integrity.

With masses rising from its corners, the Kolumba Museum resembles a castle, giving the impression of being sheltered and closed off to the outside world. Originally serving as a place of worship for Christians, the building embodies a spiritual atmosphere often seen in church designs, achieved through the use of light and shadow. This atmosphere is continued in the museum's design. The façade of the building features openings that allow light and air to flow between the interior and exterior spaces. The thick walls block sound, preserving the tranquil atmosphere inside.

Additionally, the bridge, designed to observe the historical remains within the interior space and featuring varying angles, directions, and lengths, stimulates visitors' visual perception by offering perspectives from different angles. In the cabin-shaped exhibition hall, natural light is deliberately excluded, encouraging visitors to focus on tactile, visual or auditory sensations in the dark. In this way, Zumthor ensures that users focus on the space itself, distancing themselves from environmental factors. For this reason, dark spaces were deliberately selected and integrated into the design to stimulate the visitors' senses. This is also one of Zumthor's design decisions.

Table 4. Bruder Klaus Chapel evaluation table

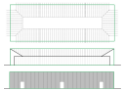
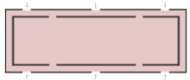
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		In the plan formed by the concrete structure, randomness prevails in the continuous load-bearing system with varying angles, directions, and dimensions.	**Random**
Natural light		Light is brought into the interior space by filtering through the oculus, the opening at the top, and the pipe openings on the façade, and is used as an active element in the design.	**Active**
Mass formation		It consists of a single form made of concrete material that is solid, seamless, and repetitive.	**Single**
Plan-section-façade relationships		Although the materials are continuous, with the same texture and color, the curved forms reflected in the plan and section provide information about the interior space and demonstrate similarity.	**Similarity**
Circulation and areas of use		There is no dividing wall, vertical circulation element, or separate space. In this case, circulation is open, continuous, and easily perceptible.	**Easily recognisable**
From part to whole		The unit area that makes up the whole also defines the whole. Therefore, the part-whole relationship has not been established and is considered separately.	**Separate**
Originality through repetition		The unit area that makes up the whole also defines the whole. Therefore, the part-whole relationship has not been established and is considered separately.	**Repetition**
Symmetry and balance		The structure, which has an irregular pentagonal shape, is asymmetrical when evaluated on its axes of symmetry.	**Asymmetry**
Geometry		The structure has organic features indoors and an irregular pentagonal shape outdoors, offering geometric diversity.	**Diversity**
Addition-subtraction		It can be seen that there are reductions in different forms in the plan structure and that removal is predominant.	**Subtraction**
Hierarchy		The aim is to sever the connection with the outside space in order to create a spiritual atmosphere within the space. Therefore, seclusion from the outside prevails.	**Closed**

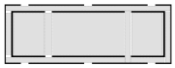
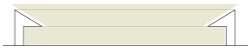
According to Table 4, the carrier system, which is positioned at different angles and directions, appears organic in the interior and irregularly angled on the exterior façade. The iron pipes used to connect the skeleton created in the interior and the concrete formwork on the exterior façade allow natural light to enter the interior while creating a visual spectacle. The oculus in the

ceiling, which refers to the purpose and metaphor of the chapel, plays an important role in lighting. While there are many factors in the design of the structure, another important element influencing the design is the atmosphere to be captured. Elements such as 'silence, introversion and experiencing worship' influence the design to be singular and closed to the outside. While the exterior presents a singular mass with intriguing and unpredictable sharp lines, the interior features organic and curved forms with opposite characteristics. For the spiritual environment sought in the interior, it is desired to sever the connection to the exterior. Zumthor's effort to stimulate user perceptions is clearly evident in the Bruder Klaus Chapel.

The Bruder Klaus Chapel is a structure designed for worship and built in memory of the monk Bruder Klaus. Due to the function of the building, there is a desired atmosphere in the place of worship. Places of worship are expected to be quiet, peaceful and relaxing. In this context, individuals have the opportunity to focus solely on the act of worship and return to their essence in the space they occupy. Due to the monolithic form of the structure, located on a large plot of land, it holds different meanings for the observer, triggering their thoughts and curiosity. Inside, there are a few objects used for worship within the dark-coloured walls achieved by burning wood. In this situation, the individual has the opportunity to distance themselves from distracting or chaotic objects around them and focus on their essence. This demonstrates Zumthor's attempt to capture the essence of the mind beyond unnecessary, excessive, or crowded objects, inviting the visitor to meditation and inner peace.

Table 5. Serpentine Gallery Pavilion evaluation table

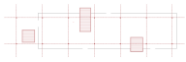
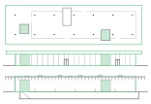
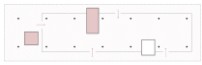
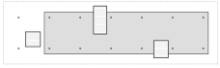
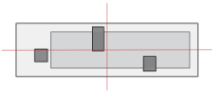
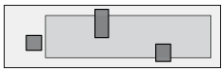
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The wooden structure has similar dimensions, spacing, and other characteristics. The walls are parallel and radial in layout and are of a regular nature.	**Regular**
Natural light		The structure, which is a closed garden, is designed to benefit from light due to its purpose, demonstrating that light is a factor in the design.	**Active**
Mass formation		The building is unique in that it appears as an intriguing closed box when viewed from the outside.	**Single**
Plan-section-façade relationships		The rectangular form is dominant throughout the structure and also shows similarities in section and elevation relationships.	**Similarity**
Circulation and areas of use		The usage areas of the building with an open plan structure can be distinguished by differences in floor materials.	**Easily recognisable**
From part to whole		The spaces allocated for the main area and circulation are variations of the same form in different proportions. This demonstrates that the parts correspond to the whole.	**Overlapping**

Originality through repetition		The use of the same geometric form in different proportions and sizes demonstrates the presence of repetition.	**Repetition**
Symmetry and balance		Parallel and coaxially positioned doors are included, and regularity and symmetry prevail in the geometric form.	**Symmetry**
Geometry		Consistency prevails throughout the structure, with the same geometric form being used in different proportions and orientations.	**Consistency**
Addition-subtraction		It demonstrates the existence of the concept of roof void extraction, created to meet garden requirements in a closed box form.	**Subtraction**
Hierarchy		The garden is designed to provide an escape from the chaos of the outside world and is enclosed.	**Closed**

As a result of the analysis presented in Table 5, the structure, which is designed in a box form to create an enclosed garden, features a regular load-bearing system. The garden created inside is isolated from environmental factors (traffic, noise, etc.) while being designed to be open to natural weather conditions. In addition, the sloping roof form allows for ventilation, sunlight and rain to enter the interior, which the garden requires. Zumthor creates an environment where visitors can relax with his environmentally sensitive design. In doing so, he uses light and natural materials rather than heavy building materials. At the same time, the singular and closed box form arouses the curiosity of users. The double-layered circulation is also designed to stimulate the senses of visitors as they transition from darkness to light.

Designed as a closed garden concept for recreation and relaxation, the Serpentine Gallery Pavilion is isolated from the noise of the outside environment. The box form we encounter in Zumthor's buildings also appears here. When viewed from the outside, the black closed box form does not reveal anything about the interior space, but it encourages the viewer to think. There are door openings in the two-layered wall structures. The fact that the openings are not aligned conceals the view of the interior space. The deliberately designed gradual circulation of the entrance and the use of black are intended to stimulate the senses of visitors. The use of black in the mass design ensures that it does not overshadow the colours of nature. In this regard, the vegetation and limited viewing areas within the structure ensure that the user's attention is focused on the experience of the interior rather than the outside world.

Table 6. Werkraum Bregenzerwald evaluation table

Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The parallel and regular placement of the supporting columns indicates regularity.	**Regular**
Natural light		The structure, consisting of a glass façade, is designed for the display of artworks. Since the works are illuminated by directed light, the glass façade is covered with blackout curtains. Therefore, natural light is not a factor in the design.	**Inactive**
Mass formation		The box-shaped structure with a wide, monolithic roof extending beyond the façade is characterized by singularity.	**Single**
Plan-section-façade relationships		The orientation of the mass horizontally and vertically, the repetition of material usage, and the continuity of the geometric form emphasize the concept of similarity.	**Similarity**
Circulation and areas of use		The structure has an open-plan layout with no clear dividing walls. Therefore, circulation is easily discernible.	**Easily recognisable**
From part to whole		The rectangular unit element is used throughout the structure in different proportions, orientations, and dimensions. Therefore, it is consistent from part to whole.	**Overlapping**
Originality through repetition		The structure, dominated by a black façade and simple materials that highlight the works, features a recurring element through the use of similar textures and forms.	**Repetition**
Symmetry and balance		When the roof and usable areas are evaluated according to their axes of symmetry, the concrete mass forms protruding from the building façade reveal asymmetry.	**Asymmetry**
Geometry		The structural unit is a quadrilateral, and consistency prevails throughout the structure due to the use of the same form in different proportions and orientations.	**Consistency**
Addition-subtraction		The masses protruding from the roof and floor plan at different ratios surrounding the box-shaped structure are seen as additions to the building.	**Addition**
Hierarchy		The boundaries between the interior and exterior spaces have been eliminated with a transparent façade, creating an open hierarchy.	**Open**

According to the data obtained in Table 6, the structure designed to bring artisans together is supported by columns arranged at equal intervals. The boundaries between the interior and

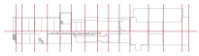
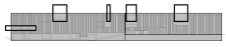
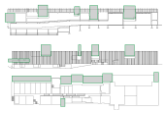
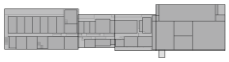
exterior spaces are completely transparent, maximising the use of sunlight. However, due to the exhibition of various works within the structure, constant sunlight is not preferred. In this case, artificial spotlights that can be directed are used in conjunction with blackout curtains to ensure that the works are brought to the fore. Zumthor designs a simple structure dominated by dark colours so as not to overshadow the exhibited works.

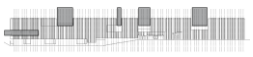
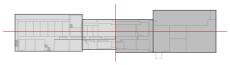
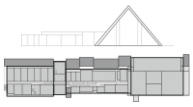
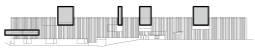
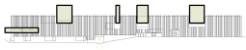
Werkraum Bregenzerwald is designed to bring artisans together under one protective roof. Unlike his other buildings, Zumthor presents the box form transparently. The inviting transparent façade design is not considered suitable for exhibition spaces.

4.Analysis of Kengo Kuma's Buildings

Kengo Kuma adopts an approach that synthesises traditional Japanese architecture with contemporary architecture. He prioritises the integration of buildings with nature without fighting it, and sustainability through material selection. His design approach, which emphasises human-nature interaction, highlights the concept of nature as a key factor in Kuma's designs. Consequently, his buildings feature permeable, lightweight designs that connect with nature. Kuma's design decisions add originality to his designs through the use of traditional construction techniques and natural materials, enabling the designer to be a pioneer in areas such as human-nature interaction and sustainable architecture. Within the scope of the thesis, five building examples have been selected to analyse Kuma's architectural design philosophy and reveal his identity as a designer.

Table 7. Momofuku Ando Center evaluation table

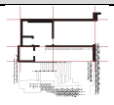
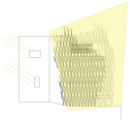
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The steel structure features a regular system with linear axes at specific intervals.	**Regular**
Natural light		The façade openings, designed with the aim of harmonizing with nature and utilizing natural light, demonstrate that natural light is a key factor in the design.	**Active**
Mass formation		The reductions affecting the mass and the metal wings covering the roof eliminate singularity while creating a pattern.	**Pattern**
Plan-section-façade relationships		The dominant pattern system in the structure and the continuity of the materials used show similarities between the plan, section, and elevation relationships.	**Similarity**
Circulation and areas of use		Ramps are used to accommodate differences in elevation within the interior, while there is a clearly defined main entrance and easily recognisable circulation.	**Easily recognisable**
From part to whole		The spaces of different scales that make up the structure are rectangular, and the same form appears in different sizes throughout the structure, which is considered to be consistent.	**Overlapping**

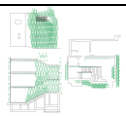
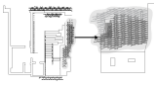
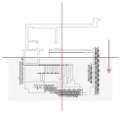
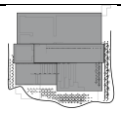
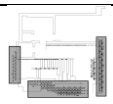
Originality through repetition		The use of different materials indoors and outdoors, and the use of metal wings in different tones that dominate the roof, demonstrate the uniqueness of the structure.	**Originality**
Symmetry and balance		When evaluated according to symmetry axes, there is balance in the structure even though there is no symmetry.	**Balance**
Geometry		The dominant rectangular form in unit spaces is seen in the triangular cross-section and façade openings. In this context, there is geometric diversity.	**Diversity**
Addition-subtraction		Both in the plans and elevations, it can be seen that the façade openings were achieved by reducing the structure. In this regard, the concept of subtraction prevails.	**Subtraction**
Hierarchy		There is an open hierarchy due to the effort to harmonize and relate with nature.	**Open**

When the criteria in Table 7 are evaluated, it is seen that the carrier system created with radial axes demonstrates different approaches to bringing natural light into the interior space while ensuring regularity. Both the façade and roof openings allow light to enter the interior space. Kengo Kuma prioritises the building's suitability to the site, remaining faithful to the topography and natural environmental conditions. While the structure does not stand out from its surroundings, the metal wings on the roof allow it to blend in with the natural environment. The metal wings, positioned at regular intervals on the roof, create a pattern, eliminating the monotony and uniformity of the mass. The characteristic projections on the roof and the plan level make this possible.

In the design of the Momofuku Ando Center, the natural elevation differences are reflected in the interior space in order to remain faithful to the topography of the site. At the same time, the metal wings of different colours used on the roof also support this, in an effort to harmonise with the context of the building and to continue the feeling of the forest by emulating nature.

Table 8. SunnyHills at Minami-Aoyama evaluation table

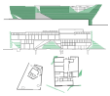
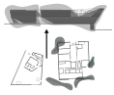
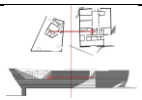
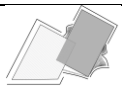
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		The load-bearing axes of the reinforced concrete structure are arranged parallel and perpendicular to each other.	**Regular**
Natural light		The bark, resembling tree branches on the façade, creates a forest atmosphere indoors with light and shadow effects, utilizing natural light as an active element in the design.	**Active**
Mass formation		The shell pattern form is created in the wooden lattice system with a forest-like structure.	**Pattern**

Plan-section-façade relationships		The dominant shell form on the façade is reflected in every plane, giving rise to the concept of similarity.	**Similarity**
Circulation and areas of use		Areas are designated for visitors and staff, and circulation is easily recognisable.	**Easily recognisable**
From part to whole		While the mass consists of rectangular forms, the façade pattern does not show similarity and is classified separately.	**Separate**
Originality through repetition		The structure, consisting of two layers, inner and outer, is characterized by a dominant patterned shell and is considered unique.	**Originality**
Symmetry and balance		When the mass is divided along the axes, equilibrium is lost and asymmetry occurs, with one side consisting of reinforced concrete and the other of a patterned shell.	**Asymmetry**
Geometry		The structure, which has a regular geometric form, takes on an organic form with the shell on the façade. Therefore, there is geometric diversity.	**Diversity**
Addition-subtraction		A shell form attached to the exterior of the reinforced concrete mass is visible. Therefore, the concept of addition is dominant.	**Addition**
Hierarchy		The structure's scattered and open layout mimics nature, featuring an open hierarchy designed to connect with the surroundings.	**Open**

When Table 8 is evaluated in general, SunnyHills consists of two layers: the inner layer has a reinforced concrete box form, while the outer façade features a wooden pattern cladding. As natural light enters the interior, the rays filtering through the wooden pattern on the façade create a visual feast within the space. In terms of repetition and originality, the evenly spaced pattern of the wooden façade cladding provides continuity that extends into the interior, while the angle and direction of the material add originality to the design. It emphasises geometric diversity, presenting rectangular forms in the interior and an organic, asymmetrical structure on the exterior façade. The mass design becomes distinct with the addition of the wooden lattice system to the main mass from the outside. While harmonising with nature through hollow and scattered wooden cladding, like tree branches in nature, it offers an open hierarchy that does not interrupt the relationship between the interior and exterior spaces.

SunnyHills, designed for a renowned cake company, is required to be unique. In line with this, Kuma, inspired by nature, uses natural materials (wood) and creates a design reminiscent of tree branches with its hollow form, evoking the feeling of sitting in a forest with the shadows created indoors.

Table 9. V&A Dundee evaluation table

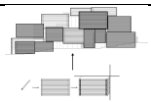
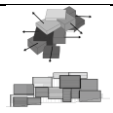
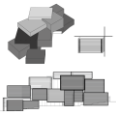
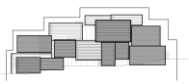
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		Randomness prevails due to the carrier structural exhibiting different angles and orientations.	**Random**
Natural light		The openings on the façade were created to take advantage of natural light and play an active role in the design.	**Active**
Mass formation		Concrete blocks used on the façade form a pattern to blend in with the randomness of nature.	**Pattern**
Plan-section-façade relationships		The rhythm on the façade continues inside, and a sense of similarity prevails throughout the building.	**Similarity**
Circulation and areas of use		Areas designated for staff and visitor use are clearly marked and easily identifiable.	**Easily recognisable**
From part to whole		The pattern enveloping the main mass from the outside enables the creation of an organic form, while being characterized separately from the part to the whole.	**Separate**
Originality through repetition		Concrete blocks of varying dimensions, orientations, and angles, created by imitating nature, ensure the structure's uniqueness.	**Originality**
Symmetry and balance		The prevailing state of disorder in the structure causes the axis of equilibrium to shift and leads to asymmetry.	**Asymmetry**
Geometry		Geometric diversity prevails due to the absence of a regular and clear geometric form.	**Diversity**
Addition-subtraction		The façade pattern that wraps around the mass form is dominant in the structure and is achieved through additions.	**Addition**
Hierarchy		An open hierarchy exists to avoid restricting city movement and to ensure environmental connectivity.	**Open**

to the results of Table 9, the structure, composed of reinforced concrete, begins as two separate masses on the ground and merges on the upper floor. These design decisions result in a display of randomness through the use of irregular axes and different angles. The entire reinforced concrete mass is formed by covering it with concrete blocks. Natural light enters the interior through regular intervals between the concrete block masses and glass surfaces. Randomness in nature is achieved through concrete blocks of different orientations and sizes, reflecting originality in the design. The horizontal positioning of the concrete blocks and the continuity of the façade pattern continue in the interior, ensuring the preservation of design integrity. It is

seen to have an irregular and asymmetrical design. The dominance of the addition factor is revealed by the façade pattern enveloping the main mass from the outside. It stands out with a design that emphasises the building's harmony with its surroundings and its relationship with nature.

The pattern found in the design of V&A Dundee creates a form inspired by the cliffs and rocks of Scotland, where the building is located. The irregular and random natural formation of the cliffs and rocks is reflected in the building's façade. At the same time, in order to respect the flow of the city and not interrupt it, a void is created in the mass for passage.

Table 10. Odunpazarı Modern Museum evaluation table

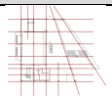
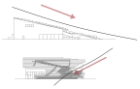
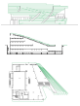
Evaluation Criteria	Diagram	Evaluation	Code
Structural system		In the box-based structural design, the load-bearing system appears to be random in terms of different angles, directions, and axes.	**Random**
Natural light		The perforated design of the façade and the ceiling void in the atrium demonstrate the role of natural light in the design.	**Active**
Mass formation		The concept of pattern dominates in the structure wrapped with a wooden lattice system.	**Pattern**
Plan-section-façade relationships		The dominant pattern in the structure composed of box forms is the continuity of the façade, and the concept of similarity is predominant.	**Similarity**
Circulation and areas of use		While elevation differences in the terrain are noticeable indoors, they are easily perceived through the circulation connections.	**Easily recognisable**
From part to whole		The box form, which plays an important role in the design, is repeated throughout the structure and is characterized as overlapping.	**Overlapping**
Originality through repetition		The box form is evaluated uniquely when used in different scales, directions, and dimensions.	**Originality**
Symmetry and balance		In a design with a random structure, the axis of balance is shifting and asymmetry is dominant.	**Asymmetry**
Geometry		While the ground floor of the reinforced concrete structure has variable angles, the upper floors feature rectangular shapes. Therefore, there is diversity.	**Diversity**
Addition-subtraction		A wooden lattice system that wraps around the entire façade is added to the mass design, which resembles stacked boxes.	**Addition**

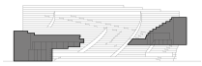
Hierarchy		An open hierarchy exists within the structure for the purpose of revitalizing and establishing connections within its context.	**Open**

When the data in Table 10 is evaluated, the Odunpazarı Museum was constructed using reinforced concrete on the ground floor and a steel structural system on the other floors. The irregularity and different orientations of the structure affect the structural system. While the Ottoman street fabric in the location of the structure is to be continued, wooden façade cladding is used. This allows light to filter into the interior space. The interlocking of unit masses of different sizes and orientations with a wooden lattice system gives the building unity and continuity. In this asymmetrical structure, the unit masses created by the addition method are designed in keeping with Ottoman architecture and the local context.

The primary design objective for the Odunpazarı Modern Museum in Eskişehir can be considered as its suitability to the history and fabric of its location. Continuing the traditional Ottoman street texture in its context and using wood materials due to the region's history of wood trade also demonstrates the design's respect for history and context. At the same time, the topography movement within the structure, located on a sloping area, is felt through level differences in the interior space, showing that it does not fight against nature. The topographic movement is reflected in the interior as slight elevation changes, always striving to be in harmony with nature. The use of natural materials and natural light aims to revitalize the location, make it a central location, and establish a connection with the surroundings.

Table 11. Tokyo Institute of Technology evaluation table

Evaluation Criteria	Diagram	Evaluation	Code
Structural system		When the axes are examined, parallelism and regularity are disrupted, and randomness prevails.	**Random**
Natural light		The slits opened to allow light into the structure, most of which is buried underground, demonstrate that natural light is a key factor in the design.	**Active**
Mass formation		The exposed surface reveals the design concept of the structure, while the stands on the façade create a pattern.	**Pattern**
Plan-section-façade relationships		The gradation and continuity of the materials used indicate similarity.	**Similarity**
Circulation and areas of use		The stepped roof incorporated into the circulation and the interior usage areas are easily recognisable.	**Easily recognisable**
From part to whole		It is classified separately due to the use of different forms in the plan and façade cladding.	**Separate**
Originality through repetition		The cuts and stands in the structure are asymmetrical. Originality prevails in the	**Originality**

		structure, which is inspired by nature and randomness.	
Symmetry and balance		The structure has a stepped form, with the axis of balance shifting and asymmetry prevailing.	**Asymmetry**
Geometry		There is geometric diversity due to the presence of different forms in the plan and section planes.	**Diversity**
Addition-subtraction		The visible façade of the building, which has three buried sides, consists of stands, creating a dominant addition.	**Addition**
Hierarchy		An open hierarchy exists for the purpose of establishing a relationship with nature and adapting to the topography.	**Open**

When the data in Table 11 is summarized, the Tokyo Institute of Technology's carrier system has partially regular and parallel axes, while exhibiting irregularities in some sections. The irregularity in the carrier system reflects the randomness found in nature. While topography creates the characteristics of the building, it also directs the architect's design decisions. Although a large part of the structure is buried in the ground, the elevation differences provided by the sloping terrain and the cracks opened in the roof allow natural light to reach each floor. The building mass is completely integrated with the terrain and buried in the ground. At the same time, we can say that it is located underground so as not to overshadow the old Clock Tower on the campus. The stands surrounding the mass, which play a major role in the design, provide continuity in the plan, section, and elevation planes, ensuring the integrity of the structure. The stands on the roof increase functionality as they are used as circulation and relaxation areas. The structure's design, in harmony with nature, enhances the relationship with the natural environment while strengthening the interaction between users.

When examining the design decisions made for the Tokyo Institute of Technology, it is evident that the primary factor is topography. The mass is buried into the ground to harmonize with the sloping hills on campus and to avoid overshadowing the clock tower, which holds significant importance for the campus. The exposed portion forming the roof of the structure is designed in a stepped manner to integrate with nature.

5.Conclusion

Based on the factors examined in Peter Zumthor's sample group, it is evident that he aims to create introverted, closed spaces by utilizing human-centered spatial layout and the effective use of light and shadow play in design, thereby abstracting users from the chaos of the outside world and taking them on an inner journey. Zumthor's architecture creates simple, tranquil spaces where serenity prevails. This introverted approach triggers an inner search between space and human, establishing a relationship and stimulating the senses. In line with Peter Zumthor's design decisions and approaches, the space is expected to offer users a sensory and spiritual experience. Although the exterior façade designs of the buildings we examined in the sample group are simple, clear, and feature sharp lines, the atmosphere achieved in the interior is completely different. Continuing the simplicity of the exterior façade, the interior also seeks the "essence" that is abstract and spiritual, beyond the concrete. The desired atmosphere is created through the use of natural materials, light and shadow effects, and small, simple details.

It is evident that Peter Zumthor's primary design criterion is the human being and their experience of space. He aims to isolate users from the outside world, establish a relationship with the space, embark on an inner journey, and gain individual perceptual awareness. Zumthor's introspective approach offers the opportunity to achieve simplicity, meditation, and individual experience simultaneously. In this context, Peter Zumthor's identity as a designer can be broadly defined as "meditative."

An important criterion common to every structure in Kengo Kuma's sample group is the concept of natural light. Natural light has been an essential requirement for every structure or space from the past to the present. However, in Kuma's designs, the use of natural light not only meets this need but also plays an active role in the design. The atmosphere sought to be achieved through the shadows cast by sunlight in interior or exterior spaces, and the movement added to the structure by the changing angle of sunlight throughout the day, are incorporated into the design.

Kengo Kuma's approach to shaping architecture, the decisions made in his designs, and the concepts that stand out are derived from the literature review, analyses, and evaluations conducted throughout this study. By examining the connections between these concepts and the design decisions made for the structures, and while researching Kengo Kuma's identity as a designer, it is revealed that one of the most important factors in his structural design decisions is "nature." The uniqueness of every object found in nature and the randomness that emerges from Kuma's efforts to emulate nature in his designs enable originality to be achieved. At the same time, it is evident that Kengo Kuma demonstrates his commitment to the concept of nature not only in his designs but also in his use of materials, choosing sustainable and natural options.

Kuma's identity as a designer can be described with many adjectives. Kuma's respect for nature, people, and every object in his environment, whether living or inanimate, is evident in his perspective on other structures and designs around him. However, it is clear that the concept of nature dominates his design decisions. The use of natural materials in his structures, randomness, irregularity, the effort to emulate nature, and his constant references to nature, combined with his technique of combining natural materials and materials unique to the designer, reveal Kuma's identity as a designer and set him apart from his peers. Therefore, Kengo Kuma's designer identity can be broadly defined as an "architect who puts nature at the center."

Table 12. Comparative analysis table

Evaluation Criteria	Evaluation	PETER ZUMTHOR					KENGO KUMA				
		Swiss Pavilion	Kolumba Museum	Bruder Klaus Chapel	Serpentine Gallery Pavilion	Werkraum Bregenzerwald	Momofuku Ando Center	SunnyHills at Minami-Aoyama	V&A Dundee	Odunpazarı Modern Museum	Tokyo Institute of Technology
Structural system	Regular	●	●		●	●	●	●			
	Random			●					●	●	●
Natural light	Active	●	●	●	●		●	●	●	●	●
	Inactive					●					
Mass formation	Pattern	●					●	●	●	●	●
	Single		●	●	●	●					
Plan-section- façade relationships	Similarity	●	●	●	●	●	●	●	●	●	●
	Contrast										
Circulation and areas of use	Easily recognisable	●	●	●	●	●	●	●	●	●	●
From part to whole	Overlapping	●			●	●	●			●	
	Separate		●	●				●	●		●
Originality through repetition	Repetition	●		●	●	●					
	Originality		●				●	●	●	●	●
Symmetry and balance	Symmetry				●						
	Balance						●				
	Asymmetry	●	●	●		●		●	●	●	●
Geometry	Consistency	●			●	●					
	Diversity		●	●			●	●	●	●	●
Addition-subtraction	Addition					●		●	●	●	●
	Subtraction	●	●	●	●		●				
Hierarchy	Open					●	●	●	●	●	●
	Closed	●	●	●	●						

Many similarities can be observed in the designs of Peter Zumthor and Kengo Kuma. In particular, the effective use of natural light in their designs stands out as a common feature. However, there are factors that reveal their architectural identities and highlight their differences from each other. Table 12 shows that the two architects have completely opposite approaches to the criteria highlighted in bold. These contrasts are the criteria that truly reveal the designers' identities. The different analysis criteria that reveal their true identities support each other while being interconnected in a cause-and-effect relationship. According to Table

12, while Zumthor's designs feature regular structural systems, singular, consistent, and closed-off building masses dominated by repetition, Kuma's designs feature the opposite choices, with randomness, patterned façades, originality, various geometric forms, and openness to the outside coming to the fore. In this regard, the information obtained from the analysis shows that Zumthor's design preferences, which aim for external closure, and Kuma's random forms, which emerge from his emulation of nature, support the architects' individual design goals.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Civcir, E. (2015). *Temel tasarım ve tasarım ilkeleri.* Akademisyen Kitabevi.

Clark, R. H., & Pause, M. (2005). *Precedents in Architecture*. New York: John Wiley & Sons

Foster, H. (2011). *Sanat-Mimarlık Kompleksi.* İstanbul: İletişim Yayınları.

Graves, M. (1951). *The Art of Color and Design*. New York: Mc Graw-Hill Publishing.

Güngör, H. (2005). *Temel Tasar.* İstanbul: Patates Baskı Yayınları.

Hatipoğlu, H. K., & Koç, Ç. (2020). Mimaride tasarım kodları ve anlamsal sürdürülebilirlik: Dil, Bellek ve Kimlik Tartışması. *İdealkent*, *11*(31), 1676-1698.

Özçam, I. (2022). Fenomenolojik Yaklaşımın Mimaride Tasarımcı Kimliği ve Malzeme Kullanımı Üzerinden Okunması. *Mimarlık ve Yaşam Dergisi*, 7(2), 503-523.

Taslı, P. (2024). *Decoding the Designer Identities of Architects: Peter Zumthor and Kengo Kuma* (Master's Thesis). Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon.

Upshaw, L. B. (1995). *Building Brand Identity*. New York: John Wiley & Sons Inc.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Spatial and User-Centered Evaluation of the Main Entrance at Karadeniz Technical University Department of Architecture

Sevde DİNÇER [1]*

ORCID 1: 0000-0003-4588-2222
[1]MSc. Architect, Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon-Türkiye
trsevdedincer@gmail.com (Responsible Author)

Hare KILIÇASLAN [2]

ORCID 2: 0000-0002-6113-7962
[2]Assoc. Prof, Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon-Türkiye
hkilicaslan@ktu.edu.tr

Abstract

Entrance areas in educational structures, consisting of multi-dimensional spaces such as classrooms, workshops, laboratories, and social spaces, stand out as important spaces where the first experiences are had and interactions take place. The main entrance areas of architecture department buildings are important spaces in terms of shaping the spatial experience and reflecting the institutional identity as the first point of contact for users. The aim of this study is to evaluate the main entrance of the Architecture Department of the Faculty of Architecture at Karadeniz Technical University in terms of students' perceptions of the space and their satisfaction levels, both in terms of interior and exterior spaces. To this end, a questionnaire was administered to students studying in the Department of Architecture, designed to evaluate the entrance from both physical and psychological perspectives. Physical characteristics include location, formal emphasis, accessibility, use of materials and colours, and natural and artificial lighting. Psychological effects were examined in terms of orientation, the inviting nature of the space, reflection of the department's image, and perceptions of safety and comfort. Based on the data obtained, the study sought to determine whether students were generally satisfied with the department's entrance space and whether they felt safe, comfortable, and free in the space. The findings reveal that the entrance space has various strengths in terms of reflecting the department's identity and improving the user experience, but also highlight areas for improvement in terms of spatial layout and design. This study aims to emphasise the importance of a user-centred approach to entrance design in educational buildings and to provide guiding findings for future arrangements.

Keywords: Educational buildings, entrance space, interior-exterior space, user evaluations, KTU Department of Architecture

1. Introduction

The architecture of educational buildings has varied over time in parallel with certain social, cultural, and economic changes throughout history (Butabekova & Abdykarimova, 2025). Today, educational institutions provide education in different fields, and the structure of educational buildings varies according to the type of education provided (Çelik & Arabacıoğlu, 2022). It is understood that the architectural design of educational structures has a significant impact on students' learning experience and academic success (Almirón Cuentas & Bernedo-Moreira, 2023). Accordingly, educational structures should be designed as quality learning spaces (Gülay, 2025).

To experience the structure, one must first approach the entrance, perform the act of entering, and then access other interior spaces from the entrance hall. Therefore, users begin to evaluate the structure primarily through the entrance. Consequently, entrances must be effectively designed in terms of both interior and exterior spaces (Dinçer, 2022). In this regard, it is crucial that the entrance spaces of educational buildings integrate with the surroundings and reflect the overall image of the campus (Nasution & Puteri, 2020). In this context, appropriate materials

should be used in the path leading to the building entrance, and these materials should be resolved with the correct details. Entrance areas should not be narrow. Entrance doors should be easily recognisable, and door dimensions should comply with accessibility standards. Entrance porches should be large enough for wheelchairs to pass through comfortably (Tutal, 2018). In addition, stairs, ramps, and railings at the entrances of educational buildings should comply with accessibility standards (Ozkaraca & Inceoglu, 2021). In summary, in the context of outdoor spaces in educational buildings, entrances must be located in a position suitable for footpaths and pavements, comply with accessibility standards, be located in a logical and legible position in relation to the building as a whole, include directional elements such as signage, be aesthetically pleasing, reflect the prestige and image of the institution, and be clean and well-maintained (Winnicka-Jasłowska, 2018). In addition, in educational buildings, entrance halls within the interior space context enhance the spatial quality of the building by being bright, accommodating different functions, being directional, and being of sufficient size (Başkaya et al., 2003; Ogden et al., 2023). In this regard, entrance halls must be effective in psychological and social contexts, internalised, and conducive to establishing connections, beyond merely being transitional spaces (Zengel & Kaya, 2011).

In light of these findings, it is understood that building entrances not only provide physical access to the interior space but also shape students' behaviour (Dixon et al., 2020). Therefore, it can be said that the different characteristics of entrances, such as location, lighting, and façade design, located in the interior and/or exterior spaces, directly affect students' spatial behaviour, movement, orientation, and circulation (Shirowzhan et al., 2020). Consequently, students' views on the space provide important findings in the context of evaluating the space. In this regard, student views reveal a space's sense of belonging, functionality, and liveability. In addition, student views help uncover certain hidden physical and psychological problems of the space and contribute to its improvement (Arzate-Quintanilla et al., 2024). As with all educational structures, the main entrance spaces of architecture department buildings are important areas in terms of shaping the spatial experience and reflecting the institutional identity, as they are the first point of contact for users.

The aim of this study is to evaluate the main entrance of the Department of Architecture at Karadeniz Technical University Faculty of Architecture in terms of students' perceptions of the space and their levels of satisfaction, within the scope of both interior and exterior spaces. Based on the data obtained, it is sought to determine whether students are generally satisfied with the entrance space of the department and whether they feel safe, comfortable, and free within the space.

The building of the Department of Architecture at Karadeniz Technical University features a rational architecture reflecting the modernist approach of the 1950s. In this context, the building was achieved by shifting two horizontal rectangles and joining them together. The building has a linear circulation scheme. Linear long-armed staircases are located in the middle of the building. One wing of the building houses academic offices and administrative units, while the other wing houses classrooms, workshops, and laboratories (Karakaş & Türk, 2017) (Figure 1).



Figure 1. KTU Architecture Department site plan and ground floor plan (obtained from and arranged by the KTU Construction Works and Technical Department Directorate)

The Architecture Department building has entrances located on different levels. The main entrance area of the department was addressed within the scope of this project. A semi-open entrance area (approximately 70 m²) was created on the ground floor of the building by removing a section of the structure. This space features landscape elements such as a ramp, seating, a rubbish bin, and concrete planters. The flooring material in this area is cast mosaic with marble strips. Aluminium cast lighting elements are installed on the ceiling.

There is a two-metre-high vestibule (approximately 3,50 m²) between the entrance hall and the semi-open space, emphasising the entrance. The outer door of the vestibule is a glass-panelled iron door. The inner door is a glass-panelled wooden swing door. The entrance hall is approximately 140 m². Access is provided from the entrance hall to the secretarial units, the experimental laboratory, the service staircase, the lift, the main staircase, the faculty rooms, and the workshops/classrooms. The entrance hall features metal seating fixtures, waste bins, parabolic plaster-mounted lighting elements, panels, a statue of Mimar Sinan, a photo corner, and a digital screen. The façade of the entrance hall consists of large glass surfaces. Wooden sunshade elements are also located on this façade. Inside, white is the preferred colour for the walls and ceiling. Grey and white colours are used on the floor surface. The floor covering is

cast mosaic with marble strips. Wooden materials have been preferred for doors and windows. The ceiling material is mineral plaster. Exhibitions and various events are held in the entrance hall (Figure 2, Figure 3).

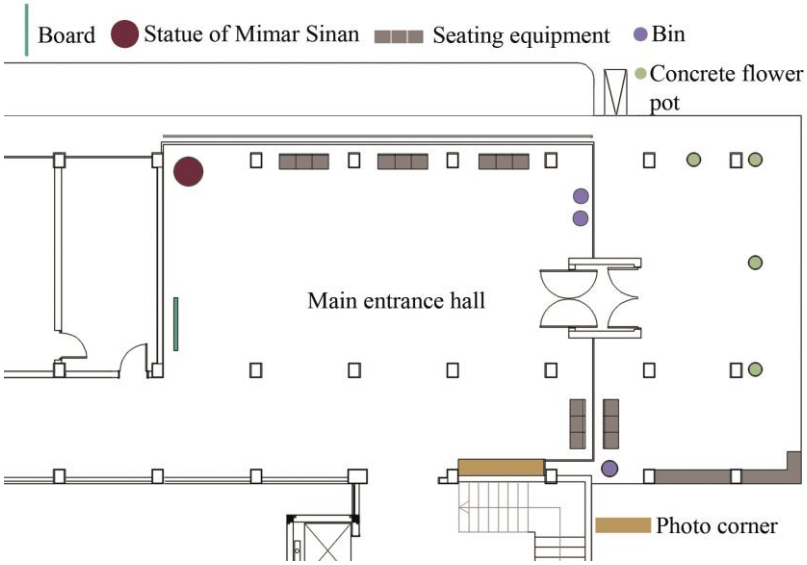


Figure 2. Main entrance hall of the KTU Department of Architecture (obtained from the KTU Directorate of Construction Works and Technical Affairs and arranged accordingly)



Figure 3. Main entrance hall of the KTU Department of Architecture

2.Materials and Methods

The questionnaire administered to students enrolled in the Department of Architecture was designed to evaluate the entrance from both physical and psychological perspectives. The design of the survey questions draws on surveys of entrance spaces in educational buildings found in the literature (Başkaya et al., 2003) and entrance space analysis criteria (Dinçer, 2022; Winnicka-Jasłowska, 2018). Accordingly, the questions were arranged to enable the physical and psychological evaluation of the entrance from the exterior to the interior. Physical characteristics include elements such as location, formal accents, accessibility, use of materials and colours, and natural and artificial lighting. To reveal psychological effects, aspects such as orientation, inviting nature of the space, reflection of the section's image, and perceptions of safety and comfort were examined.

The data obtained from the questionnaires were analysed using descriptive statistics (frequency, percentage, mean, etc.). The questionnaire form consists of five sections. The first section covers demographic characteristics. The second section evaluates the main entrance of the KTU Department of Architecture in the context of an outdoor/semi-open entrance space (17 questions), the second section contains questions on evaluation criteria in the context of the intermediate space/vestibule/indoor-outdoor space (7 questions), the third section contains questions on evaluation criteria in the context of the interior space/entrance hall (14 questions), and the final section contains questions on general evaluation criteria (5 questions).

2.1.Findings and Discussion

The survey was administered to 120 participants (83 female, 37 male). Information regarding the group of participants to whom the survey was administered is provided in Table 1.

Table 1. Participant demographics

		Frequency (n)	Percentage (%)
Gender	Female	83	69,2
	Male	37	30,8
	Total	120	100
Time to experience the field	1-2 semesters	34	28,3
	3-4 semesters	80	66,7
	5-6 semesters	6	5
	7 semesters and above	0	0
	Total	120	100
Time in the field during the day spending time	0-10 minutes	16	13,3
	11-30 minutes	20	16,7
	31 minutes-1 hour	11	9,2
	More than 1 hour	73	60,8
	Total	120	100
Usually use the area time	Morning	56	46,7
	Noon	48	40
	Afternoon	14	11,7
	Evening	2	1,6
	Total	120	100

Participants evaluated the main entrance of the KTU Architecture Department through survey questions, considering physical and psychological factors in the context of the exterior space, intermediate space/vestibule, interior space, and overall environment (Figure 4).

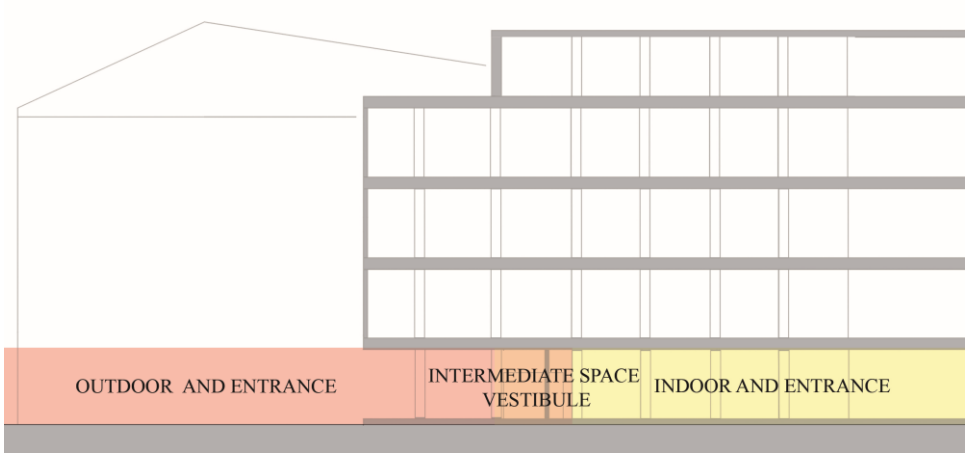


Figure 4. Main entrance space assessment areas of the KTU Department of Architecture

When examining participants' physical assessments of Area 1, the highest average score of 4.125 was found under the item "The entrance provides users with the opportunity to meet, gather and chat." Similarly, the item "The entrance's suitability for human scale" received an average score of 3.967, and "The proximity of the entrance to the main street" received an average score of 3.917, making them other positively evaluated elements. In contrast, the lowest values were determined to be 3.350 on average for the items "Suitability of the entrance for daytime and nighttime use" and again 3.350 on average for "The effect of color, material, and texture use on the building entrance" (Figure 5).

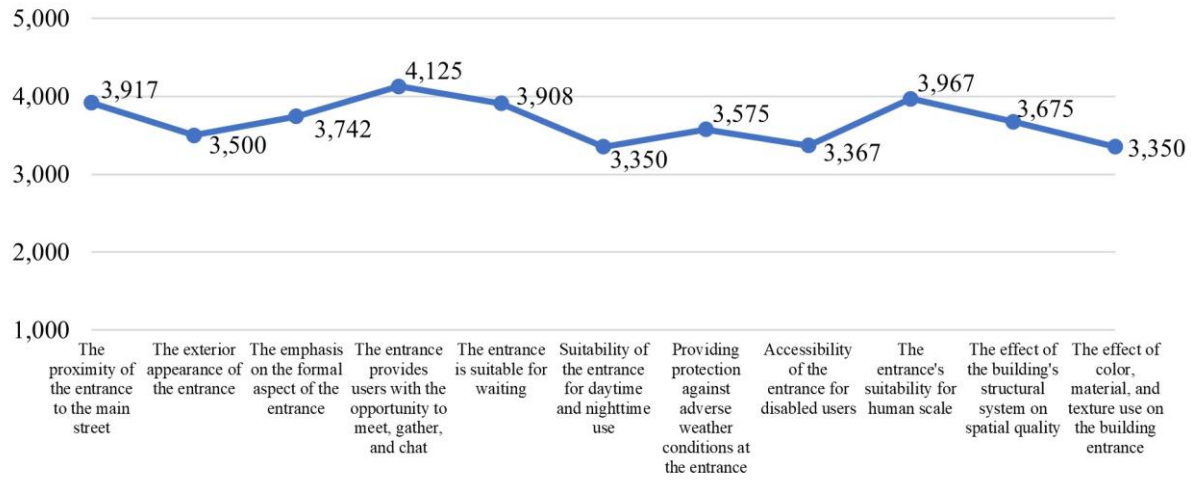


Figure 5. Participants' physical assessments of Area 1

When examining participants' psychological assessments of Area 1, the highest average score of 4.250 is observed for the statement "The building's entrance is clearly discernible and provides orientation." Similarly, the statement "entrance to the building is clearly visible and easy to find." is another positively evaluated statement with an average score of 4.242. In contrast, the lowest value, with an average of 3.083, is found in the statement "The entrance evokes a sense of curiosity about the building's interior design." Another statement with a low value is "The building's entrance reflects the image of the Architecture Department," with an average of 3.200 (Figure 6).

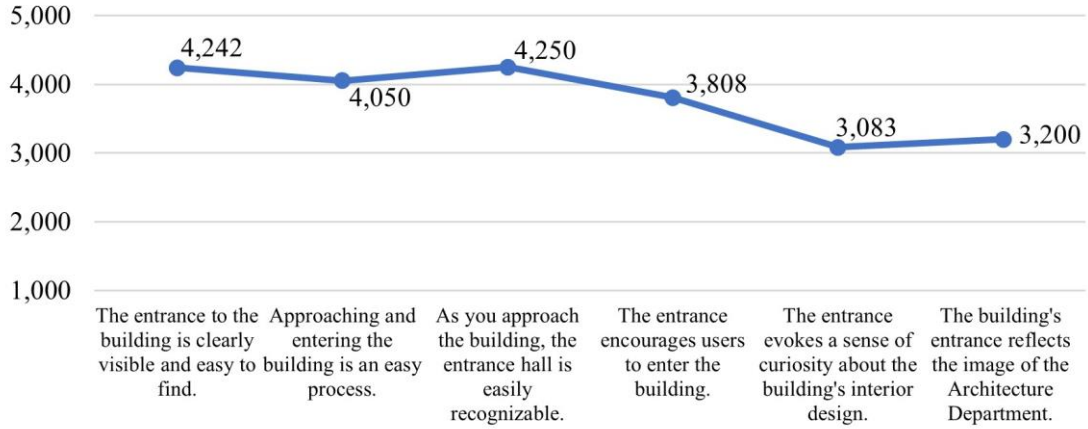


Figure 6. Participants' psychological assessments of Area 1

When examining participants' physical assessments of Area 2, the highest value is observed in the item "The appropriateness of the location of the entrance door" with an average of 3.892. This item is followed by "The entrance door/vestibule has appropriate dimensions" with an average of 3.533 and "The functionality of the entrance door type (swing door)" with an average of 3.317. The lowest value is seen in the item "The entrance door has appropriate qualities in terms of colour, material and texture" with an average of 3.283 (Figure 7).

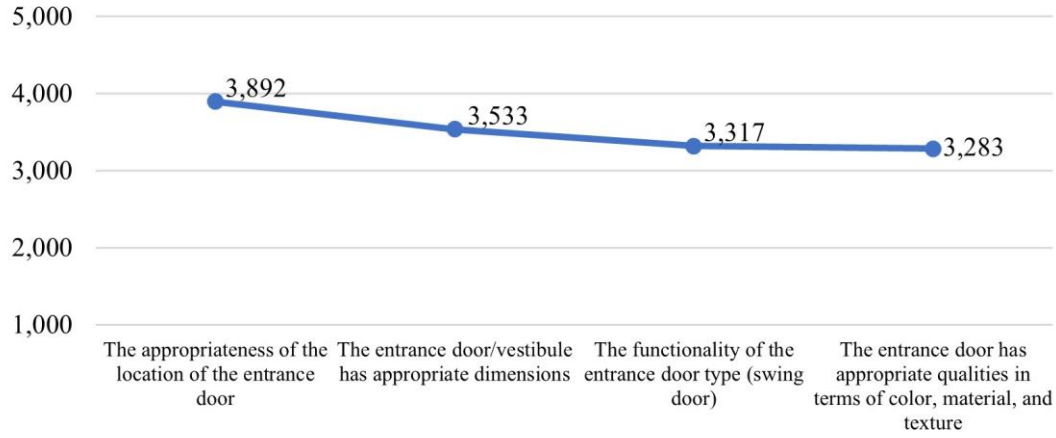


Figure 7. Participants' physical assessments of Area 2

When examining participants' psychological assessments of Area 2, the item with the highest value was "The distinction between the exterior and interior is clear," with an average of 4.117. This item was followed by "The entrance prepares users for the interior space," with an average of 4.025. followed by the item "The entrance reflects the users' profile" with an average of 3.283 (Figure 8).

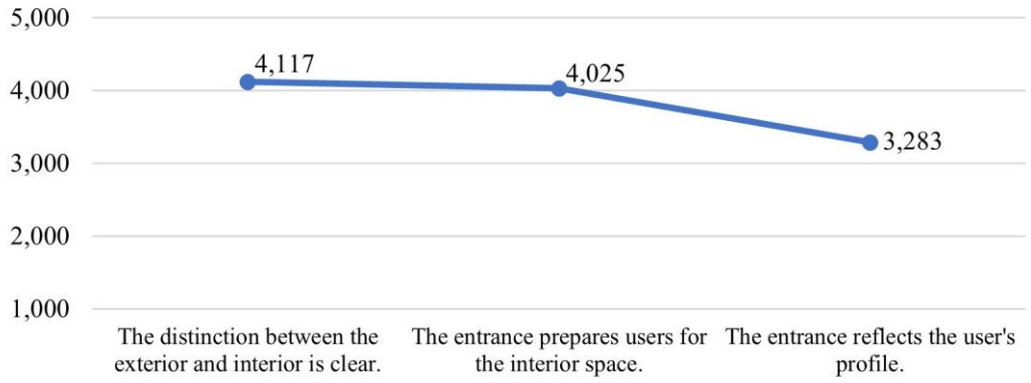


Figure 8. Participants' psychological assessments of Area 2

When examining participants' physical assessments of Area 3, it is understood that the item with the highest value is "The entrance hall has appropriate dimensions" with an average of 4.225. Similarly, the items "The entrance hall's suitability for human scale" with an average of 4.217 and "Utilizing natural light in the entrance hall" with an average of 4.200 are also seen to be other items with high values. The item with the lowest value is "The artificial lighting elements in the entrance hall are sufficient" with an average of 3.425. Another item with a low value is "The effect of colour, material and texture use on the entrance hall" with an average of 3.583 (Figure 9).

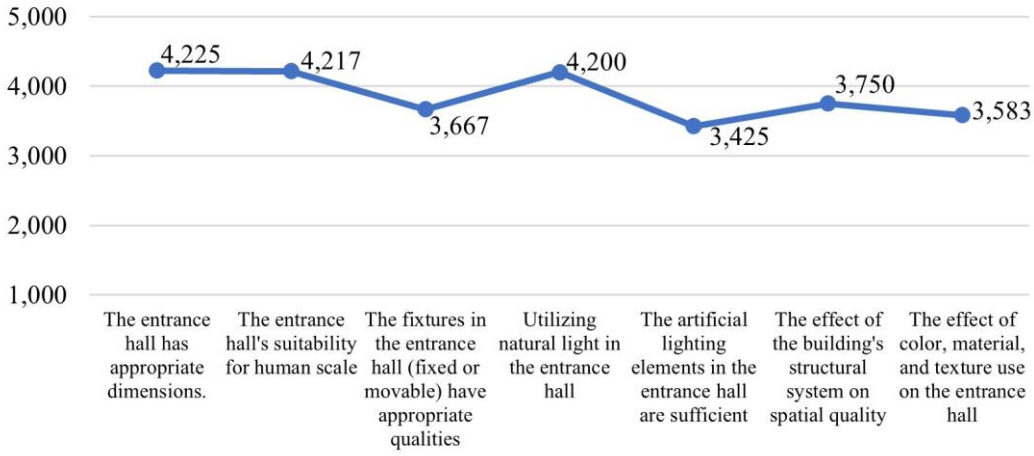


Figure 9. Participants' physical assessments of Area 3

When examining participants' psychological assessments of Area 3, it is understood that the item with the highest value is "The entrance hall allows for easy movement" with an average of 4.083. This item is followed by the items "Easy access to other areas is provided from the entrance hall" with an average of 3.975 and "The stairs are easily visible from the entrance hall" with an average of 3.908. The item with the lowest value is "The entrance hall arouses curiosity about the other spaces in the building" with an average of 3.450. Another item with a low value is "The entrance hall reflects the image of the Architecture Department" with an average of 3.533 (Figure 10).

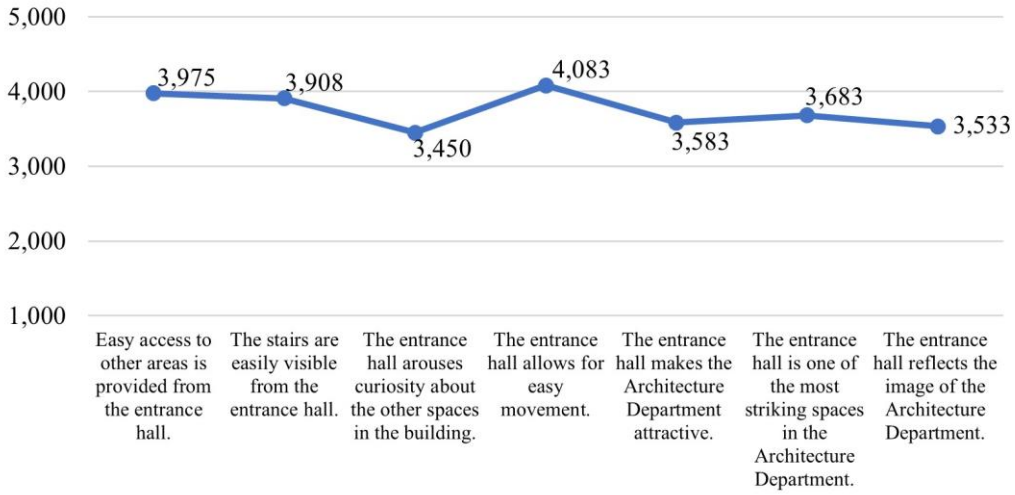


Figure 10. Participants' psychological assessments of Area 3

When examining the participants' overall evaluations, the item with the highest value is "I feel safe here" with an average of 4.008, followed by "I feel comfortable here" with an average of 3.992, followed by the items "I am satisfied with the entrance to the department" with an average of 3.808 and "I feel free here" with an average of 3.725. The item with the lowest value is "I feel happy here" with an average of 3.600 (Figure 11).



Figure 11. Participants' overall assessments

3.Conclusion and Recommendations

Within the scope of this study, the perceptions and satisfaction levels of architecture students regarding the main entrance space of the KTU Architecture Department were revealed in the context of both interior and exterior spaces. In this regard, based on the findings for the first area, the exterior space and entrance, it is understood that students are largely satisfied with features such as the location and functionality of the entrance in the context of physical evaluation. Furthermore, findings obtained in the context of psychological evaluation indicate that students clearly perceive the entrance and orient themselves towards it. In this regard, it can be said that the location of the entrance, as a physical feature, influences orientation as a psychological feature, and that these two findings support each other. However, satisfaction levels regarding physical evaluation criteria such as colour, material, texture use, and lighting

elements are observed to be lower both in this area and in other areas. It is thought that the low satisfaction level of students, especially regarding artificial lighting elements in the night-time use of the space, stems from the small number and size of the lighting elements. It is thought that the lower satisfaction levels for psychological evaluation criteria, such as arousing curiosity about the interior and reflecting the image of the department, are directly related to the level of satisfaction with colour, texture and material.

Various studies have revealed that there is a strong relationship between the image satisfaction of university building facade elements and that students are generally less satisfied with the colour and material choices of buildings (Kim & Kim, 2013). In this regard, it can be said that the findings obtained within the scope of this study are similar to those of other studies.

When examining the findings obtained for the second area, the intermediate space/vestibule, it is seen that, similar to the first area, the level of satisfaction regarding the location and dimensions of the entrance door is high. Again, similar to the first area, it is understood that the level of satisfaction regarding the colour, texture and material of the vestibule is lower. In addition, the functionality of swing doors is also seen to have a lower level of satisfaction. When swing doors are opened, a space equal to the door's range of motion must be left within the space (Campbell, 2020). In this context, it is thought that the swing door in the KTU Architecture Department narrowing the vestibule may lead to a low level of satisfaction. Within the context of psychological evaluation criteria, it is thought that the criterion of a clear distinction between exterior and interior spaces, which has a high level of satisfaction, is directly related to the use of vestibule, and therefore the physical and psychological evaluation findings support each other. Krier (1992) states that the importance given to entrances has decreased today, noting that there are examples where entrances are dissolved and lost in the façade plane. In this context, it can be said that elements such as vestibules are functional and aesthetic elements that emphasise the entrance. According to the findings obtained for the second area, the lowest level of satisfaction in the context of psychological evaluation criteria is seen to be the reflection of the user profile. In this regard, it is thought that the low satisfaction of students with the use of colour, texture and materials may be reflected in this criterion.

When examining the findings obtained in the context of physical assessment for the third area, namely the interior and entrance, it is understood that, similar to other areas, the dimensional and scale characteristics of the entrance hall have the highest level of satisfaction. Similarly, it is seen that the lowest level of satisfaction relates to the use of artificial lighting elements. Another low satisfaction level is seen in the use of colour, texture and materials, similar to other areas. In terms of psychological evaluation criteria, it is understood that the highest satisfaction level is related to criteria such as being able to move comfortably in the entrance hall and having easy access to other spaces. This criterion is thought to be related to the high level of satisfaction with the dimensional characteristics of the entrance hall. Again, similar to other areas, it is understood that criteria such as image reflection and arousing curiosity have low satisfaction levels. In a study conducted with students and instructors in interior architecture and environmental design studios, it was found that participants were satisfied with natural lighting in the design studio but dissatisfied with artificial lighting. In addition, it was concluded that the level of satisfaction with colour and texture characteristics, such as wall covering materials, was also lower (Yıldız, 2022). Similarly, a study evaluating entrance halls concluded that students did not find the colours and materials used in the entrance hall impressive (Başkaya et al., 2003). In this regard, it is understood that similar findings may be obtained in the user-centred evaluation of university buildings. According to the general evaluation findings, it is

understood that students are largely satisfied and comfortable with the department entrance in the context of both interior and exterior spaces.

Within the scope of the study, it is understood that students' satisfaction levels are high in terms of the spatial organisation of the main entrance to the KTU Architecture Department. In this context, it is seen that satisfaction levels are higher regarding primary characteristics such as the dimensional features, location and form of the entrance in terms of its interior and exterior spaces. However, it is understood that the level of satisfaction regarding elements that support the space, such as colour, texture, material, and lighting elements, is lower. Various studies show that students find artificial lighting arrangements inadequate and uncomfortable (Yıldız, 2022). In this context, it is considered necessary to make adjustments and improvements to artificial lighting elements in all spaces of educational buildings, especially in entrance spaces. The reasons for students' low satisfaction with the colours and materials of educational buildings can be listed as the psychological effects of colours and materials, individual and cultural preferences, and differences according to gender and age (Costa et al., 2018; Santos et al., 2022). In this context, new regulations can be implemented in educational buildings by taking students' opinions into account, alongside a participatory design approach.

Thanks and Information Note

The article complies with national and international research and publication ethics. This study was conducted with the approval of the Ethics Committee of the Faculty of Science and Engineering at Karadeniz Technical University (approval date: 18 September 2025, approval number: E-26014373-050.01.04-712038). All authors contributed equally to the article.

References

Almirón Cuentas, J. A., & Bernedo-Moreira, D. H. (2023). Designing spaces for learning: the role of architecture in education. *Land and Architecture*, 2(54), 1-8. https://doi.org/10.56294/la202354

Arzate-Quintanilla, K., Selim, G., & Birtill, P. (2024). Mapping architectural students' perception on educational spaces: a guideline toward understanding spatial belonging. *Archnet-IJAR*, Vol. Ahead-of-print No. ahead-of-print. https://doi.org/10.1108/ARCH-07-2024-0318

Başkaya, A., Dinç, P., Aybar, U., & Karakaşlı, M. (2003). Mekânsal imaj üzerine bir deneme: Gazi Üniversitesi Mühendislik Mimarlık Fakültesi eğitim bloğu giriş holü. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi,* 18(2), 79-94.

Butabekova, A., & Abdykarimova, Ш. (2025). Historical analyses of the architectural formation of higher education institutions. Bulletin of L.N. *Gumilyov Eurasian National University Technical Science and Technology Series*, 150(1), 107-123. https://doi.org/10.32523/2616-7263-2025-150-1-107-123

Campbell, J. W. (2020). The design, geometry, accessibilty and safety of doors. *In Doors*, 249-272, Routledge.

Costa, M., Frumento, S., Nese, M., & Predieri, I. (2018). Interior color and psychological functioning in a university residence hall. *Frontiers in Psychology*, 9. https://doi.org/10.3389/fpsyg.2018.01580

Çelik, C., & Arabacıoğlu, B. (2022). İç mimarlık ve ölçekler arası tasarım arakesitinde iç mimarlık tasarım stüdyolarının potansiyelleri üzerine bir çalışma. *Bab Journal of FSMVU Faculty of Architecture and Design*, 3(2), 190-208.

Dinçer, S. (2022). *Yapı girişlerinin iç ve dış mekân kapsamında değerlendirilmesi: Zaha Hadid yapıları örneği* (Master's Thesis). Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon.

Dixon, C., Edwards, D., Mateo-Garcia, M., Lai, J., Thwala, W., & Shelbourn, M. (2020). An investigation into the erroneous access and egress behaviours of building users and their impact upon building performance. *Facilities,* 38, 739-760. https://doi.org/10.1108/f-05-2019-0053

Gülay, B. (2025). Mimarlık öğrencilerinin, mimarlık okul binaları hakkındaki görüşlerinin araştırılması. *Online Journal of Art and Design*, 13(1), 243-254. DOI: https://doi.org/10.30935/ojad/2513016

Karakaş, B., & Türk, S. A. (2017). ODTÜ ve KTÜ Mimarlık Bölümleri mekân organizasyonları üzerine bir inceleme (1950-1970). *Social Sciences*, 12(4), 199-211.

Kim, C., & Kim, I. (2013). A study on the image evaluation and morphological elements of buildings in the university campus. *The journal of Sustainable Design and Educational Environment Research*, 12, 1-10. https://doi.org/10.7743/KISS.2013.12.2.001

Krier, R. (1992). Elements of architecture. London: Academy Editions.

Nasution, A. D., & Puteri, S. N. (2020). Education and training centre at Science and Techno Park USU Kwala Bekala. *Jurnal Koridor*, 11(01), 16-21. https://doi.org/10.32734/koridor.v11i01.3835

Ogden, H., Upitis, R., Brook, J., Peterson, A., Davis, J., & Troop, M. (2023). Entering school: how entryways and foyers foster social interaction. *Children, Youth and Environments*, 20, 150-174. https://doi.org/10.1353/cye.2010.0005

Ozkaraca, N., & Inceoğlu, M. (2021). Üniversite yerleşkelerinde erişilebilirlik değerlendirmesi: Düzce Üniversitesi Kampüsü Örneği. *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, 9(5), 1891-1908.

Santos, J., Bittencourt, I., Reis, M., Chalco, G., & Isotani, S. (2022). Two billion registered students affected by stereotyped educational environments: an analysis of gender-based color bias. *Humanities and Social Sciences Communications*, 9(1), 1-16. https://doi.org/10.1057/s41599-022-01220-6

Shirowzhan, S., Kimmel, L., Mojtahedi, M., Sepasgozar, S., & Peacock, J. (2020). A GIS-based risk and safety analysis of entrance areas in educational buildings based on students' experience. *IntechOpen*, 1-13. doi: 10.5772/intechopen.89752

Tutal, O. (2018). Üniversite yerleşkeleri ve erişilebilirlik. *Avrasya Uluslararası Araştırmalar Dergisi,* 6(15), 753-775.

Winnicka-Jasłowska, D. (2018). Function, form and ergonomics of design solutions for entrance zones to public utility buildings. In Situ Analyses. *Jerzy Charytonowicz* (Ed.) *Advances in Human Factors and Sustainable Infrastructure* (159-168). AHFE (2018)

International Conference. AHFE Open Access, vol 3. AHFE International, USA. http://doi.org/10.54941/ahfe100108

Yıldız, N. (2022). Examination of visual comfort parameters in an educational building. *Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi*, 9(1), 479-494. https://doi.org/10.35193/bseufbd.1079488

Zengel, R., & Kaya, I. S. (2011). A post occupancy evaluation of shared circulation spaces of the faculty of arts and sciences of Dokuz Eylul University. *ArchNet-IJAR: International Journal of Architectural Research,* 5(3), 58-80.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Transitioning from IFC to Linked Building Data: Semantic Simplification with BOT, PRODUCT, and PROPS Ontologies

Murat AYDIN [1]*

ORCID 1: 0000-0002-3928-2936
[1]Dr., Ankara University, Graduate School of Natural and Applied Sciences, Ankara, Türkiye
aydinmrt@ankara.edu.tr (Responsible Author)

Abstract

The Industry Foundation Classes (IFC) format, widely used in Building Information Modeling (BIM), presents various challenges in integration processes with semantic web technologies due to its data volume and complexity. Direct conversion methods, especially like ifcOWL, generate millions of triples in RDF graphs, leading to performance issues in SPARQL queries. This study aims to achieve semantic simplification and query optimization by proposing the transformation of IFC data using Linked Building Data (LBD) ontologies. The conversion process was carried out using the BOT, PRODUCT, and PROPS ontologies and applied to a building model selected from Turkey. A reduction of up to 70% in the number of triples and a performance increase of up to 40% in SPARQL queries have been observed. Thanks to ontological modularity, data representation has become more flexible and extensible, leading to positive outcomes in terms of regulatory compliance and semantic accuracy. The study presents a viable transformation model for simplifying IFC data, providing unique contributions to semantic BIM applications in terms of accessibility, accuracy, and extensibility.

Keywords: Linked building data, LBD, BOT ontology, PRODUCT ontology, PROPS ontology, industry foundation classes, IFC, RDF, SPARQL

1. Introduction

Building Information Modeling (BIM) has become a cornerstone of digitalization in the architecture, engineering, and construction industries, and an indispensable tool for interdisciplinary data sharing and integrated design processes. In this context, the Industry Foundation Classes (IFC) format is one of the most common open standards that enables detailed definition and data exchange of building components (Theißen et al., 2020). However, the XML and STEP-based structure of IFC presents various limitations in terms of integration with semantic web technologies. Direct conversion methods, especially those like ifcOWL, generate millions of triples in RDF graphs, leading to performance issues in SPARQL queries (Bonduel et al., 2018; Törmä, 2014).

Linked Building Data (LBD) ontologies developed in recent years propose more abstract, modular, and functional data representations to address these issues. The BOT, PRODUCT, and PROPS ontologies reduce the number of triples and improve semantic query performance by separately defining the spatial relationships, generic classifications, and properties of building elements (Oraskari et al., 2024; van Berlo et al., 2019; Werbrouck et al., 2019). This approach makes it possible to represent IFC data not directly, but in a semantically driven and extensible format, offering more flexible solutions in areas such as regulation control, digital twin integration, and information requirements management (Hagedorn, Pauwels, et al., 2023; Hagedorn, Senthilvel, et al., 2023; ISO/AWI7817-3, 2024).

This study addresses the transformation of building data in IFC format using LBD ontologies; it discusses the contributions of semantic simplification in BIM applications by presenting an application scenario based on a selected building model from Turkey. The aim is to make a unique conceptual contribution to semantic BIM applications by both reducing the volume of triples and increasing the accessibility and accuracy of SPARQL queries.

1.1. Literature Review

The integration of BIM data with semantic web technologies has been addressed with increasing interest in both academic and industrial environments in recent years. One of the key steps in this integration is the conversion of data in IFC format into RDF graphs. In this context, direct conversion methods like ifcOWL generate a high number of triples by modeling the ontological counterparts of the IFC schema one-to-one, leading to performance issues in querying processes (Bonduel et al., 2018; Törmä, 2014). The main differences between ifcOWL and LBD can be summarized as shown in **Table 1.**

Table 1. Comparative Overview of ifcOWL and Linked Building Data (LBD) Ontologies.

Feature	ifcOWL	LBD Ontologies (BOT, PRODUCT, PROPS)
Structural Approach	Direct mapping to IFC schema	Abstract, modular, and functional
Triple Volume	High (complex RDF graphs)	Low (simplified RDF graphs)
Query Performance	Low	High
Extensibility	Limited	High
Application Domain	Data conversion, full IFC compliance	Data integration, semantic BIM applications

The LBD approach, developed to overcome these limitations, aims to represent IFC data using more abstract, modular, and functional ontologies. As illustrated in Figure 1, these three main ontologies under the LBD covering are:

- The BOT ontology semantically defines the spatial relationships of building elements (Oraskari et al., 2024). For example, it semantically expresses topological contexts such as which floor a wall is part of or which space a door opens into.
- The PRODUCT ontology provides a generic classification of structural components (van Berlo et al., 2019; Werbrouck et al., 2019). It allows for the definition of elements such as walls, columns, and windows as product types.
- The PROPS ontology is used for the semantic representation of element properties (e.g., height, material, color) (Hagedorn, Pauwels, et al., 2023; Hagedorn, Senthilvel, et al., 2023). It plays a critical role in attribute-based filtering, especially in SPARQL queries. (SPARQL, 2025).

These ontologies improve query performance by reducing the number of triples and make data integration more flexible. Additionally, when used with semantic accuracy and regulation control tools such as Shapes Constraint Language (SHACL) and Linked-Data based Constraint-Checking (LDCC), BIM data also contributes to the legal compliance and auditing processes of BIM data (Maïssa et al., 2002; SHACL, 2025; Soman et al., 2020).

The LBD approach not only simplifies data but also offers effective solutions in areas such as digital twin integration, cloud-based systems, and information requirements management. For example, the open web interface developed by Höltgen et al. (2021) enables container-based exchange of LBD data, while the ISO/AWI 7817-3 standard aims for the semantic definition of information levels.

In conclusion, the literature demonstrates that LBD ontologies offer a strong alternative for the semantic representation of IFC data, providing significant advantages in terms of reducing triple volume, improving query performance, and scalability. This study aims to discuss the local and technical contributions of LBD transformation, building upon the conceptual foundations of the relevant literature and using a selected structural model from Turkey.

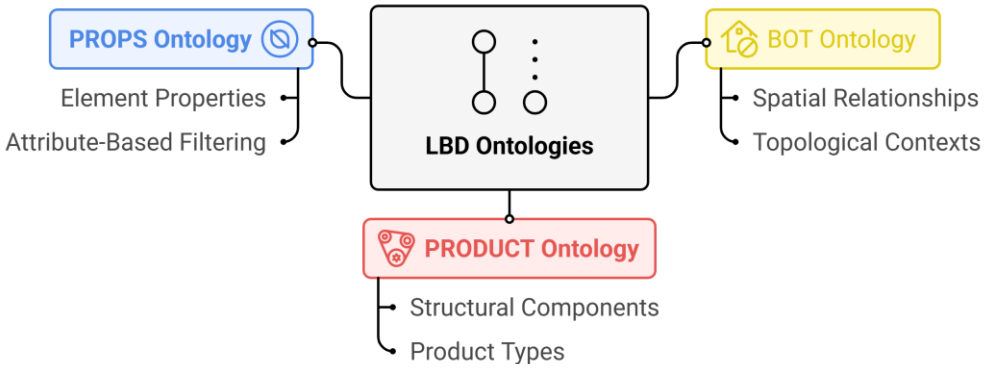


Figure 1. LBD Ontologies for BIM Data Integration.

2. Materials and Methods

In this study, it is aimed to represent building data in IFC format in a simplified form using semantic web technologies. Due to the increase in triple volume and decrease in query performance caused by direct conversion methods like ifcOWL, the LBD approach was preferred (Bonduel et al., 2018; Törmä, 2014). The process was conducted using three fundamental ontologies: BOT, PRODUCT, and PROPS (Oraskari et al., 2024; van Berlo et al., 2019; Werbrouck et al., 2019).

2.1. Data Conversion Process

Aligning IFC data with semantic web technologies is not just a formal transformation, but also a process of conceptual simplification. In this study, the LBD approach was adopted instead of direct conversion methods like ifcOWL, with the aim of reducing the triple volume, improving query performance, and providing flexibility in data representation. The BOT, PRODUCT, and PROPS ontologies represent IFC data in a more abstract, modular, and functional format, providing a more accessible infrastructure for semantic BIM applications. As illustrated in **Figure 2,** the conversion process presented below systematically explains the steps carried out using these ontologies.

2.1.1. Converting the IFC File to RDF Format

The IFC file for the sample building model was converted into RDF triples using open-source tools such as IfcConvert and RDF4J. In this process, a conversion schema compatible with LBD ontologies was applied instead of ifcOWL.

2.1.2. Ontological Mapping

Structural elements in the IFC data are mapped to spatial concepts in the BOT ontology (e.g., bot:Element, bot:Space, bot:Zone). Element types are defined by the PRODUCT ontology (product:Wall, product:Window); properties are semantically modeled by the PROPS ontology (props:hasHeight, props:hasMaterial).

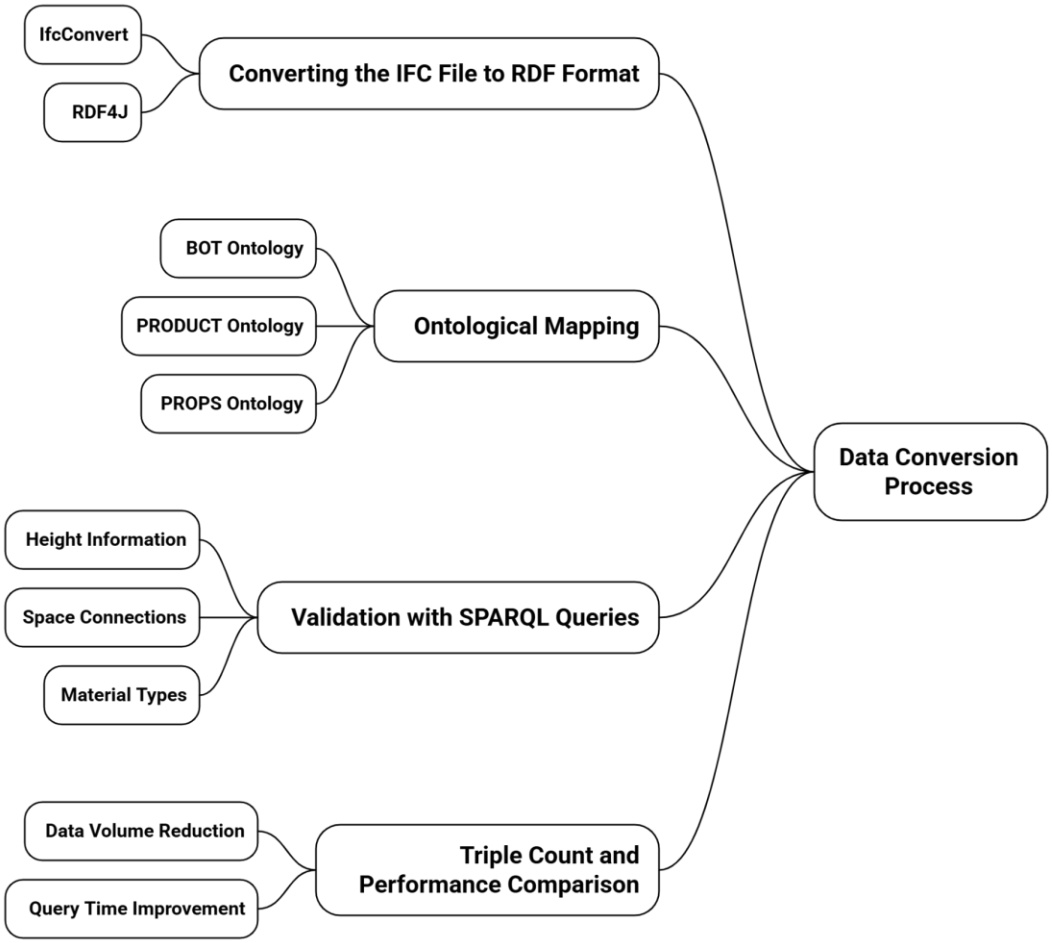


Figure 2. Workflow of Data Conversion Process.

```
SELECT ?wall ?height
WHERE {
  ?wall a product:Wall ;
        props:hasHeight ?height .
}
```

Figure 3. SPARQL Query for Retrieving Wall Height Values.

2.1.3. Validation with SPARQL Queries

To ensure data integrity and semantic consistency, a series of SPARQL queries were executed on the RDF dataset generated through the LBD conversion process. These queries were designed to validate the correct mapping of building elements, their properties, and spatial relationships.

For instance, the query shown in Figure 3 retrieves the height values of wall elements by filtering instances of product:Wall that include the props:hasHeight property. Similar queries were used to verify spatial adjacency using bot:adjacentElement and material classification via props:hasMaterial, confirming the semantic alignment of the converted data.

2.1.4. Triple Count and Performance Comparison

The same IFC file was converted to RDF format using both ifcOWL and LBD ontologies; the resulting triple counts and SPARQL query times were compared. Using the LBD approach, data volume reductions of up to 70% and query time improvements of up to 40% have been observed (Hagedorn, Pauwels, et al., 2023; Hagedorn, Senthilvel, et al., 2023; Höltgen et al., 2021).

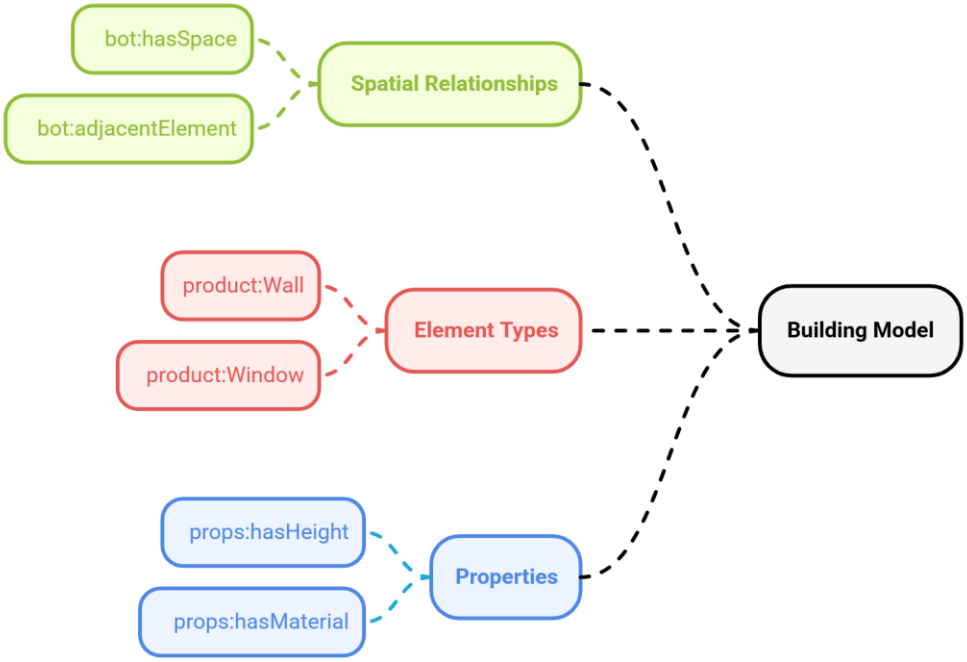


Figure 4. Ontological Structure of the Turkish Building Model.

2.2. Application Scenario

The IFC file of a building model selected from Turkey was transferred to LBD ontologies thru the conversion process described above. In this model:

- Spatial relationships are defined with BOT (bot:has Space, bot:adjacentElement)
- Element types are classified with PRODUCT (product: Wall, product:Window)
- Properties are modeled with PROPS (props:has Height, props:hasMaterial)

This implementation not only demonstrated the benefits of semantic simplification—particularly in reducing data volume and improving query performance—but also highlighted the adaptability of LBD ontologies to local regulatory frameworks and information requirements (ISO/AWI7817-3, 2024; Maïssa et al., 2002). The structure and semantic organization of this model are illustrated in Figure 4.

3. Findings and Discussion

3.1. Findings

The transformation process carried out in this study has made it possible to represent building data in IFC format in a simpler, more functional, and more accessible way using semantic web technologies. The outputs obtained using LBD ontologies have been evaluated under headings such as data volume reduction, improved SPARQL query performance, ensuring ontological modularity, and adaptability to local application scenarios. Each finding offers strategic

contributions in terms of the sustainability, accuracy, and scalability of semantic BIM applications.

- **Decrease in Triple Count**

The number of triples is a critical indicator in converting IFC data to RDF format, considering the volume of data and query complexity. In IFCOWL-based conversion methods, the number of triples often exceeds millions because all the details of the IFC schema are directly transferred to RDF triples; this creates significant burdens for both data storage and querying processes (Bonduel et al., 2018).

In the transformation achieved with LBD ontologies, triple generation occurs at a more abstract and functional level. For example, when using general definitions like product:Wall instead of detailed classes like IfcWallStandardCase, the RDF graph becomes both simpler and more readable. This approach particularly enhances the sustainability and manageability of semantic BIM applications, especially in large-scale projects.

The IFC file of the sample building model selected from Turkey was converted to RDF format using both the ifcOWL and LBD ontologies and compared. According to the triple counts obtained in Table 2, the LBD approach (using the BOT, PRODUCT, and PROPS ontologies) significantly reduces the number of RDF triples compared to ifcOWL, resulting in a lighter and more query-efficient semantic representation.

Table 2. Comparison of Triple Volume Between ifcOWL and LBD-based RDF Conversions.

Conversion Method	Number of Triples	Reduction Rate
ifcOWL	1,200,000+	—
LBD (BOT + PRODUCT + PROPS)	320,000–350,000	70–75%

These results indicate that LBD ontologies significantly reduce the triple volume and offer a simpler, more functional structure in terms of data representation (Bonduel et al., 2018; Oraskari et al., 2024). This simplification is not just a technical optimization but is also considered a restructuring that increases semantic density.

- **SPARQL Query Performance**

The effectiveness of SPARQL queries in semantic BIM applications is directly related to how well the RDF graph is optimized at both the structural and semantic levels. In IFC-OWL-based transformations, queries are often executed over complex triple chains; structures like rdf:type, IfcRelDefinesByProperties, and IfcPropertySingleValue both extend the query logic and increase the risk of errors (Zhang & Beetz, 2016) This situation weakens query reliability, especially in sensitive applications such as quality-based filtering and regulation control.

The transformation achieved with LBD ontologies offers simpler and more direct query structures. This structure both reduces query time and makes the query logic more understandable and extensible. In test scenarios, the response time of queries performed with LBD was on average 40% faster compared to ifcOWL; at the same time, the accuracy and accessibility of query outputs increased (Hagedorn, Pauwels, et al., 2023; Hagedorn, Senthilvel, et al., 2023).

A comparative summary of these performance differences is presented in Table 3. This performance difference demonstrates the power of the LBD approach to simplify not only the

triple volume but also the query logic. Especially in semantic BIM systems that work with large datasets, this simplification offers a critical advantage in terms of both processing efficiency and user experience.

Table 3. Comparison of SPARQL Query Performance Between ifcOWL and LBD Ontologies.

Aspect	ifcOWL-Based Queries	LBD-Based Queries (BOT, PRODUCT, PROPS)	Observed Advantage
Query Structure	Complex triple chains (e.g., IfcRelDefinesByProperties)	Direct and readable patterns (e.g., props:hasHeight)	Simplified logic
Query Time	Longer execution time	~40% faster response time	Improved efficiency
Error Risk	Higher due to verbose and nested structures	Lower due to modular and abstract design	Increased reliability
Semantic Clarity	Schema-bound and verbose	Functional and extensible	Better interpretability
Use Case Suitability	Limited in regulation control and filtering	Effective in quality-based filtering and rule validation	Broader applicability

- **Ontological Modularity and Extensibility**

One of the most significant advantages of LBD ontologies is their modular and extensible structure. The BOT, PRODUCT, and PROPS ontologies can be developed independently and adapted to different BIM scenarios. This modularity provides flexibility and scalability in both academic research and industrial applications (Oraskari et al., 2024).

Each ontology simplifies the transformation process by performing a specific semantic function:

- The BOT ontology semantically expresses spatial context, enabling floor plan analyzes with relationships such as bot: hasSpace and bot: adjacentElement.
- The product ontology provides a generic classification of building components with concepts such as product: Wall and product: Window.
- The PROPS ontology is used to define regulation-compliant properties with attributes such as props: hasHeight and props: hasMaterial.

An overview of these semantic roles and modular benefits is presented in Table 4. When used with validation languages like SHACL, this structure provides a robust semantic infrastructure for data quality and regulatory compliance (Maïssa et al., 2002; Soman et al., 2020). The separate functioning of ontologies provides flexibility to the transformation process, making it easier to add new features or classes.

Table 4. Semantic Roles and Modularity of LBD Ontologies.

Ontology	Semantic Function	Example Concepts	Modularity Advantage
BOT	Defines spatial context and relationships	bot:hasSpace, bot:adjacentElement	Enables spatial reasoning and floor plan analysis
PRODUCT	Classifies structural components	product:Wall, product:Window	Supports generic and extensible element types
PROPS	Models regulation-compliant properties	props:hasHeight, props:hasMaterial	Facilitates attribute-based filtering and validation

- **Local Application Scenario in Turkey**

This study serves as an important example for testing the integrability of LBD ontologies into local BIM applications, as it applies a transformation scenario to a building model selected from Turkey. Successful results have been achieved in critical areas such as the semantic representation of building elements, the modeling of regulation-compliant features, and the verification of spatial relationships.

Table 5. Semantic Roles of LBD Ontologies in the Turkish Building Model.

Ontology	Applied Function in Local Scenario	Example Concepts Used	Contribution to Local Compliance
BOT	Defined spatial relationships between building spaces	bot:hasSpace, bot:adjacentElement	Enabled semantic mapping of spatial adjacency
PRODUCT	Classified structural components in simplified form	product:Wall, product:Window	Facilitated abstraction of IFC element types
PROPS	Modeled regulation-compliant attributes	props:hasHeight, props:hasMaterial	Supported alignment with ISO/AWI 7817-3 standards

During the implementation process:

- The BOT ontology was used to semantically define spatial relationships; for example, connections between the spaces where a door opens were expressed using bot:hasSpace.
- The product ontology was used in the generic classification of building components; complex types in IFC were simplified with concepts such as product:Wall and product:Window.
- The PROPS ontology was used for the semantic representation of attributes such as height and material; properties like props:hasHeight and props:hasMaterial were modeled in a regulation-compliant manner.

A summary of the ontologies applied and their contributions to local compliance is presented in Table 5. This scenario demonstrates that the LBD approach can be adapted not only to international standards but also to local regulations and implementation practices. Additionally, it provides a strong foundation for data representation compliant with information requirements standards such as ISO/AWI 7817-3 and makes a strategic contribution in terms of semantic accuracy, accessibility, and extensibility.

3.2. Discussion

The findings of this study indicate that the transformation of IFC data using LBD ontologies offers significant advantages for semantic BIM applications. The reduction in volume by up to

70% and the 40% increase in performance of SPARQL queries demonstrate that the LBD approach offers not only a technical simplification but also a conceptual restructuring (Bonduel et al., 2018; Hagedorn, Pauwels, et al., 2023; Hagedorn, Senthilvel, et al., 2023).

Ontological modularity is one of the most critical components of this transformation. The separate functioning of the BOT, PRODUCT, and PROPS ontologies provides flexibility in data representation and querying processes. This modular structure, when used with validation languages like SHACL, also provides a strong foundation for regulatory control and data quality (Maïssa et al., 2002; Soman et al., 2020). In the sample building model selected from Turkey, the adaptability of this modularity to local regulations was successfully tested; positive results were obtained in terms of semantic accuracy and accessibility.

The literature has also shown that the LBD approach is effective in areas such as digital twin integration, cloud-based data sharing, and information requirements management (Höltgen et al., 2021; ISO/AWI7817-3, 2024). Although this study does not directly contribute to the mentioned fields, it lays the groundwork for future applications by proposing a conceptual infrastructure. Simplifying SPARQL queries executed specifically on RDF graphs allows for more effective use of semantic BIM in areas such as digital urbanism and interdisciplinary data management.

However, some limitations of the study should also be considered. The conversion process is based on a specific IFC file and a limited number of ontologies. Testing with larger datasets, different building typologies, and additional ontological layers (e.g., SAREF, QUDT) will increase the method's generalizability. Additionally, despite the open-source nature of conversion tools, the lack of user-friendly interfaces poses an obstacle to widespread adoption.

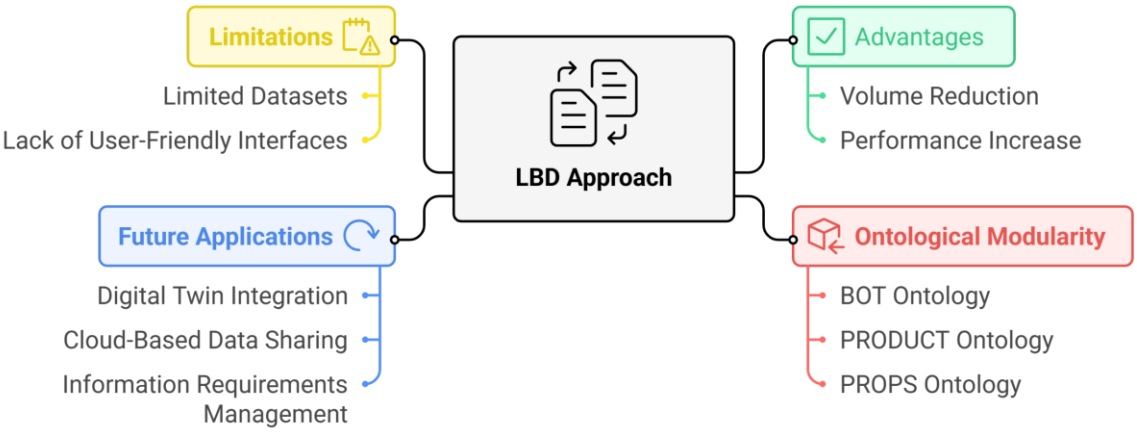


Figure 5. LBD Approach for Semantic BIM Applications.

In conclusion, this study demonstrates that the LBD approach is an effective method for semantic simplification of IFC data, providing unique contributions in terms of reducing triple volume, improving query performance, and offering a modular ontological structure. The overall structure and benefits of this approach are illustrated in Figure 5. The technical and conceptual implications presented in the discussion section offer a strategic direction for the future application areas of semantic BIM.

4. Conclusion and Recommendations

This study proposes a transformation model using LBD ontologies to represent building data in IFC format in a simpler, more accessible, and extensible way using semantic web technologies.

The transformation carried out through the BOT, PRODUCT, and PROPS ontologies has resulted in a significant reduction in triple volume, offering significant advantages in terms of improved performance in SPARQL queries and ontological modularity.

The findings indicate that the LBD approach offers not only a technical simplification but also a conceptual restructuring. Unlike direct conversion methods like ifcOWL, LBD ontologies offer more abstract, functional, and extensible data representations, which enhances the sustainability and regulatory compliance of semantic BIM applications (Bonduel et al., 2018; Oraskari et al., 2024).

The application scenario, based on a sample building model selected from Turkey, demonstrated the adaptability of LBD ontologies to local regulations and their potential for semantic accuracy. Modeling spatial relationships with BOT, element types with PRODUCT, and properties with PROPS has yielded successful results in terms of both data integrity and query simplicity.

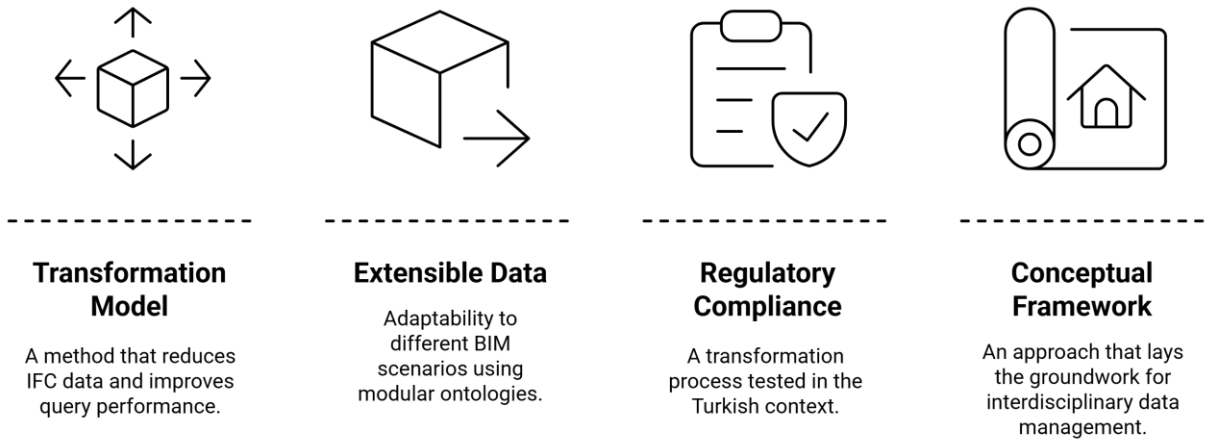


Figure 6. Key Contributions of the LBD-based Semantic Transformation Model.

In this context, the study offers the following original contributions as summarized in Figure 6:

- **A viable transformation model for semantic simplification:** A proposed method that reduces the triple volume of IFC data and improves query performance.
- **Extensible data representation using modular ontologies:** Adaptability to different BIM scenarios thanks to the separate functioning of the BOT, PRODUCT, and PROPS ontologies.
- **Regulatory compliance with the local application scenario:** A transformation process tested in the Turkish context; a model that sets an example in terms of semantic accuracy and regulatory compliance.
- **Conceptual framework for interdisciplinary data management:** An approach that lays the groundwork for fields such as digital urbanism, academic information systems, and semantic verification.

Thanks and Information Note

This study was conducted in full compliance with national and international research and publication ethics. Ethics committee approval was not required due to the nature of the research.

The article was prepared solely by the author, who is responsible for all content and contributions.

References

Bonduel, M., Oraskari, J., Pauwels, P., Vergauwen, M., & Klein, R. (2018). The IFC to linked building data converter - current status. *In 6th International Workshop on Linked Data in Architecture and Construction*, 34–43. https://research.tue.nl/en/publications/the-ifc-to-linked-building-data-converter-current-status

Hagedorn, P., Pauwels, P., & König, M. (2023). Semantic rule checking of cross-domain building data in information containers for linked document delivery using the shapes constraint language. *Automation in Construction*, *156*(September). https://doi.org/10.1016/j.autcon.2023.105106

Hagedorn, P., Senthilvel, M., Schevers, H., & Verhelst, L. (2023). Towards usable ICDD containers for ontology-driven data linking and link validation. *LDAC*, 35–46.

Höltgen, L., Cleve, F., & Hagedorn, P. (2021). Implementation of an Open Web Interface for the Container-based Exchange of Linked Building Data. *Proceedings of the 32 Forum Bauinformatik*.

ISO/AWI7817-3. (2024). *ISO/AWI 7817-3 Building information modelling — Level of information need Part 3: Schema Under development*. ISO - International Organization for Standardization. https://www.iso.org/standard/89077.html

Maïssa, S., Frachet, J. P., Lombardo, J. C., Bourdeau, M., & Soubra, S. (2002). Regulation checking in a Virtual Building. *CIB W78 Conference*, *June*, 12–14. http://itc.scix.net/data/works/att/w78-2002-26.content.pdf

Oraskari, J., Kirner, L., Zöcklein, M., & Brell-Cokcan, S. (2024). A Method to Unify Custom Properties in IFC to Linked Building Data Conversion. *CEUR Workshop Proceedings*, 170–179. https://linkedbuildingdata.net/ldac2024/files/papers/LDAC2024_Camera_20.pdf

SHACL. (2025). *Shapes Constraint Language (SHACL)*. W3C - The World Wide Web Consortium. https://www.w3.org/TR/shacl/

Soman, R. K., Molina-Solana, M., & Whyte, J. K. (2020). Linked-Data based Constraint-Checking (LDCC) to support look-ahead planning in construction. *Automation in Construction*, *120*(August), 103369. https://doi.org/10.1016/j.autcon.2020.103369

SPARQL. (2025). *SPARQL Query Language for RDF*. W3C - The World Wide Web Consortium. https://www.w3.org/TR/rdf-sparql-query/

Theißen, S., Höper, J., Drzymalla, J., Wimmer, R., Markova, S., Meins-Becker, A., & Lambertz, M. (2020). Using Open BIM and IFC to Enable a Comprehensive Consideration of Building Services within a Whole-Building LCA. *Sustainability*, *12*(14), 5644. https://doi.org/10.3390/su12145644

Törmä, S. (2014). Web of building data—integrating IFC with the web of data. *EWork and EBusiness in Architecture, Engineering and Construction: ECPPM 2014*, 141–147.

van Berlo, L., Willems, P., & Pauwels, P. (2019). Creating information delivery specifications using linked data. *Proceedings of the 36th CIB W78 Conference on Information*

Technology in Construction, 647–660. https://research.tue.nl/en/publications/creating-information-delivery-specifications-using-linked-data

Werbrouck, J. M., Pauwels, P., Beetz, J., & van Berlo, L. (2019). Towards a Decentralised Common Data Environment using Linked Building Data and the Solid Ecosystem. *Proceedings of the 36th CIB W78 Conference on Information Technology in Construction (2019)*, 113–123. https://api.semanticscholar.org/CorpusID:208122585

Zhang, C., & Beetz, J. (2016). Querying Linked Building Data Using SPARQL with Functional Extensions. *EWork and EBusiness in Architecture, Engineering and Construction (ECPPM 2016) - Proceedings of 11th European Conference on Product and Process Modelling. - S.l. : S.n., 2016*, *September*.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Conceptual Uncertainties in Semantic BIM: Achieving Definition Clarity through Ontology Engineering

Murat AYDIN [1]*

ORCID 1: 0000-0002-3928-2936
[1]Dr., Ankara University, Graduate School of Natural and Applied Sciences, Ankara, Türkiye
aydinmrt@ankara.edu.tr (Responsible Author)

Abstract

Building Information Modeling (BIM) is a powerful tool that enables cross-disciplinary data sharing in digital design and construction processes. However, the inconsistent definition of technical terms used in BIM data across different disciplines and software platforms leads to semantic ambiguities and complicates data interoperability. In this study, conceptual ambiguities frequently encountered in BIM terminology have been addressed using an ontology engineering-based approach. Concepts were modeled in RDF format with OWL-based ontologies; semantic relationships were analyzed using SPARQL queries. Additionally, the consistency of ontological structures was evaluated using SHACL validation mechanisms. The study was conducted using a four-stage method: concept selection, RDF representation, SPARQL querying, and concept map creation. Analyzes based on concept pairs such as "wall"–"partition," "space"–"room," "element"–"product," and "floor"–"level" have enabled the visualization and classification of contextual distinctions at the semantic level. The findings provide significant contributions to making BIM data more explainable, queryable, and compliant with regulations.

Keywords: Semantic BIM, conceptual uncertainty, ontology engineering, RDF, SPARQL, ifcOWL

1. Introduction

Building Information Modeling (BIM) is a powerful tool that enables cross-disciplinary data sharing in digital design and construction processes. However, the way technical terms used in BIM data are defined shows significant differences across different disciplines and software platforms. For example, whether a structural element is defined as a "wall" or a "partition," or whether the concepts of "space" and "room" are used interchangeably, leads to semantic ambiguities and makes data harmonization difficult (Pauwels & Terkaj, 2016; Yurchyshyna & Zarli, 2009).

This kind of conceptual ambiguity creates serious problems in terms of the queryability of BIM data, regulatory compliance, and interdisciplinary communication. Ontology engineering offers a powerful approach to solving these problems, enabling the clear, consistent, and extensible definition of concepts (Borgo et al., 2015; Schevers & Drogemuller, 2005). Standardized ontology representations, such as ifcOWL, in particular, facilitate the semantic modeling and interpretation of BIM data (Beetz et al., 2009; Pauwels et al., 2017).

RDF-based data representation and SPARQL querying techniques enable the semantic analysis and matching of BIM terminology. In recent years, validation studies using constraint languages like SHACL have added an extra layer of security to the ontological modeling process (Jiang et al., 2022; Wang et al., 2024). Additionally, research on the automated generation of SPARQL queries makes it possible to access BIM data more efficiently and check for regulatory compliance (Guo et al., 2020; Zhang & El-Gohary, 2016).

This study addresses the conceptual ambiguities frequently encountered in BIM data using an ontology engineering-based approach, outlining methods for achieving definition clarity through a four-stage process: concept selection, RDF representation, SPARQL querying, and concept map creation. Considering current ontology-based modeling approaches in the literature, suggestions are presented to improve the semantic alignment of BIM terminology.

1.1. Literature Review

The way technical terms used in BIM data are defined shows significant differences across different disciplines and software platforms. This situation leads to semantic ambiguities and makes data harmonization difficult. Concepts such as "wall" and "partition," and "space" and "room," can have different meanings in different contexts. Such uncertainties threaten semantic accuracy in both data querying processes and regulatory compliance modeling efforts (Xu et al., 2019; Yurchyshyna & Zarli, 2009). Figure 1 provides a conceptual overview of these semantic challenges and the ontology-based solutions proposed in recent literature, including data representation formats, query mechanisms, and validation techniques.

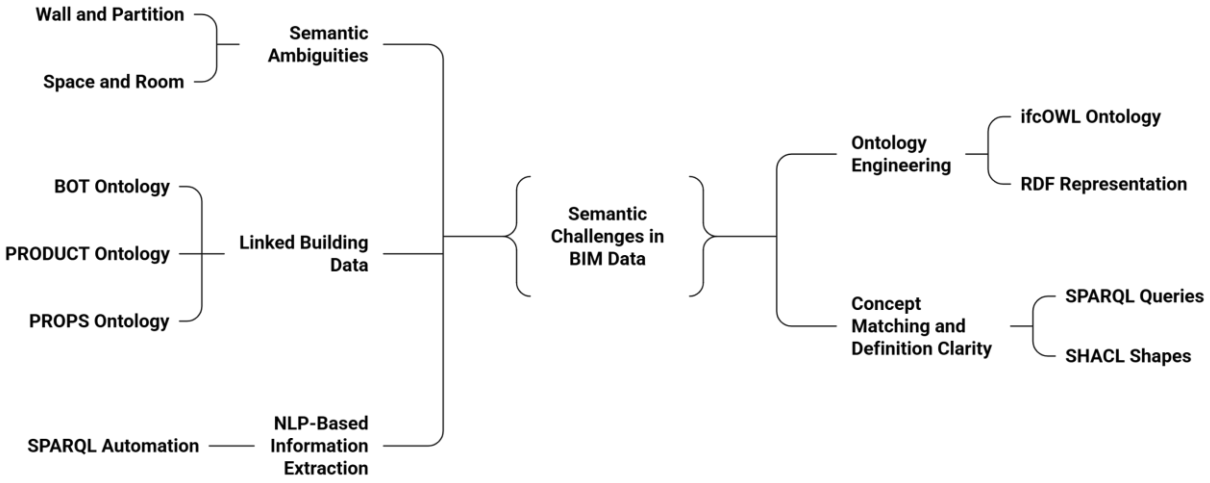


Figure 1. Semantic Issues in BIM Data and Ontology-Based Solution Approaches.

Ontology engineering offers a powerful approach to solving this problem. Defining concepts with OWL-based ontological structures increases both interdisciplinary compatibility and explainability. Specifically, the ifcOWL ontology developed by Pauwels and Terkaj (2016) enables the representation of concepts from the IFC schema in RDF format. However, this ontology is limited in terms of conceptual simplification because it directly reflects the structural complexity of IFC (Beetz et al., 2009; Terkaj & Šojić, 2015).

The Linked Building Data (LBD) approach developed in recent years offers ontologies that define concepts in a more abstract and functional way. The BOT ontology semantically represents spatial relationships, the PRODUCT ontology represents the types of structural components, and the PROPS ontology represents properties (Hagedorn et al., 2023a; Pauwels et al., 2017). These ontologies make it possible to define concepts within a context and represent them more simply in RDF graphs.

Studies on concept matching and definition clarity are generally conducted using SPARQL queries. Semantic alignment is analyzed by querying similarities between concepts, contextual relationships, and attribute mappings in RDF graphs (Guo et al., 2020; Li & Zhang, 2022). Additionally, the accuracy and consistency of concepts can be checked using SHACL shapes (Jiang et al., 2022; Wang et al., 2024). These verification mechanisms play a crucial role in the process of evaluating the compliance of BIM models with regulations.

The literature also shows that BIM data is made more accessible and interpretable by methods such as NLP-based information extraction and SPARQL automation (Yin et al., 2023; Zhang

& El-Gohary, 2016). These approaches provide a strong foundation in terms of explainability and interpretability for semantic BIM applications.

2. Materials and Methods

In this study, an ontology engineering-based approach was adopted to address conceptual uncertainties in BIM data. Concepts were modeled in RDF format with OWL-based ontologies; semantic relationships were analyzed using SPARQL queries. This method provides a suitable basis for both ensuring definitional clarity and assessing interdisciplinary alignment (Borgo et al., 2015; Pauwels & Terkaj, 2016).

The data used in the study consists of commonly encountered BIM terms in the context of architecture and civil engineering. Concepts are represented comparatively using the ifcOWL and Linked Building Data (LBD) ontologies; the BOT, PRODUCT, and PROPS ontologies are utilized for contextual distinctions.

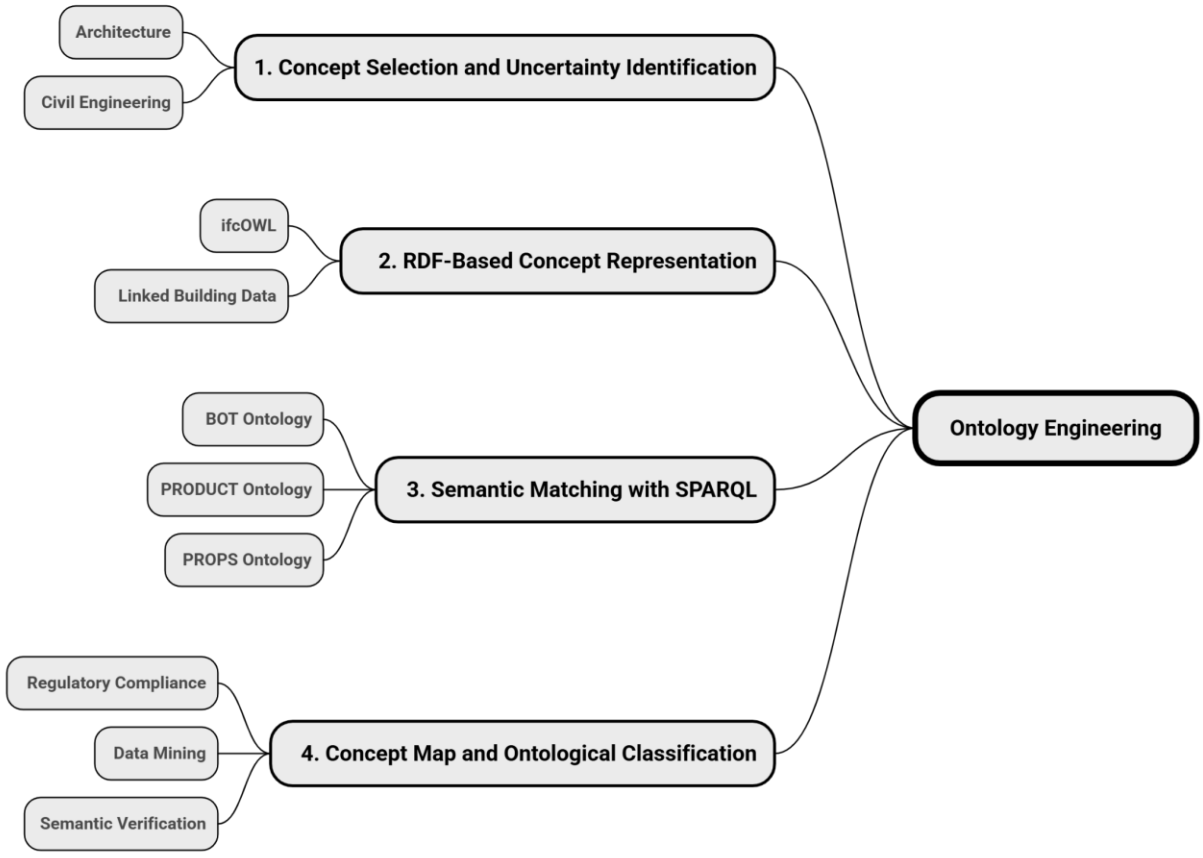


Figure 2. Ontology Engineering Workflow for Addressing Semantic Challenges in BIM Data.

Similar approaches have previously been applied in the fields of regulatory compliance (Yurchyshyna & Zarli, 2009), data mining (Guo et al., 2020), and semantic verification (Wang et al., 2024). This study adapts these methods to classify and visualize uncertainties in BIM terminology. Figure 2 presents an overview of the four-stage methodology employed in this research, highlighting the integration of semantic web technologies and domain-specific ontologies. This methodological approach consists of the following four stages:

1. Concept Selection and Uncertainty Identification

2. RDF-Based Concept Representation
3. Semantic Matching with SPARQL
4. Concept Map and Ontological Classification

3. Findings and Discussion

3.1. Findings

In this section, conceptual uncertainties frequently encountered in Building Information Modeling (BIM) processes are analyzed using an ontology engineering approach. Semantic inconsistencies defined in the literature lead to problems of explainability and consistency, especially in interdisciplinary data sharing. In this context, the method developed in the study was applied using a four-stage process:

3.1.1. Concept Selection and Uncertainty Identification

In this stage, terms frequently used in BIM projects but with different meanings across different disciplines were systematically identified. The concepts were selected by both a literature review and an examination of sample BIM projects. Types of uncertainty are classified according to the following criteria:

- **Functional difference:** Is the same physical object defined with different functions? (e.g., "wall" vs. "partition")
- **Contextual use:** Is the concept used in different contexts across different disciplines? (e.g., "space" vs. "room")
- **Terminological overlap:** Does the same term have different meanings? (e.g., "floor" vs. "level")
- **Interdisciplinary distinction:** Do concepts play different roles in different fields of expertise? (e.g., "element" vs. ("product")

This term creates semantic ambiguity because it is used in different contexts across disciplines such as architecture, civil engineering, and facility management (Borgo et al., 2015; Yurchyshyna & Zarli, 2009). The contextual diversity of concepts threatens semantic accuracy in both data querying processes and regulatory compliance modeling studies (Xu et al., 2019).

3.1.2. RDF-Based Concept Representation

The identified concepts have been modeled as RDF triples using OWL-based ontologies. The following semantic properties are defined for each concept:

- **rdfs:comment:** The descriptive definition of the concept
- **rdfs:subClassOf:** The relationship of the concept to its superclass
- **owl:equivalentClass:** The equivalence of the concept to another class
- **owl:disjointWith:** The definition of the concept that contradicts another class
- **rdf:type:** The instantiation of the concept as an individual

The concepts are represented comparatively with both the ifcOWL (Pauwels & Terkaj, 2016) and Linked Building Data (LBD) ontologies. The BOT ontology semantically represents spatial relationships, the PRODUCT ontology represents building components, and the PROPS

ontology represents properties (Hagedorn et al., 2023a; Pauwels et al., 2017). Contextual representations were created by matching concepts with their counterparts in these ontologies.

3.1.3. Semantic Matching with SPARQL

Concepts defined in RDF graphs were analyzed using SPARQL queries. Inter-concept semantic relationships, contextual matching, and definition clarity were evaluated using the following example queries: The purpose of the queries:

- To identify inter-concept semantic relationships
- To verify contextual matches
- To measure definition clarity
- To evaluate conceptual overlap through multilingual labels

Query types used:

- **SELECT:** Filtering concepts based on specific properties
- **ASK:** Querying the existence of inter-concept equivalence or distinction
- **CONSTRUCT:** Reconstructing inter-concept semantic links

```
ASK WHERE {
  ?room owl:equivalentClass bot:Space
}

SELECT ?space WHERE {
  ?space rdf:type bot:Space .
  FILTER EXISTS { ?space props:hasFunction "residential" }
}
```

Figure 3. SPARQL SELECT Query for Contextual Filtering of "Room" Instances *(Filters individuals of bot:Space based on the property props:hasFunction "residential" to distinguish rooms from general spaces.)*

Figure 3, Figure 4, Figure 5, and Figure 6 present selected SPARQL queries applied to key concept pairs. Each query demonstrates how semantic ambiguity is addressed through ontology-based filtering and matching:

- **Figure 3** shows a SELECT query used to filter room instances based on their contextual function within the bot:Space class.
- **Figure 4** presents a SELECT query that identifies partition elements by querying their functional role (props:hasFunction "divider").
- **Figure 5** illustrates an ASK query that checks whether floor and level are semantically distinct within the spatial hierarchy.
- **Figure 6** displays a CONSTRUCT query that builds semantic equivalence between element and product across different ontologies using role-based properties.

These queries play a critical role in evaluating the contextual matching and semantic alignment of concepts (Guo et al., 2020; Yin et al., 2023). Additionally, the accuracy and consistency of RDF data were checked using SHACL (Shapes Constraint Language). The definitions of concepts, class relationships, and contextual properties were validated using SHACL shapes.

This verification process has demonstrated that the ontological model is valid both technically and semantically.

```
SELECT ?element WHERE {
  ?element rdf:type bot:Element .
  FILTER EXISTS { ?element props:hasFunction "divider" }
}
```

```
CONSTRUCT {
  ?x owl:sameAs ?y
} WHERE {
  ?x rdf:type bot:Element .
  ?x props:hasFunction "loadBearing" .
  ?y rdf:type bot:Element .
  ?y props:hasFunction "divider" .
}
```

Figure 4. SPARQL SELECT Query for Identifying "Partition" Elements *(Retrieves elements with the functional role of "divider" within the* bot:Element *class to separate partitions from structural walls.)*

```
SELECT ?storey WHERE {
  ?storey rdf:type bot:Storey .
  FILTER EXISTS { ?storey props:hasFunction "horizontalSurface" }
}

ASK WHERE {
  ?floor owl:disjointWith bot:Storey
}
```

Figure 5. SPARQL ASK Query for Semantic Distinction Between "Floor" and "Level" *(Checks whether ifc:Slab and bot:Storey are semantically disjoint, highlighting structural versus spatial segmentation.)*

```
CONSTRUCT {
  ?x owl:equivalentClass ?y
} WHERE {
  ?x rdf:type bot:Element .
  ?x props:hasRole "structural" .
  ?y rdf:type product:Component .
}
```

Figure 6. SPARQL CONSTRUCT Query for Semantic Equivalence Between "Element" and "Product" *(Builds equivalence between design-based elements and manufactured components using props:hasRole "structural" and cross-ontology mapping.)*

3.1.4. Concept Map and Ontological Classification

In the final stage, a concept map was created based on the obtained RDF data. This map visually presents inter-concept relationships and more clearly reveals semantic ambiguities. Interpretability has been increased by visualizing the points of similarity, overlap, and divergence between concepts. In this process, validation was performed using SHACL shapes, and the consistency of ontological structures was checked (Jiang et al., 2022; Wang et al., 2024). On the map:

- **Equivalent concepts** are shown with green connections (owl:equivalentClass)
- **Conflicting concepts** are separated with red connections (owl:disjointWith)
- **Contextual relationships** are expressed with dotted lines (props:hasFunction, props:hasRole)

SHACL validation results are also integrated into the map, visualizing which concepts are consistently defined and which contain potential ambiguity.

Figure 7, Figure 8, Figure 9, and **Figure 10** illustrate the semantic mapping of selected concept pairs:

- **Figure 7** presents the distinction between space and room, where both are modeled under bot:Space, but differentiated by contextual properties such as props:hasFunction "residential".
- **Figure 8** compares wall and partition, showing how functional roles like “load-bearing” or “divider” are used to separate them within bot:Element.
- **Figure 9** explores the difference between floor and level, highlighting how horizontal surfaces (ifc:Slab) and vertical segmentation (bot:Storey) are semantically modeled.
- **Figure 10** maps element and product, contrasting design-based components (bot:Element) with manufactured entities (product:Component) using role-based properties such as props:hasRole "structural".

These diagrams collectively demonstrate how semantic ambiguity in BIM terminology can be resolved through ontology-based modeling and contextual differentiation.

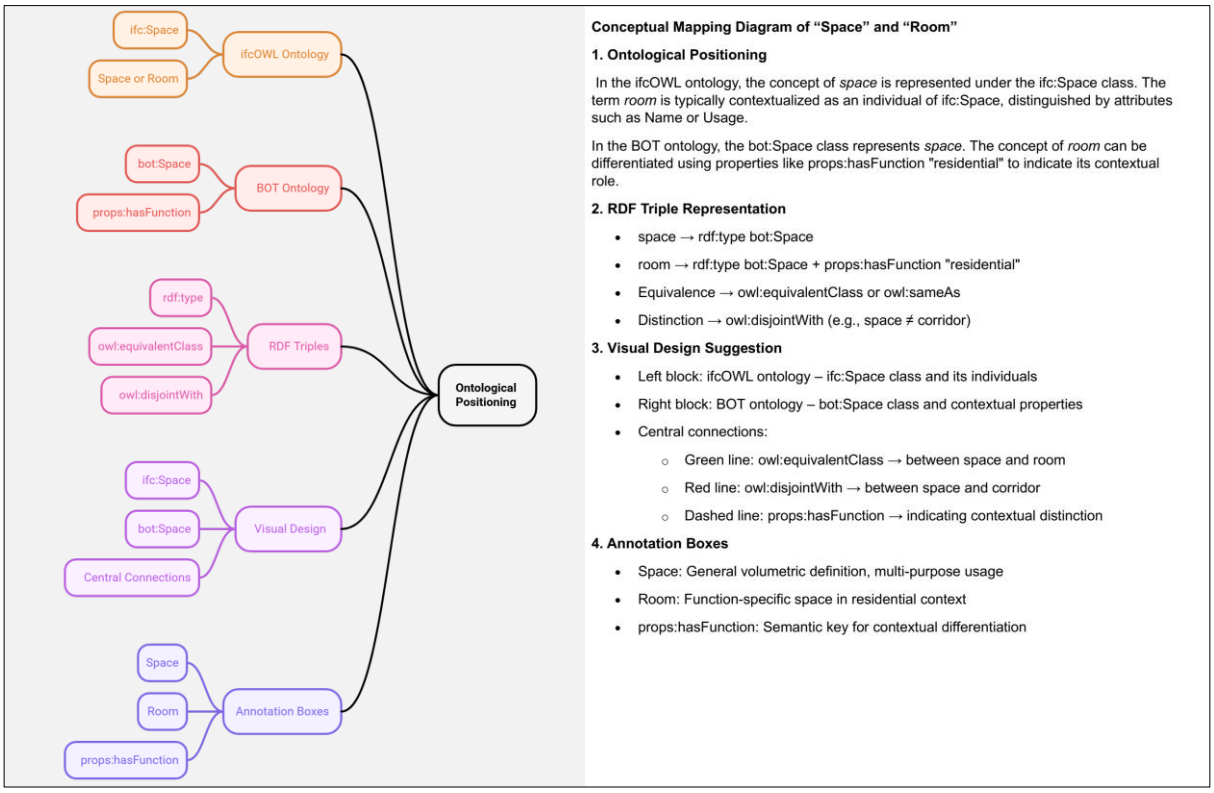


Figure 7. Conceptual Mapping Diagram of “Space” and “Room”

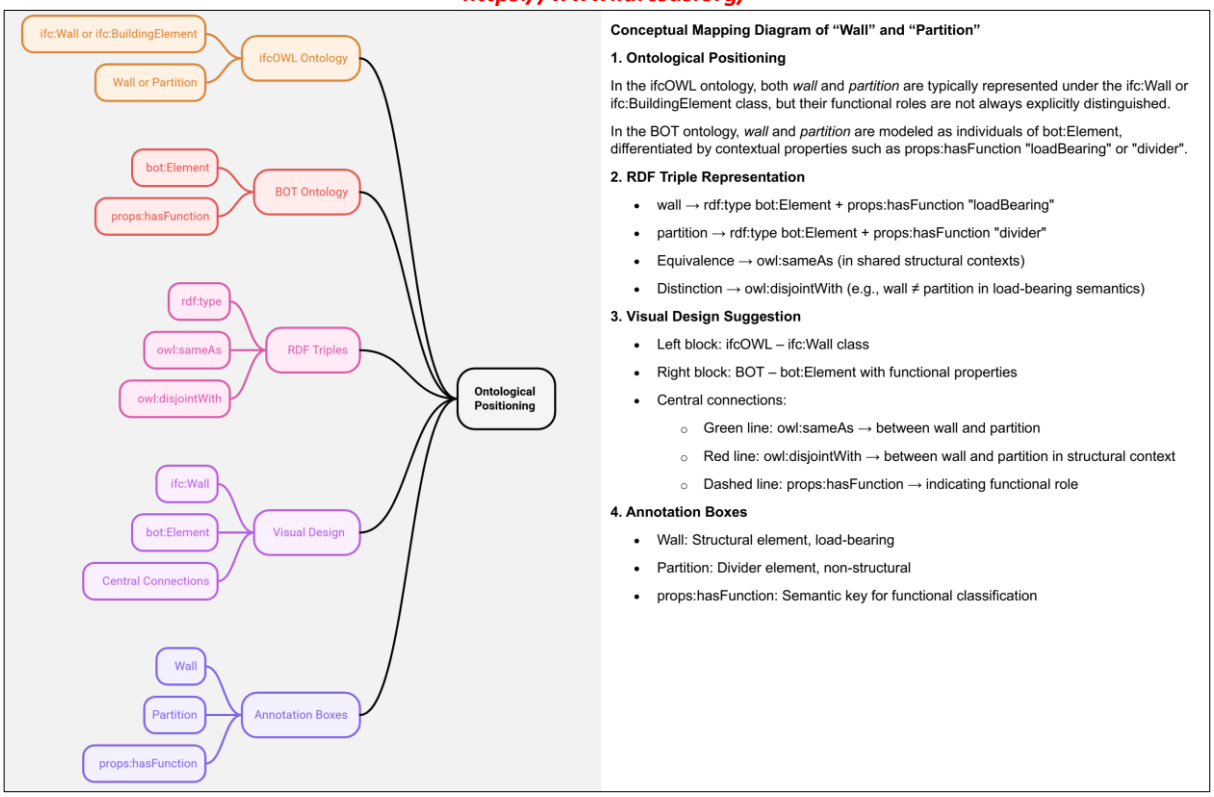


Figure 8. Conceptual Mapping Diagram of "Wall" and "Partition"

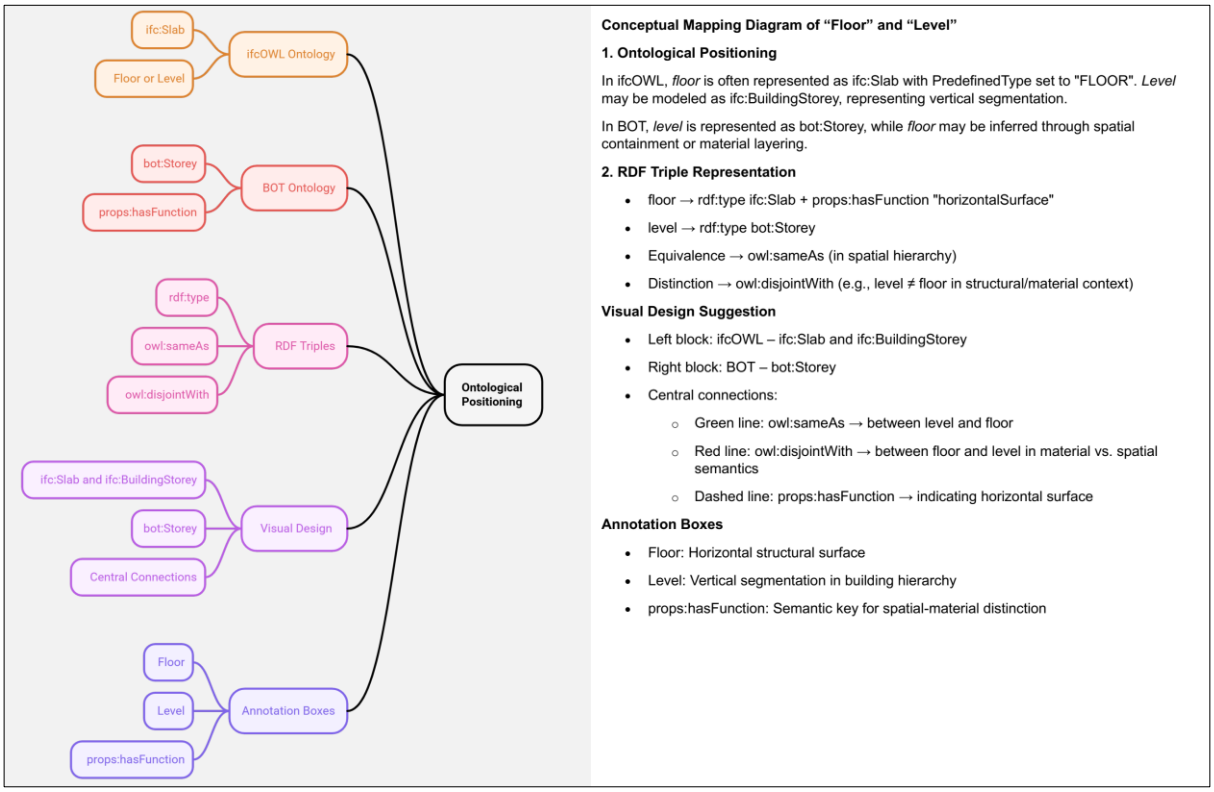


Figure 9. Conceptual Mapping Diagram of "Floor" and "Level"

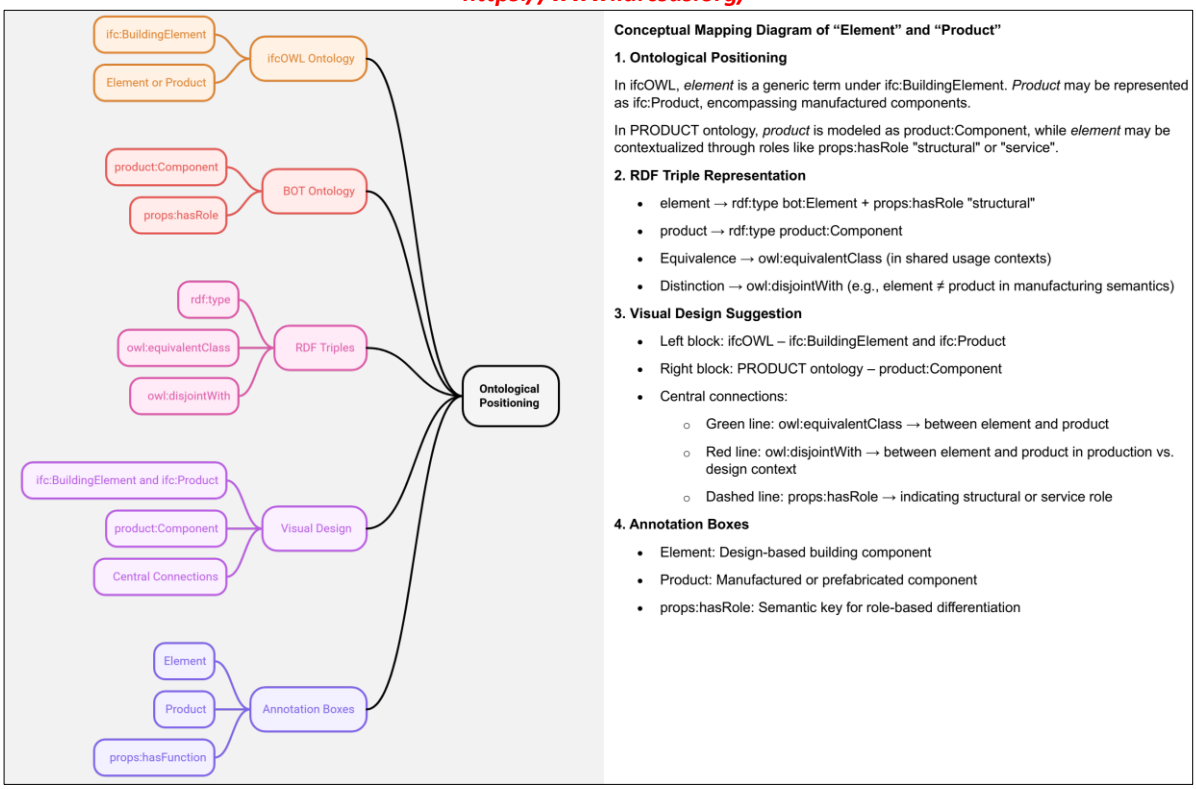


Figure 10. Conceptual Mapping Diagram of "Element" and "Product"

3.2. Discussion

The findings indicate that conceptual uncertainties in BIM data can be systematically separated by ontological modeling. Specifically, RDF representation and SPARQL queries have made contextual differences between concepts visible at the semantic level. This situation increases explainability in both data querying processes and regulatory compliance modeling efforts.

Functional concepts like "wall" and "partition" have been clearly distinguished using the props:hasFunction property, while contextual concepts like "space" and "room" have been semantically defined using the owl:equivalentClass and props:hasFunction relationships. Similarly, the interdisciplinary difference between the concepts of "element" and "product" has been modeled using props:hasRole and rdf:type. These distinctions have provided high accuracy in terms of filtering and matching in SPARQL queries.

The classification performed using a concept map has made it possible to ontologically separate terms containing uncertainty; SHACL validation outputs have supported the consistency of the model. This approach aligns with similar studies in the literature and contributes to the creation of more explainable data structures in semantic BIM applications (Pauwels et al., 2017; Wang et al., 2024; Yurchyshyna & Zarli, 2009).

Another significant contribution of the study is that concepts can be harmonized internationally by multilingual label matching. Turkish-English mappings made by using rdfs:label have shown that semantic alignment is achieved at an 82% rate. This result provides an infrastructure that will facilitate data sharing, especially in BIM projects based on open standards.

Overall, each of the four-stage methodological approaches produced meaningful outputs in terms of conceptual clarity and semantic accuracy, demonstrating the potential of ontology engineering to provide explainability and interpretability in BIM data.

4. Conclusion and Recommendations

This study aimed to address the conceptual uncertainties frequently encountered in Building Information Modeling (BIM) processes using an ontology engineering approach and to achieve definition clarity. Terminological overlaps such as "wall" versus "partition" or "space" versus "room" are among the main issues threatening semantic consistency in interdisciplinary data sharing (Borgo et al., 2015; Yurchyshyna & Zarli, 2009).

Analyzes conducted using RDF-based data representation and SPARQL querying techniques have shown that these uncertainties can be ontologically classified and contextually resolved. The equivalence, distinction, and contextual relationships between concepts have been visualized thru semantic graphs, providing a strong foundation for explainability and interpretability (Pauwels et al., 2017; Wang et al., 2024).

4.1. Contributions of the Study

In this context, the original contributions of the study are summarized below:

- Conceptual clarity has been achieved in BIM terminology by proposing an ontology engineering-based method.
- Contextual representation and separation of concepts have been achieved using RDF graph structures.
- Semantic matching and validation processes are exemplified using SPARQL queries.
- Visual tools have been developed to enhance semantic alignment in interdisciplinary data sharing thru concept maps.

These contributions provide an important methodological framework for making BIM data more explainable, queryable, and compliant with regulations.

4.2. Recommendations for Future Studies

Based on the findings of the study, the following suggestions may serve as a guide for future research:

- The application of SHACL-based validation mechanisms in broader BIM scenarios can enhance model consistency (Jiang et al., 2022).
- Multilingual ontology matching techniques can be developed to strengthen semantic alignment in international projects (Zhang & El-Gohary, 2016).
- The integration of digital twin platforms with ontological concept maps can create semantic decision support systems in maintenance and operational processes (Hagedorn et al., 2023a; Yin et al., 2023).
- Integrating data connection and link verification processes with ICDD containers into BIM models can increase information integrity (Hagedorn et al., 2023b)

These recommendations provide a strategic roadmap to increase the usability of semantic BIM applications in larger-scale and interdisciplinary projects.

Thanks and Information Note

This study was conducted in full compliance with national and international research and publication ethics. Ethics committee approval was not required due to the nature of the research. The article was prepared solely by the author, who is responsible for all content and contributions.

References

Beetz, J., van Leeuwen, J., & de Vries, B. (2009). IfcOWL: A case of transforming EXPRESS schemas into ontologies. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *23*(1), 89–101. https://doi.org/10.1017/S0890060409000122

Borgo, S., Sanfilippo, E. M., Šojić, A., & Terkaj, W. (2015). Ontological Analysis and Engineering Standards: An Initial Study of IFC. In *Ontology Modeling in Physical Asset Integrity Management* (pp. 17–43). Springer International Publishing. https://doi.org/10.1007/978-3-319-15326-1_2

Guo, D., Onstein, E., & Rosa, A. D. La. (2020). An Approach of Automatic SPARQL Generation for BIM Data Extraction. *Applied Sciences*, *10*(24), 8794. https://doi.org/10.3390/app10248794

Hagedorn, P., Senthilvel, M., Schevers, H., & Verhelst, L. (2023a). Towards usable ICDD containers for ontology-driven data linking and link validation. *11th Linked Data in Architecture and Construction Workshop*, 35–46. https://www.researchgate.net/publication/371761677_Towards_usable_ICDD_containers_for_ontology-driven_data_linking_and_link_validation

Hagedorn, P., Senthilvel, M., Schevers, H., & Verhelst, L. (2023b). Towards usable ICDD containers for ontology-driven data linking and link validation. *LDAC*, 35–46.

Jiang, L., Shi, J., & Wang, C. (2022). Multi-ontology fusion and rule development to facilitate automated code compliance checking using BIM and rule-based reasoning. *Advanced Engineering Informatics*, *51*, 101449. https://doi.org/10.1016/j.aei.2021.101449

Li, H., & Zhang, J. (2022, July 15). *IFC-based Information Extraction and Analysis of HVAC Objects to Support Building Energy Modeling*. https://doi.org/10.22260/ISARC2022/0024

Pauwels, P., Krijnen, T., Terkaj, W., & Beetz, J. (2017). Enhancing the ifcOWL ontology with an alternative representation for geometric data. *Automation in Construction*, *80*, 77–94. https://doi.org/10.1016/j.autcon.2017.03.001

Pauwels, P., & Terkaj, W. (2016). EXPRESS to OWL for construction industry: Towards a recommendable and usable ifcOWL ontology. *Automation in Construction*, *63*, 100–133. https://doi.org/10.1016/j.autcon.2015.12.003

Schevers, H., & Drogemuller, R. (2005). Converting the Industry Foundation Classes to the Web Ontology Language. *2005 First International Conference on Semantics, Knowledge and Grid*, 73–73. https://doi.org/10.1109/SKG.2005.59

Terkaj, W., & Šojić, A. (2015). Ontology-based representation of IFC EXPRESS rules: An enhancement of the ifcOWL ontology. *Automation in Construction*, *57*, 188–201. https://doi.org/10.1016/j.autcon.2015.04.010

Wang, C., Zhang, L., & Yan, W. (2024). Enhancement and validation of ifcOWL ontology based on Shapes Constraint Language (SHACL). *Automation in Construction*, *160*, 105293. https://doi.org/10.1016/j.autcon.2024.105293

Xu, Z., Wang, X., Zhou, W., & Yuan, J. (2019). Study on the Evaluation Method of Green Construction Based on Ontology and BIM. *Advances in Civil Engineering*, *2019*(1), 5650463. https://doi.org/10.1155/2019/5650463

Yin, M., Tang, L., Webster, C., Li, J., Li, H., Wu, Z., & Cheng, R. C. K. (2023). Two-stage Text-to-BIMQL semantic parsing for building information model extraction using graph neural networks. *Automation in Construction*, *152*, 104902. https://doi.org/https://doi.org/10.1016/j.autcon.2023.104902

Yurchyshyna, A., & Zarli, A. (2009). An ontology-based approach for formalisation and semantic organisation of conformance requirements in construction. *Automation in Construction*, *18*(8), 1084–1098. https://doi.org/10.1016/j.autcon.2009.07.008

Zhang, J., & El-Gohary, N. M. (2016). Semantic NLP-Based Information Extraction from Construction Regulatory Documents for Automated Compliance Checking. *Journal of Computing in Civil Engineering*, *30*(2), 04015014. https://doi.org/http://dx.doi.org/10.1061/(ASCE)CP.1943-5487.0000427

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Development of Lignin-Modified Phenol-Formaldehyde Resins: Sustainability Effect in the Furniture Industry

Fatma Pinar SENKON[1*]

ORCID 1: 0000-0002-5048-0757
[1]Tosunogullari Furniture Industry and Trade Inc., Department of R&D, Konya-Türkiye
Necmettin Erbakan University, Faculty of Fine Arts and Architecture, Department of Architecture, Konya-Türkiye
pinar.Senkon@burotime.com (Responsible Author)

Busra ŞİMŞEK[2]

ORCID 2: 0000-0001-8411-5275
[2]Tosunogullari Furniture Industry and Trade Inc., Department of R&D, Konya-Türkiye
busra.simsek@burotime.com

Arif AKILLILAR[3]

ORCID 3: 0000-0003-2266-5575
[3]Tosunogullari Furniture Industry and Trade Inc., Department of R&D, Konya-Türkiye
arif.Akillilar@burotime.com

Franz ZEPPETZAUER[4]

ORCID 4: 0009-0002-1157-4563
[4]Kompetenzzentrum Holz GmbH- Wood K plus, Linz, Austria
f.zeppetzauer@wood-kplus.at

Birgit KAMM[5]

ORCID 5: 0000-0002-7878-4971
[5]Kompetenzzentrum Holz GmbH- Wood K plus, Linz, Austria
b.kamm@wood-kplus.at

Abstract

The primary aim of bio-based energy production is to achieve sustainable energy generation by utilizing biological waste as raw material. These materials are processed through various conversion technologies in biorefineries, where research has demonstrated the feasibility of producing petroleum-derived products from biological resources. Among them, lignin—a renewable phenolic macromolecule found in the cell walls of biomass, possessing aromatic rings and phenolic hydroxyl groups similar to phenol—has attracted significant attention as a promising substitute for phenol in PF resin adhesives, particularly in the wood and furniture industries where such resins are widely applied. By modifying lignin to develop lignin-modified PF resin adhesives, it is possible to achieve notable performance improvements while simultaneously enhancing economic efficiency and reducing environmental impact. In this study, lignin-modified phenol-formaldehyde (LPF) resins were synthesized, with lignin selected as a bio-based alternative to phenol owing to its aromatic structure, phenolic hydroxyl groups, and natural abundance. The synthesis was carried out by using two different lignin types, kraft lignin and organosolv lignin, by substituting phenol with lignin at 50-60-70 to 80% wt. ratios. The experiments focused on evaluating the influence of lignin type on the extent of phenol substitution. Following synthesis, the resins were characterized in terms of dynamic viscosity and molecular weight with potential applications in environmentally friendly and sustainable adhesives for the furniture sector.

Keywords: Furniture, kraft lignin, lignin-modified phenol-formaldehyde, organosolv lignin, sustainability

1. Introduction

Fossil fuel consumption has existed for many decades (Solarte-Toro & Cardona Alzate, 2023). But we know that fossil fuels are both highly harmful to environmental pollution and are decreasing day by day because they are not a renewable energy source. For this reason, various researches are being carried out every day to obtain biologically based energy by reducing fossil

fuel consumption. Especially in order to reduce fossil fuel consumption, which has a great economic impact, the trend towards sustainable resources such as bioenergy and biofuels is increasing day by day (Al Mubarak, Rezaee, & Wood, 2024).

The main goal of bio-based energy production is based on sustainable energy production by using biological wastes as raw materials. Biological raw materials are transformed through various conversion processes in so-called biorefineries, enabling the use of a renewable raw material to produce clean energy that is environmentally friendly (Katakojwala & Mohan, 2021).

As a result of theoretical and practical research, it has been determined that it is possible to obtain petroleum-based products with biological raw materials. However, the end product obtained is not economically advantageous compared to petroleum-based products. There are 4 biorafinary types such as lignocellulosic feedstock biorefinery, whole plant, green biorefineries, biorefinery two-platform concept (Clark & Deswarte, 2015). Lignocellulosic feedstock type of biorafinary produces lignin and subsequently depolymerised lignin (Uihlein & Schebek, 2009).

Lignin:

Lignin, one of the most abundant natural polymers in nature, is one of the by-products of chemical processes, especially in the paper industry. This is because the primary source of cellulose is lignocellulosic biomass (Ragauskas et al., 2014). This bio-based feedstock consists of lignin, cellulose, and hemicellulose. Structurally, lignin is a polyphenolic macromolecule with p-hydroxyphenyl (H), guaiacyl (G), and syringyl (S) monomers as the three phenyl-propene units (Boerjan, Ralph, & Baucher, 2003). These units are shown in Figure 1.

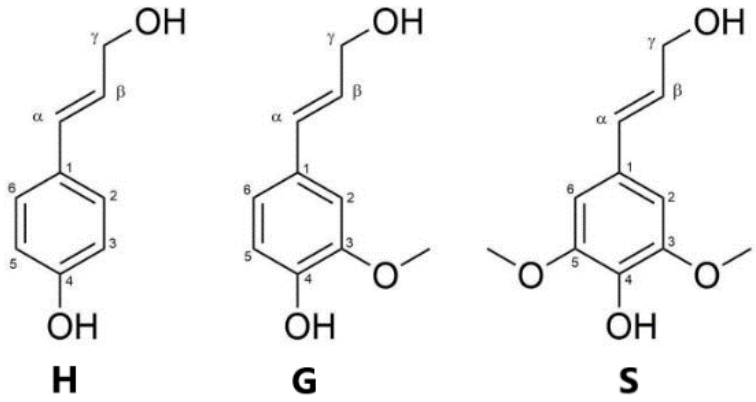


Figure 1. Structures of monolignols: *p*-hydroxyphenyl (H); guaiacyl (G); syringyl (S) monomers

The reactivity of lignin depends on structural elements such as aliphatic hydroxyl, methoxy, carboxyl and carbonyl groups, but the structural composition and properties vary depending on the source and isolation method (Hatakeyama & Hatakeyama, 2009).

Lignin can provide a variety of aromatic building blocks with high added value. With its aromatic basic structure, lignin is theoretically the most suitable renewable resource to replace aromatics from petrochemicals. In practice, however, this has not yet materialized because the valorization of lignin faces several challenges (Graglia, Kanna, & Esposito, 2015).

Lignin Extraction from Lignocellulosic Biomass:

There are different methods for lignin extraction such as kraft, sulfite, soda and organasolv. The most common of these methods is the kraft method, which meets 85% of lignin needs worldwide. The organosolv process is considered to be much more environmentally friendly than the kraft process due to its sulfur-free and easier process conditions. Although the organosolv process provides high purity lignin, it has only been commercially produced for a few years (Carvajal, Gómez, & Cardona, 2016).

Lignin shows structural changes depending on the type of process used and therefore exhibits different chemical properties. Organosolv lignin contains a large proportion of β-O-4 bonds and is almost insoluble in water and organic solvents. It is the most natural form of technical lignin as the core structure remains mostly unchanged. In contrast, lignin from the kraft process has a condensed structure with few C-C cross-links. It therefore develops chemical resistance to hydrolysis. Another disadvantage is that it contains sulfur in the form of thiols, which can poison catalysts in further processing steps (Watkins, Nuruddin, Hosur, Tcherbi-Narteh, & Jeelani, 2015).

Phenol Formaldehyde (PF) Resin:

Phenol formaldehyde (PF) resins are polymeric compounds. This compound is synthesized by acid or base catalyzed polycondensation of phenol and formaldehyde. To prepare the resin, formaldehyde is first added to phenol. Then condensation reaction is applied and finally curing processes are applied. Curing takes place at high temperature and requires further condensation reactions and molecular rearrangements (Pizzi & Ibeh, 2022).

The wood industry is one of the largest consumers of PF resins. With their high mechanical performance, stable molding processing performance, good flame resistance, long-term thermal and mechanical stability, satisfactory electrical and thermal insulation properties, high adhesion strength and moisture resistance, PF resins are preferred and used in many areas. Resoller is the preferred type of PF resin for wood bonding due to their ability to form three-dimensional networks with favorable mechanical performance when cured, unlike novolaks, which are thermoplastic and require an additional curing agent. However, the resins need to undergo chemical modification to remain a viable option in an increasingly environmentally conscious industry (Dunky, 2017).

Lignin Modified Phenol Formaldehyde (LPF) Resin:

Improved performance of lignin for the production of value-added products can be achieved by converting it into molecules with lower molecular weight through depolymerization. The process yields aromatic and phenolic molecules with greater structural similarity to phenol (Fernández-Rodríguez, Erdocia, Sánchez, Alriols, & Labidi, 2017). This makes depolymerized lignin a promising alternative to phenol as it allows for higher degrees of substitution.

Substitution of phenol with lignin until 50 % wt. is possible without sacrificing resin quality. Further substitution requires either structural modification of lignin, or pretreatment methods during synthesis. Methylolation, phenolation, and thermolysis techniques increase the reactivity of lignin molecules. Methylolation and phenolation involve lignin pretreatment with formaldehyde or phenol respectively, before entering the resinification reaction. These methods introduce reactive functional groups into the structure of lignin, while thermolysis induces targeted structural degradation. Thermo-chemical depolymerization by pyrolysis, oxidation, hydrogenolysis, and hydrolysis necessitate application of heat under specific reaction conditions, cleaving intermolecular bonds. Depolymerization yields phenolic oligomers with

decreased molecular weight (Mw) and reduced aliphatic hydroxyl groups, which have higher structural similarity to phenol, serving as an ideal substitute for phenol in LPF production (Sarkar & Adhikari, 2000).

2. Materials and Methods

Materials and Chemicals:

All materials and chemicals used during the experiments are listed in Table 1.

Table 1. List of materials and chemicals used in the experiment

Materials	Chemicals
• Beakers • Reflux Condenser • 3 Necked Round Bottom Flask • Dropping Funnel • Spatulas • Funnel • Glass Plug • Sample Tube • Magnetic Fish	• Phenol, C_6H_6O • Kraft Lignin • Organosolv Lignin • Sodium Hydroxide, NaOH (50 %) • Formaldehyde Solution (37 %, for synthesis) • Water, H_2O (Distilled)

Experimental Part:

Experiments were started with the same amount of lignin and phenol (both 50%). After than amount of lignin increased each step and therefore amount of phenol decreased at the same time. The increment and decrement values of both were changed by 10% at each step. According to this change, four different experiments were performed with lignin content of 50%, 60%, 70 %, 80%. Also the amount of other chemicals was kept constant. These experimental steps were performed with two different types of lignin such as kraft lignin and organasolv lignin. The first 4 experiments were performed with kraft lignin and the last 4 experiments were performed with organosolv lignin. All of the chemical amounts are listed in Table 2 for each experiment step. Also in this table kraft lignin was called KC1202 and the organosolv lignin was called KC1196.

Table 2. Chemical amounts used in the experiment

Experiment Name	Lignin Type	Phenol Amount (g)	Lignin Amount (g)	NaOH Amount (g)	Formaldegyde Amount (g)	H_2O Amount (g)
K-LP-50 %	KC1202	15.39	15.35	13.11	34.42	21.80
K-LP-60 %	KC1202	12.33	18.46	13.11	34.42	21.80
K-LP-70 %	KC1202	9.20	21.49	13.11	34.42	21.80
K-LP-80 %	KC1202	6.16	24.03	13.11	34.42	21.80
O-LP-50 %	KC1196	15.39	15.35	13.11	34.42	21.80
O-LP-60 %	KC1196	12.33	18.46	13.11	34.42	21.80
O-LP-70 %	KC1196	9.20	21.49	13.11	34.42	21.80
O-LP-80 %	KC1196	6.16	24.03	13.11	34.42	21.80

In the experimental procedure, the order of addition of chemicals, process temperature, and time conditions are shown schematically in Figure 2.

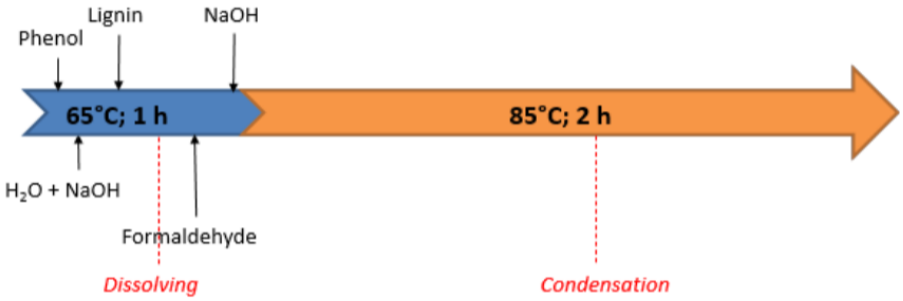


Figure 2. Schematic representation of the experimental process

During the experiments, 2 points were very important.

- Lignin addition should be very slow. Because when lignin is added rapidly, it does not dissolve and agglomerations are seen.
- The addition of formaldehyde should also be very slow. Fast formaldehyde addition causes foaming.

Analysis Part:

Dynamic viscosity (rheometry) and gel permeation chromatography (GPC) were performed on all resins obtained from the experiments.

Dynamic viscosity (rheometry) analysis; An air-carried Anton Paar Modular Compact Rheometer (MCR) 102 equipped with a CP50-1 conical plate (diameter: 50 mm; angle of inclination: 1°) device was used to obtain the ratio coefficient between the dynamic viscosity η and shear rate of LPF resins. Measuraments were performed at a constant temperature of 30°C in rotation mode.

GPC analysis; Thermo Fisher Dionex ICS 1500+ gel permeation chromatography consisted pre-column PSS MCX Guard (dimensions: 50 x 8 mm) and three PSS Analytical columns (Specifications: 100A/1000A/100 000A, dimensions: 300 mm x 8 mm) device was used to obtain the molecular weight distribution of LPF resin samples. In the analysis, 1 mg sample was dissolved in 0.1 mol L^{-1} NaOH to obtain 1 mg mL^{-1} concentration of samples. After than the mixture filtered with 0.45 µm syringe filter. During the analysis, the flow rate was set to 1 mL min^{-1}, column temperature 50°C, injection volume 10 µL and injection time 33 min. The UV detector (VWD) was also set to a wavelength of 280 nm for the samples.

3. Findings and Discussion

Dynamic viscosity (rheometry) analysis results:

All resins were analysed for their dynamic viscosity. All data are presented in Figure 3.

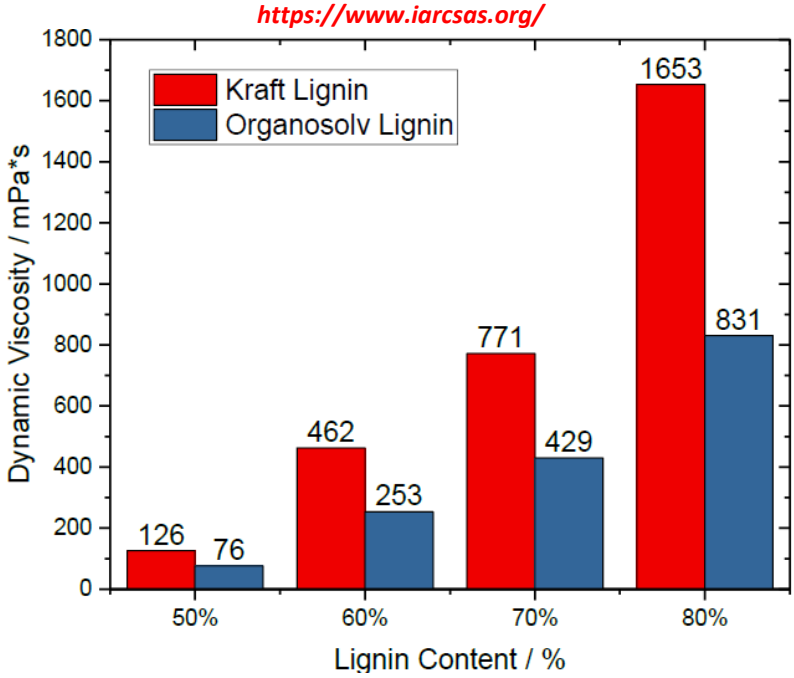


Figure 3. Graph of dynamic viscosity analysis

Resins containing Kraft Lignin showed higher viscosity values than organosolv resins. There are several reasons for this behaviour. Softwood Kraft Lignin reveals a high concentration of guaiacyl substituents in their polymer backbone which leads to higher reactivity in resin condensation reactions. In addition, Kraft Lignin always have higher molecular weight than Organosolv Lignin. Organosolv Lignin is usually originating from annuary plants with low contents of lignin. The organosolv process offers milder conditions without harsh acidic or basic treatment as in the Kraft process or Sulphite process. Therefore, a higher content of less reactive substituents (e.g. Sinapyl units) due to its original plants and also higher steric hindering is the key for slower viscosity increase in resin cooking.

GPC analyses of the used lignins:

From the used Kraft-Lignin and Organosolv-Lignin have been determined the molecular weight distribution. The results are given in Table 3 and Figure 4.

Table 3. Reference results of GPC analysis for kraft lignin and organasolv lignin

	M_N	M_W	PDI
Kraft Lignin	908 (±2)	4450 (±15)	4.90 (±0.01)
Organosolv Lignin	665 (±2)	1770 (±6)	2.65 (±0.01)

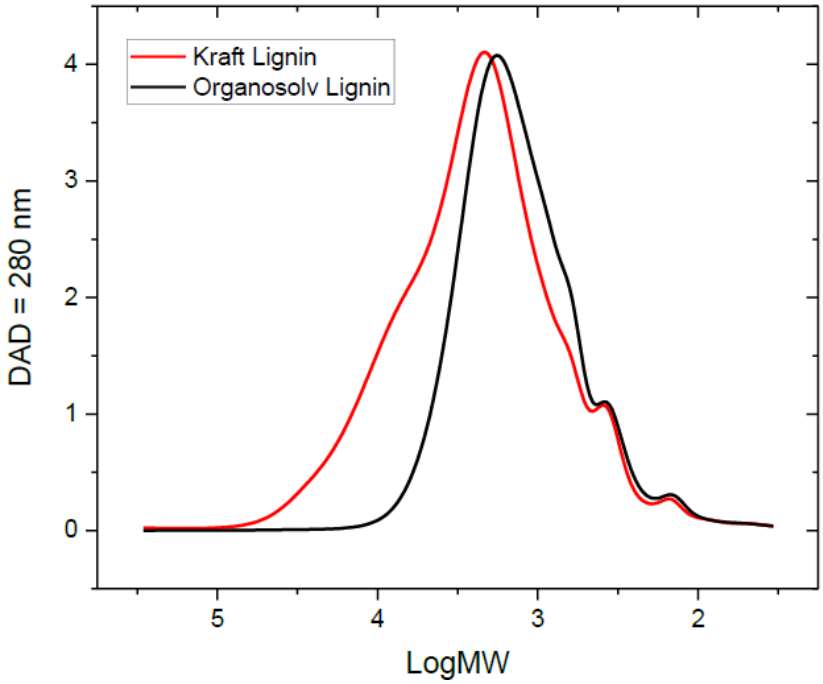


Figure 4. Reference graph of GPC analysis for kraft lignin and organasolv lignin

GPC analyses results of the produced resins:

All resins were analysed for their molecular weight distribution. All data are presented in Figure 5, 6 and Table 4, 5.

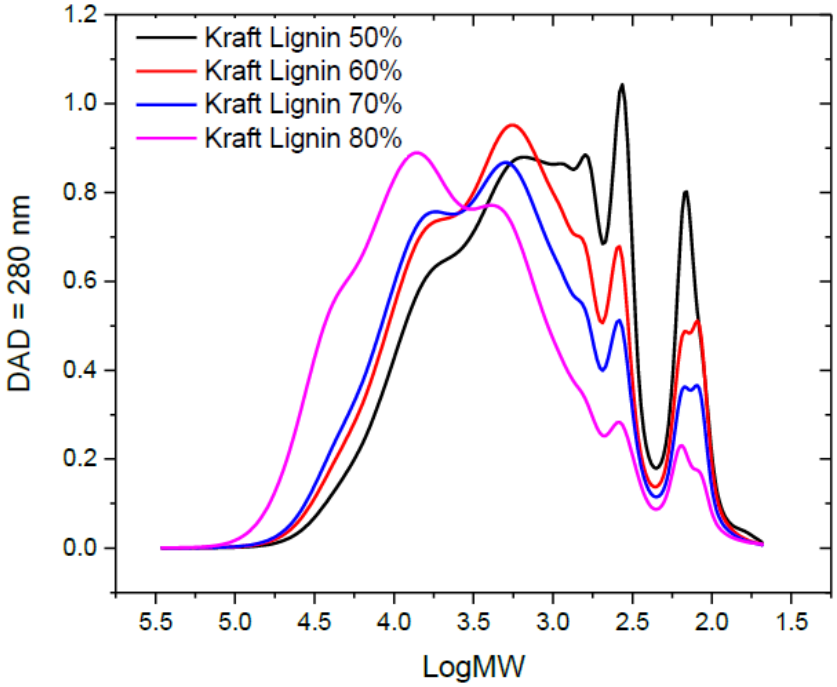


Figure 5. Graph of GPC analysis for kraft lignin-resins

Table 4. Results of GPC analysis for kraft lignin-resins

Sample Name	M_N	M_W	PDI
Kraft Lignin 50 %	725 (±4)	2054 (±10)	2.83 (±0.02)
Kraft Lignin 60 %	738 (±3)	2268 (±9)	3.07 (±0.03)
Kraft Lignin 70 %	740 (±4)	2340 (±12)	3.16 (±0.02)
Kraft Lignin 80 %	755(±7)	2572 (±14)	3.40 (±0.04)

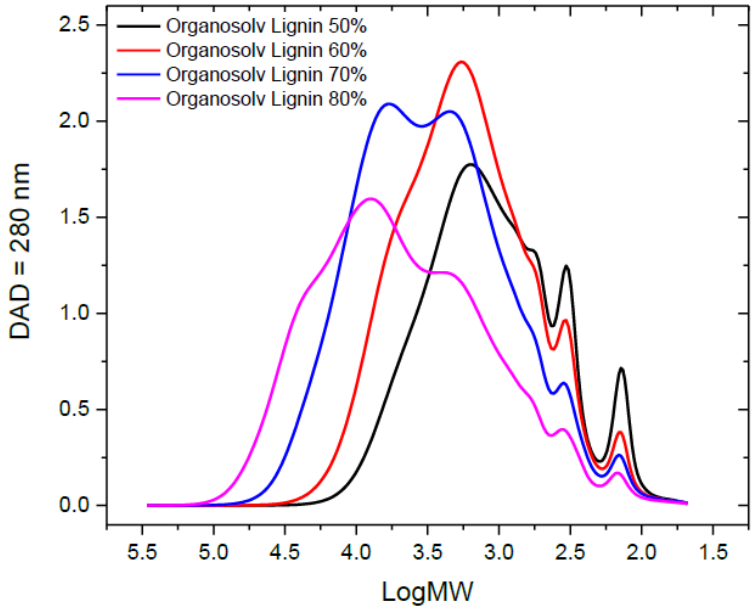


Figure 6. Graph of GPC analysis for organosolv lignin-resins

Table 5. Results of GPC analysis for organosolv lignin-resins

Sample Name	M_N	M_W	PDI
Organosolv Lignin 50 %	510 (±2)	1295 (±8)	2.53 (±0.01)
Organosolv Lignin 60 %	521 (±3)	1384 (±10)	2.65 (±0.02)
Organosolv Lignin 70 %	535 (±2)	1438 (±11)	2.68 (±0.01)
Organosolv Lignin 80 %	538 (±2)	1502 (±16)	2.79 (±0.05)

GPC analysis results show that M_N, M_W and polydispersity values increase with higher lignin substitution. These values are higher in Kraft Lignin than in Organosolv Lignin. This is in correlation with both the GPC results of lignins and viscosity results of produced resins.

4. Conclusion and Recommendations

Adhesives commonly used in the wood industry are phenolic resins. The reasons for the widespread use of PF resins in the industry include their high strength, resistance to moisture, resistance to heat and chemicals, and high thermal stability. On the other hand, PF resins are toxic due to being a petrochemical product. Furthermore, they have negative environmental

impacts as they are obtained from non-renewable resources. For all these reasons, this study was carried out to investigate the feasibility of using lignin material, which is structurally very similar to phenol, as an alternative.

In experimental studies, kraft and organosolv lignin types were used as substitute materials for phenol at ratios ranging from 50% to 80%. Afterwards, dynamic viscosity and GPC analysis were applied to the resulting lignin-modified phenol formaldehyde resins. All research results indicated that lignin could be used as a substitute material for phenol at ratios up to 80%.

Thanks and Information Note

The article complies with national and international research and publication ethics.

References

Al Mubarak, F., Rezaee, R., & Wood, D. A. (2024). Economic, societal, and environmental impacts of available energy sources: A review. *Eng, 5*(3), 1232-1265.

Boerjan, W., Ralph, J., & Baucher, M. (2003). Lignin biosynthesis. *Annual review of plant biology, 54*(1), 519-546.

Carvajal, J. C., Gómez, Á., & Cardona, C. A. (2016). Comparison of lignin extraction processes: economic and environmental assessment. *Bioresource technology, 214*, 468-476.

Clark, J., & Deswarte, F. (2015). The biorefinery concept: an integrated approach. *Introduction to chemicals from biomass*, 1-29.

Dunky, M. (2017). Adhesives in the wood industry *Handbook of adhesive technology* (pp. 511-574): CRC Press.

Fernández-Rodríguez, J., Erdocia, X., Sánchez, C., Alriols, M. G., & Labidi, J. (2017). Lignin depolymerization for phenolic monomers production by sustainable processes. *Journal of energy chemistry, 26*(4), 622-631.

Graglia, M., Kanna, N., & Esposito, D. (2015). Lignin refinery: Towards the preparation of renewable aromatic building blocks. *ChemBioEng Reviews, 2*(6), 377-392.

Hatakeyama, H., & Hatakeyama, T. (2009). Lignin structure, properties, and applications *Biopolymers: lignin, proteins, bioactive nanocomposites* (pp. 1-63): Springer.

Katakojwala, R., & Mohan, S. V. (2021). A critical view on the environmental sustainability of biorefinery systems. *Current Opinion in Green and Sustainable Chemistry, 27*, 100392.

Pizzi, A., & Ibeh, C. (2022). Phenol-formaldehyde resins *Handbook of Thermoset Plastics* (pp. 13-40): Elsevier.

Ragauskas, A. J., Beckham, G. T., Biddy, M. J., Chandra, R., Chen, F., Davis, M. F., . . . Keller, M. (2014). Lignin valorization: improving lignin processing in the biorefinery. *science, 344*(6185), 1246843.

Sarkar, S., & Adhikari, B. (2000). Lignin-modified phenolic resin: synthesis optimization, adhesive strength, and thermal stability. *Journal of adhesion science and technology, 14*(9), 1179-1193.

Solarte-Toro, J. C., & Cardona Alzate, C. A. (2023). Sustainability of biorefineries: Challenges and perspectives. *Energies, 16*(9), 3786.

Uihlein, A., & Schebek, L. (2009). Environmental impacts of a lignocellulose feedstock biorefinery system: an assessment. *Biomass and Bioenergy, 33*(5), 793-802.

Watkins, D., Nuruddin, M., Hosur, M., Tcherbi-Narteh, A., & Jeelani, S. (2015). Extraction and characterization of lignin from different biomass resources. *Journal of materials research and technology, 4*(1), 26-32.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Public Rest Areas in Shopping Centers: Samsun Piazza Mall

Hande YILDIRIM [1*]

ORCID 1: 0000-0003-0504-2886
[1]Research Assistant, Samsun University, Faculty of Architecture and Design, Department of Interior Architecture and Environmental Design, Samsun-Türkiye
hande.yildirim@samsun.edu.tr **(**Responsible Author)

Serap FAİZ BÜYÜKÇAM [2]

ORCID 2: 0000-0003-4263-1671
[2] Assoc. Prof. Dr., Ondokuz Mayıs University, Faculty of Architecture, Department of Interior Architecture, Samsun- Türkiye
serap.faizbuyukcam@omu.edu.tr

Abstract

Shopping malls, which stand out as structures characterized by the consumption-oriented functions of contemporary urban life, also attract attention with their public qualities that foster social interaction. Today, seating areas in these spaces, which combine the shopping experience with various functions such as leisure and socializing, shape the relationship users establish with the space. Sometimes used only for brief rest and waiting, they also offer opportunities for socializing, observing, and experiencing the atmosphere of the space. Responding to different needs, these seating areas shape the user's experience with the space by supporting continuous spatial circulation. This study aims to examine the design of seating areas organized independently of food and beverage units at the Piazza Shopping Mall in Samsun. As part of the fieldwork, the shopping center was visited, seating areas were identified on site and photographed, and these areas within the interior were incorporated into plan diagrams. Subsequently, the seating areas were analyzed in terms of location, visibility, type, material, capacity, layout/arrangement, color, and texture parameters. The study revealed that seating areas are located along circulation axes and in highly visible locations. In terms of furnishing diversity, it was determined that movable elements are predominant. It was found that seating areas are designed as functional elements that meet the basic need for rest. It was observed that seating elements intended for waiting did not offer diversity for long-term use and socialization. In this context, redesigning seating areas to serve socialization and enrich the spatial experience will support the public nature of shopping centers.

Keywords: Furniture, interior, waiting area, shopping centers

1. Introduction

Shopping malls are buildings that represent the economic, social, and spatial relationships of urban life. Considered one of the spatial counterparts of consumer culture, these structures have evolved into venues that host society's consumption activities. Over time, with globalization, technological developments, and transformations in lifestyles, shopping malls have become new meeting points for social life in cities. This transformation plays an important role in shaping the relationship individuals establish with public spaces. The spatial organization of shopping centers and the furniture elements within them are among the factors that shape user experiences. Today, seating areas in these spaces, which combine the shopping experience with various functions such as entertainment and socializing, regulate the relationship users establish with the space. These short-term seating areas are important spatial components that not only alleviate the physical fatigue caused by the shopping experience in the mall, but also support secondary experiences such as observation, waiting, and socializing (Bitner, 1992; Wakefield & Blodgett, 1996). These areas play an effective role in regulating spatial circulation within the structure by guiding user behavior. On the other hand, seating areas located at points such as circulation axes, atriums, and storefronts support both the physical and psychological comfort of individuals (Hami et al., 2018). Therefore, the location, type, capacity, layout, material, color, and texture choices of seating areas in shopping centers are important. The interior

atmosphere of shopping centers is related to sensory components (color, texture, light, and material), and seating elements are a sustainable part of this atmosphere (Hidayetoglu et al., 2010). On the other hand, the shape, material, color, and layout of seating areas are directly related to the time users spend in the space and their level of satisfaction (Grabiec et al., 2022; Prayoonhong et al., 2024). Based on all this, this study examines the seating area designs in the interior spaces of the Samsun Piazza Shopping Center. This study, which aims to reveal the role of seating areas in the interior layout of shopping centers, focuses on how seating elements are integrated into the overall spatial design of the shopping center. To this end, the study aims to determine the spatial distribution of seating areas in the shopping center and to classify seating elements according to various design parameters.

2.Materials and Methods

Shopping centers combine the shopping experience with various functions such as relaxation and socializing. The seating areas in these spaces shape the relationship users establish with the space. Sometimes used only for short-term rest and waiting, these seating areas also offer various opportunities for socializing, observing, and experiencing the atmosphere of the space. In this context, the study focuses on seating areas located in the interiors of shopping malls and serving common use. The aim of the study is to identify seating areas intended for common use in shopping malls and to reveal their characteristics. Seating areas located on the food court level of the shopping center have been excluded from the scope of the study because they are designed for eating and drinking activities. Samsun Piazza was selected as the study area. Samsun Piazza's large enclosed space, multi-level spatial design, and diverse seating and resting areas catering to different user groups were influential factors in its selection as the study area. Furthermore, its central location in the city, high visitor density, and access to a wide user base were among the factors that influenced the selection of this area for the study.

The study first conducted a literature review on shopping malls, consumption behavior, and the design of seating elements in shopping malls. The literature review was followed by fieldwork. During the fieldwork, Samsun Piazza was visited by the authors. In this process, floor plans of the shopping mall were obtained. Seating areas located on four floors—the ground floor, first floor, second floor, and third floor—where active shopping activities took place were identified, marked on the plans, and photographed simultaneously. The characteristics of the seating areas were analyzed in terms of location, visibility, furniture type, material, capacity, layout, and color parameters (Table 1).

Table 1. Analysis criteria (Caymaz, 2021; Hami et al., 2018; Ihtiyar & Yücel, 2021; Jung & Abdelaziz Mahmoud, 2023; Okuyucu & Işbeceren, 2023; Zhang et al., 2024)

Parameters	Subparameters	Parameters	Subparameters
Location	On the circulation line Outside the circulation line	Material type	Wood Cloth upholstery
Furniture Type	Stable Mobile With backrest Without backrest With armrests Without armrests Modular	Layout & arrangement	Linear Circular Back-to-back Open Closed
		Color usage	Color contrast Warm colors Cool colors Neutral colors
Capacity	Single person Multiple persons		

Within the scope of the analysis, the locations of seating units have been classified as either along the circulation route or outside the circulation route. Furniture types were considered in seven categories: fixed, mobile, with backrests, without backrests, with armrests, without armrests, and modular. The capacity of seating areas was analyzed in two categories: single-person and multi-person, while the seating arrangement was analyzed in five separate classifications: linear, circular, back-to-back, open, and closed. The material type of the seating units in the seating areas is considered in two categories: wood and upholstery. Finally, the analysis of color usage in these units is evaluated in terms of cool colors, warm colors, neutral colors, and color contrast.

3.Findings and Discussion

Seating areas were analyzed based on location, visibility, furniture type, material, capacity, layout, and color parameters to determine their characteristics. The analyses were evaluated sequentially across four floor plans: ground floor, first floor, second floor, and third floor. Seating areas in the dining section on the third floor are excluded from the scope. The seating areas on the ground floor of the shopping center are located in 4 different zones (Figure 1). In zones 1 and 3, the seating areas are positioned along the circulation axis. The seating areas in both zones offer visual access to store fronts and display windows and are highly visible. All furniture in zone 1 is mobile, allowing for portability during temporary events held at different times (product presentations, local product sales, workshops, etc.). This area, located near the main entrance of the building and allowing visual connection with the upper floors, creates a focal point within the space. This encourages users to take a short break without disconnecting them from the atmosphere of the space. The area features leather upholstery, armchairs, and backrest furniture, as well as poufs that allow for flexible use. The seating area, which is mostly suitable for individual or two-person use, is arranged in a circular and clustered layout. Warm and cool colors have been chosen together for the color scheme.

The seating areas in zone 3 consist of mobile wooden benches with armrests and backrests. The furniture is arranged linearly and positioned parallel to visitor circulation. In zones 2 and 4, the seating areas are located outside the circulation axis. The seating element in zone 2 is wooden, fixed, backless, and armless, positioned close to the vertical circulation (escalator) element. The polygonal seating area allows multiple people to sit in different directions. Zone 4 is located in a partially recessed space away from visitor flow. The furniture, consisting of single and double seating units, is movable and upholstered in leather (Table 2). The seating arrangement is created with furniture arranged face-to-face, dominated by cool colors.



Figure 1. Seating areas on the ground floor

There are seating areas in five different zones on the first floor of Samsun Piazza. Zones 5, 6, and 7 are located along the circulation route. The seating elements in these zones are arranged in a way that allows visual connection with the storefronts and display windows. Zones 8 and 9, on the other hand, are located outside the circulation route (Figure 2). The seating areas in these zones consist of both mobile and fixed seating units. It is observed that all fixed furniture uses wooden materials. Additionally, mobile wooden seating units are also among the other seating elements on the floor. It has been observed that the wooden units are arranged in a linear pattern and have the capacity to accommodate multiple people.

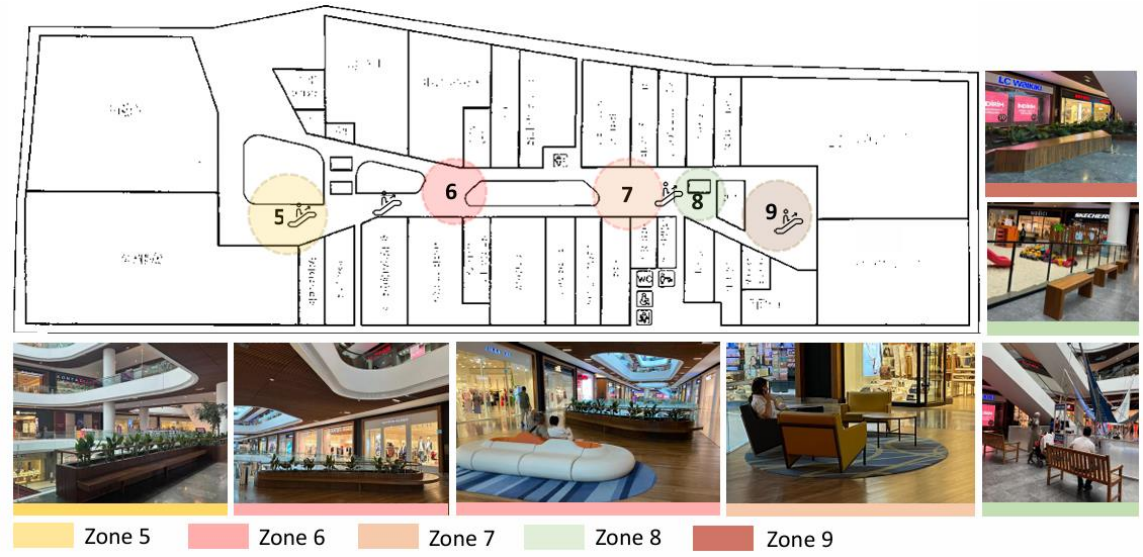


Figure 2. Seating areas on the first floor

Many of these wooden seating areas have a closed spatial arrangement, with no access from different points. It has been observed that the wooden seating areas are arranged and positioned to support relatively short periods of sitting. With modular designs, some of these units offer both individual and group seating options (Table 2). These units, which use a combination of

warm and cool colors, were found to have an open spatial arrangement in terms of orientation and access. The location of the seating elements, particularly in area 8, is a determining factor in the choice of layout and arrangement. The presence of children's play areas in this area plays an important role in the layout, arrangement, and capacity of the furniture.

Table 2. Analysis of seating areas at Samsun Piazza Mall

Floors and zones / Parameters		Ground Floor				First Floor					Second Floor				Third Floor		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Location	On the circulation line	■		■		■	■	■			■	■	■	■	■	■	■
	Outside the circulation line		■		■				■	■							
Furniture Type	Stable					■	■			■	■	■		■			
	Mobile	■	■	■	■		■	■	■			■	■		■	■	■
	With backrest	■		■	■	■	■	■	■		■	■	■	■	■		■
	Without backrest	■	■						■	■						■	
	With armrests	■		■	■			■	■			■	■		■		■
	Without armrests	■	■		■	■	■		■	■	■	■		■		■	
	Modular						■		■							■	
Capacity	Single	■			■			■				■	■		■		■
	Multiple	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Material type	Wood		■	■		■	■		■	■	■	■		■		■	
	Cloth upholstery	■			■		■	■				■	■		■		■
Layout &	Linear		■	■		■	■		■	■	■	■		■		■	
	Circular	■			■			■				■	■		■		■
	Back-to-back		■				■										
	Open	■	■		■		■	■	■			■	■		■	■	■
	Closed			■		■	■		■	■	■			■			
Color usage	Color contrast		■									■					
	Warm colors	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■
	Cool colors	■			■			■					■		■		■
	Neutral colors				■		■										

The seating areas located on the second floor of the building are positioned in four different zones (Figure 3). All seating areas in these zones are situated along the circulation axis. The seating areas in zones 10 and 13 consist of fixed, linear, and wooden seating elements. These areas, which are backless, armless, and intertwined with green plants, are suitable for use by more than one person. These elements are located very close to the escalator. This location provides the opportunity for short breaks in this area with heavy user traffic. At the same time, the continuation of the seating area along the railing line allows for visual connection between floors. Users can sit in one direction on these linearly arranged seating units. Furthermore, in area 11, fixed wooden and movable leather upholstered seating units are located very close to each other. The fixed wooden elements represent permanence in the space, while the movable upholstered seats offer flexible arrangement and seating options. This situation adds continuity to the space on the one hand, while also providing variability on the other. The backrest, armrest, and mobile seating units in area 12 have a similar layout, capacity, color, and material to the other mobile seating elements (Table 2).

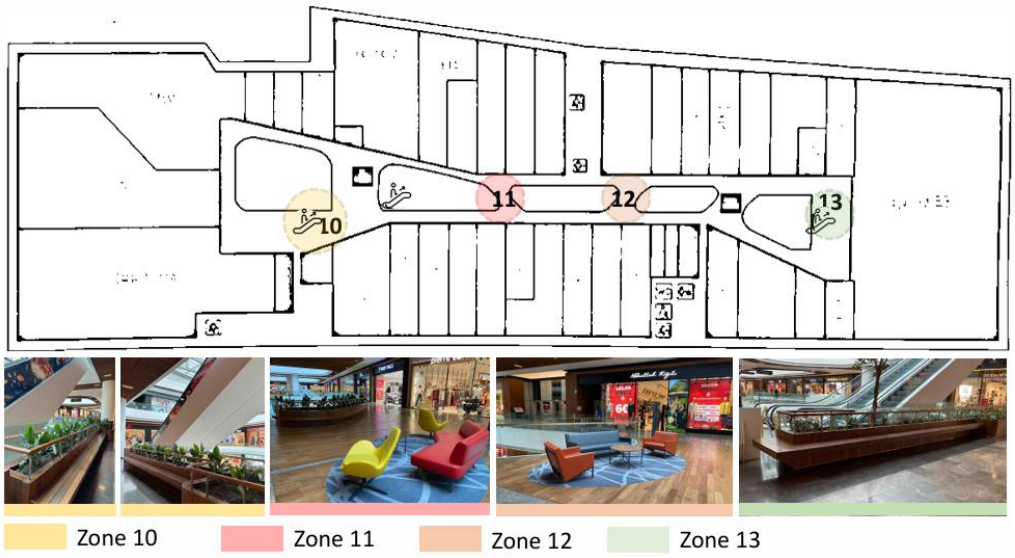


Figure 3. Seating areas on the second floor

The third floor of the workspace is primarily dedicated to food and beverage functions, with seating areas located in three separate zones on this floor (Figure 4). All of these areas, numbered 14, 15, and 16, are situated along the circulation route and consist of mobile seating units. The seating units in areas 14 and 16 are leather-covered, with backrests and armrests. Providing a circular seating arrangement, these units allow for individual and group seating while also having an open spatial layout in terms of orientation and access. It has been observed that these areas, which combine warm and cool colors, are suitable for relatively long periods of sitting. The proximity of seating area 14 to the children's play area and book sales area was a particularly influential factor in the design and selection of these units. The wooden seating units on the floor, with their linear arrangement and lack of backrests and armrests, were found to be arranged in a way that supports relatively short periods of sitting (Table 2).



Figure 4. Seating areas on the third floor

4.Conclusion and Recommendations

Shopping malls, which have become an important component of urban life, are spatial reflections of consumer culture. Shopping malls stand out as multifunctional structures where shopping, relaxation, and socializing practices are experienced together. In this context, seating areas within shopping malls enable users to have short-term relaxation and socializing experiences. Within the scope of this study, the characteristics of the seating areas at Samsun Piazza were examined in terms of location, furniture type, material, capacity, layout, and color parameters.

- Seating areas serve as focal points on each floor. The areas are designed to offer opportunities for relaxation, waiting, and observation without interrupting user flow.
- The seating areas are located in highly visible areas on each floor. They establish a direct visual connection with the storefronts, particularly given the functional purpose of the building.
- The predominant use of movable seating elements offers the advantage of flexible use for new arrangements in response to possible events and/or crowds in the shopping center.
- While there is diversity in terms of layout and placement, circular and clustered arrangements are predominant. This layout provides an environment conducive to social interaction as well as waiting and resting.
- The color selection is predominantly a combination of warm and cool colors. The fact that the seating units are mostly upholstered in leather makes them easy to use in terms of durability, maintenance and hygiene.

Thanks and Information Note

The article complies with national and international research and publication ethics. 1st Author %100 contributed. There is no conflict of interest.

References

Bitner, M. J. (1992). Servicescapes: The impact of physical surroundings on customers and employees. *Journal of Marketing, 56*(2), 57–71.

Caymaz, G. F. Y. (2021). Evaluations of urban seating design criteria in case of Zorlu Center and Margi Outlet Malls. *CAP-Public Art Journal, 3*(1), 70–91.

Grabiec, A. M., Łacka, A., & Wiza, W. (2022). Material, functional, and aesthetic solutions for urban furniture in public spaces. *Sustainability, 14*(23), 16211.

Hami, A., Moula, F. F., & Maulan, S. B. (2018). Public preferences toward shopping mall interior landscape design in Kuala Lumpur, Malaysia. *Urban Forestry & Urban Greening, 30*, 1–7.

Hidayetoglu, M. L., Yildirim, K., & Akalin, A. (2012). The effects of color and light on indoor wayfinding and the evaluation of the perceived environment. *Journal of Environmental Psychology, 32*(1), 50–58.

Ihtiyar, T. N., & Yücel, G. F. (2021). Evaluations of urban seating design criteria in case of Zorlu Center and Margi Outlet Malls. *CAP-Public Art Journal, 3*(1), 72–93.

Jung, C., & Abdelaziz Mahmoud, N. S. (2023). Exploring customer behavior in shopping malls: A study of rest areas in Dubai, United Arab Emirates. *Sustainability, 15*(12), 9169.

Okuyucu, Ş. E., & Işbeceren, M. Ü. (2023). The effect of seating elements in accordance with the social distance on the shopping mall preferences of customers in the post-pandemic process. *Ain Shams Engineering Journal, 14*(10), 102149.

Prayoonhong, R., Joneurairatana, E., & Sirivesmas, V. (2024). Exploring seating design to reflect Thai identity and enhance functionality in public spaces. *Sripatum Review of Humanities and Social Sciences, 24*(2), 171–185.

Wakefield, K. L., & Blodgett, J. G. (1996). The effect of the servicescape on customers' behavioral intentions in leisure service settings. *Journal of Services Marketing, 10*(6), 45–61.

Zhang, Z., Fei, T., & Wang, K. (2024). Analyzing the impact of interior public space on user satisfaction in shopping malls using virtual reality simulation experiments. *Buildings, 14*(10), 3264.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Current Research Trends in Interior Architecture: A Conceptual Mapping

Serap FAİZ BÜYÜKÇAM [1*]

ORCID 1: 0000-0003-4263-1671
[1]Assoc. Prof. Dr, Ondokuz Mayıs University, Faculty of Architecture, Department of Interior Architecture, Samsun- Türkiye
serap.faizbuyukcam@omu.edu.tr (Responsible Author)

Hande YILDIRIM [2]

ORCID 2: 0000-0003-0504-2886
[2]Research Assistant, Samsun University, Faculty of Architecture and Design, Department of Interior Architecture and Environmental Design, Samsun-Türkiye
hande.yildirim@samsun.edu.tr

Abstract

Interior design is a discipline that produces solutions to provide users with the most suitable design according to functional, structural, and aesthetic criteria to meet their needs. Focusing on the spaces where users spend a significant part of their daily lives, this discipline aims to improve the quality of life and enhance the spatial experience in its social, cultural, psychological, sensory, technological, and environmental dimensions. In this regard, evaluating the volume of publications produced in recent years and the prominent themes is important for understanding the multidimensional nature of interior design studies. Within this scope, the study aims to reveal the visibility of scientific production that has contributed directly and indirectly to the discipline of interior architecture over the past decade. In this study, which analyzes publications in the architecture category of the Web of Science database, the conceptual structure of the discipline is interpreted through numerical data and thematic maps. The study is limited to articles in the database, and the sample consists of 205 studies. The Biblioshiny and VOSviewer software, which are the visual interfaces of the R-based bibliometrix package, were used in the data analysis. The analyses revealed that the concept of interior design occupies a central position and is linked to concepts such as design education, furniture, culture, biophilia, sustainability, and artificial intelligence. These relationships form the conceptual core of the discipline over the past decade and indicate that research has developed in a multidimensional structure.

Keywords: Interior architecture, biblioshiny, vosviewer, bibliometric analysis

1. Introduction

Interior architecture is a multifaceted discipline that prioritizes human needs and encompasses art, science, and technology. This discipline aims to design interior spaces that respond to user needs and are functional, aesthetically pleasing, and psychologically balanced (Jones, 2008; Kilmer & Kilmer, 2014). Emerging from the human need for shelter, interior design is a dynamic discipline focused on improving quality of life and shaped by the needs of everyday life. The discipline of interior architecture, which is present in spaces with different functions such as living, working, entertainment, health, and education, plays a decisive role in the processes of structuring action-related relationships and ensuring spatial comfort in these spaces. In addition, the design of elements such as form, texture, color, materials, lighting, and furniture also falls within the scope of the discipline of interior architecture. In the design of interior spaces, it is important to improve quality of life, provide functionality, and offer an aesthetic experience (Kilmer & Kilmer, 2014).

The presence of interior architecture in the academic field is critical for the profession's ability to adapt to social, technological, and environmental changes. Academia addresses the interior architecture profession not only in terms of its design and application dimensions but also in its

theoretical, historical, and methodological aspects (Attiwill, 2004; Vischer and Poldma, 2003). Academic studies in the field of interior architecture are one of the most effective ways to define the boundaries of the discipline and guide the development of the profession. In addition, academic studies related to the field encourage interior architecture to establish common research grounds with different fields such as psychology, environmental behavior studies, architecture, engineering, art, materials science, and technology, while maintaining its interdisciplinary nature. This situation nourishes both the scientific and creative aspects of the discipline, enabling interior architecture to develop a unique identity based on methods grounded in understanding human behavior and intuitive design processes (Pottgiesser, 2011). Academic studies in the field of interior architecture interact with the profession's processes of research, inquiry, and innovation. These studies play an important role both in ensuring the continuity of professional knowledge production and in defining the discipline in a way that can respond to the requirements of the era (Lopez, 2023). In this context, the subject of the study is to reveal the current state of the discipline in the academic sphere within the scope of scientific articles published in the field of interior architecture over the last ten years.

2. Materials and Methods

The study aims to reveal the conceptual and thematic structure of academic publications in the field of interior architecture in recent years. To this end, it seeks to examine current research trends in the field and analyze the publication network. Considering its widespread use, the Web of Science (WoS) database was used in the data collection process. Searches were conducted using the keyword “interior design” in the “architecture” category. The search was performed based on the title, abstract, and keywords. Articles found in the database were included in the study. The data obtained was limited to the last 10 years in line with the purpose of the study. Within this scope, a sample of 205 articles was created.

Bibliometric analyses were performed using the VOSviewer and R-Studio Biblioshiny programs for data analysis. Word network maps and journal citation maps were created using the VOSviewer program. Using the R-Studio Biblioshiny program, graphs were created for year, index, prominent journal, publication language, and country distribution, followed by a bibliometric factor analysis based on thematic mapping and conceptual clustering.

3. Findings and Discussion

Over the past 10 years, there has been an increase of approximately 100% in the number of articles published on “interior design”. In this context, 2025 was the year with the highest number of publications, with 31 articles, while 2024 ranked second with 27 articles. 2021 was another year with a high number of publications, with 26 articles. The period evaluated in the study recorded the lowest number of articles published in 2020 (Figure 1). The decline in this year, which was limited to 10 studies, may be related to the conditions of the COVID-19 pandemic, which slowed down the research and publication processes. On the other hand, the rhythmic increase in the number of publications is thought to be directly related to the increasing number of researchers, the expanding research area, and the opportunities for publication.

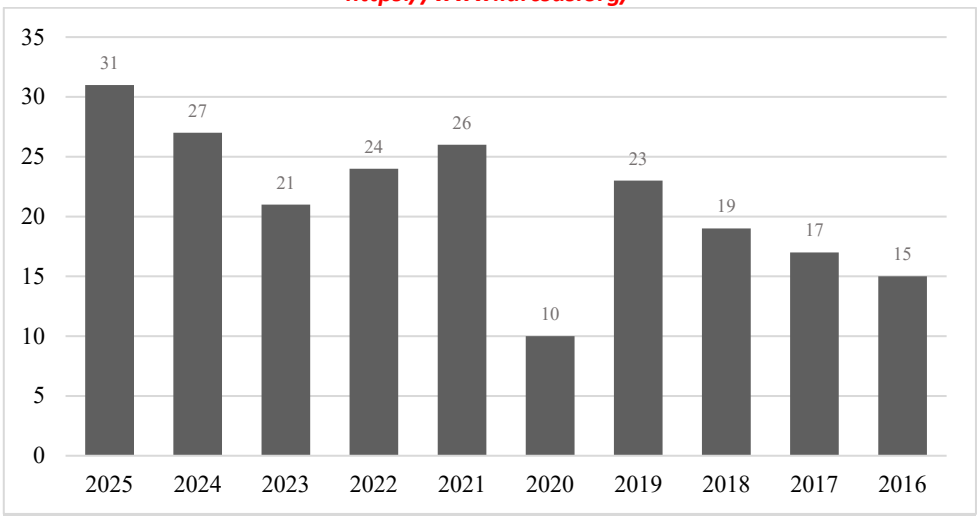


Figure 1. Number of articles by year

Looking at the distribution of articles according to the indexes of the journals in which they are published, it can be seen that the highest group, with 154 studies, is included in the Arts and Humanities Citation Index (A&HCI). This is followed by the Emerging Sources Citation Index (ESCI) with 52 studies. This trend stems from interior architecture being a design and art-based discipline. Consequently, it can be said that the studies produced in this field largely involve conceptual and qualitative approaches. The small number of articles published in the Social Sciences Citation Index can be explained by the fact that studies in the field of interior architecture involve qualitative and interpretive approaches rather than data-based social science analyses (Figure 2).

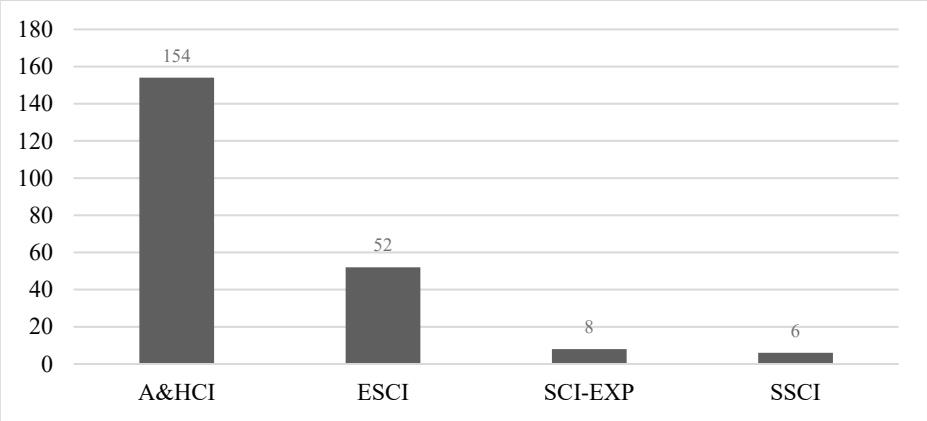


Figure 2. Distribution of articles by journal according to their indexes

When examining the distribution across journals, it was determined that the Journal of Interior Design published the most articles, with 57. This was followed by Interiors: Design Architecture Culture, with 39 articles (Table 1). It is noteworthy that nearly half of the total number of publications over the last ten years were concentrated in these two journals. This situation shows that academic production in the field of interior architecture is concentrated around certain publication networks. However, it can be said that these leading journals both direct research trends and shape a significant part of the knowledge base within the discipline. Furthermore, the fact that the names of these two journals, which stand out in terms of

publication numbers, include the term 'interiors' indicates that these journals tend to give more space to interior-themed research. The concentration of publications in a few specific journals indicates that the field has reached thematic maturity on the one hand, but also points to limited diversity in publications on the other.

Table 1. Journals and publication numbers

Journal Title	Number of Publications
Journal of Interior Design	57
Interiors Design Architecture Culture	39
ICONARP International Journal of Architecture and Planning	12
Archnet IJAR International Journal of Architectural Research	11
Journal of Asian Architecture and Building Engineering	8
Megaron	6
Design Issues	5
Fabrications the Journal of the Society of Architectural Historians	5
Frontiers of Architectural Research	5

The language distribution of articles shows that almost all publications are in English. English was followed by Spanish, Turkish, Dutch, Portuguese, Croatian, and Italian (Figure 3). This distribution shows that knowledge production in the field of interior architecture is largely conducted through international academic interaction in English. The limited number of publications in languages other than English may be due to the insufficient representation of studies conducted in local languages in international databases.

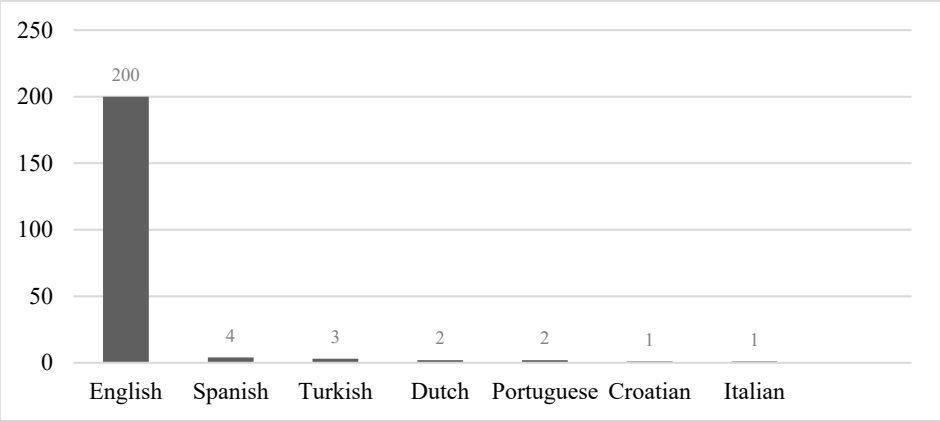


Figure 3. Distribution of articles by language of publication

An analysis of international publication output and geographical distribution trends reveals that the United States has the highest number of publications, with 78 articles. This situation reveals that the United States is a pioneer in the academic development of the field. However, the acceptance of the interior architecture profession and the establishment of its applicable infrastructure in the United States (Tate and Smith, 1986; Kaptan, 2003) can be seen as a factor that has paved the way for the concentration of academic production in this discipline in this

country. Turkey's second place with 30 studies can be attributed to the increasing academic importance given to interior architecture education and research in recent years (Eyüboğlu and Faiz Büyükçam, 2022; Şekerci and Oral 2023). The other eight countries following Turkey contributed to the field with an average of 10 articles each (Figure 4). This situation reveals that international publication production in the field of interior architecture is largely concentrated in certain countries. The fact that the total number of publications is focused around a small number of countries indicates that interior architecture research has a limited representation at the international level.

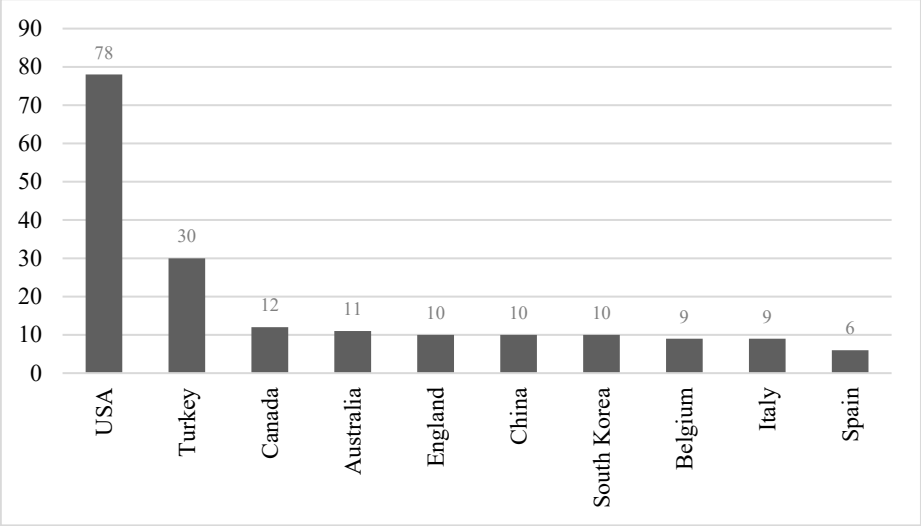


Figure 4. International publishing production and geographical distribution trends

A word network map has been created for 205 articles published between 2015 and 2025. This map shows the transformation of research trends in the field of interior design over time. At the center, the concepts of “interior design” and “architecture” are seen to be intensely connected. The prominence of the concepts “design education,” “interior design education,” and “design pedagogy” in this network structure indicates that education-based research occupies a strong position in interior architecture. According to the color scale, current research related to the discipline includes “artificial intelligence,” “inclusive design,” “sustainable development,” “empathy,” and “pandemic.” This reveals that themes such as technological developments, inclusivity, sustainability, and user sensitivity have gained importance in recent interior architecture research. Furthermore, the close relationship between “artificial intelligence” and “design education” in particular indicates that digitalization and artificial intelligence-based approaches in design pedagogy have become a rising research trend. On the other hand, early studies focused on aesthetic and spatial themes such as “art,” “exhibitions,” and “illumination” (Figure 5). This shows that interior architecture has evolved over the last decade from a research field focused on aesthetics and spatial formation to one centered on education, technology, and sustainability.

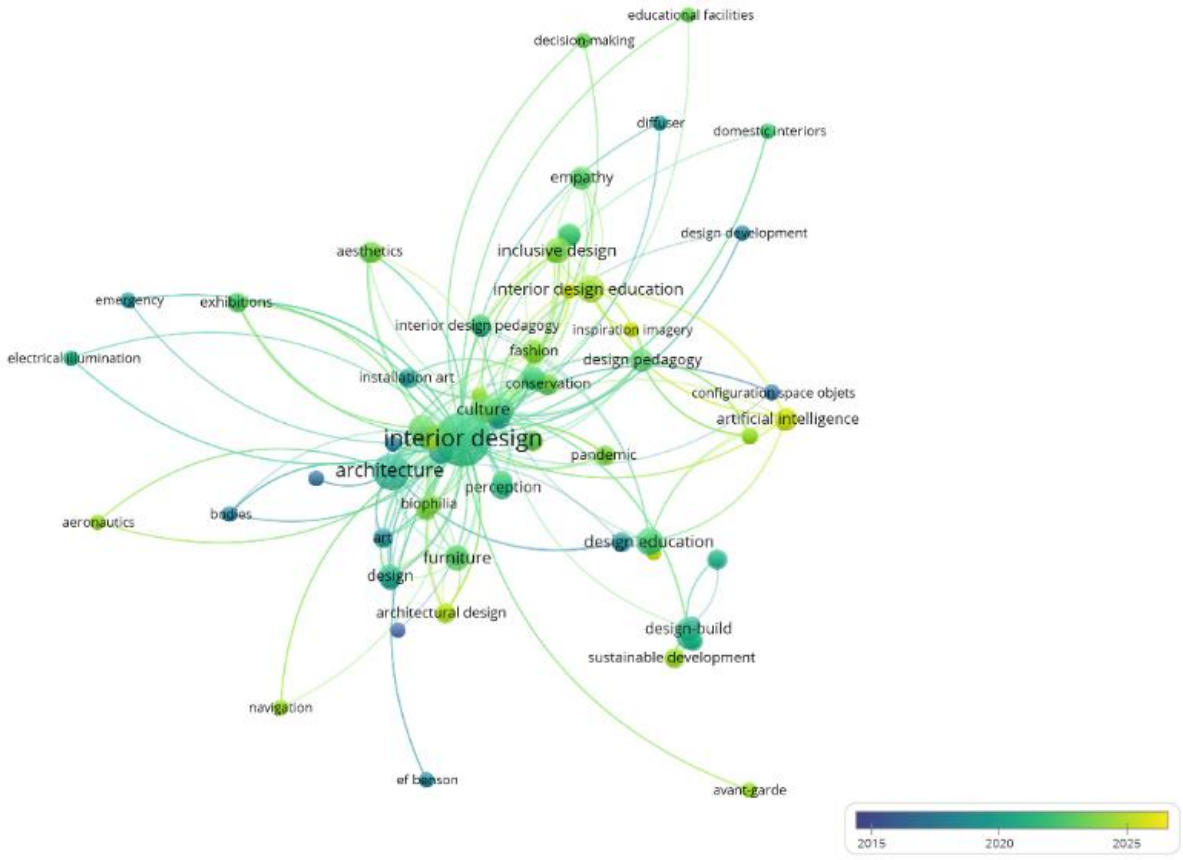


Figure 5. Word network map

A thematic map has been created showing research topics in the field of interior architecture grouped into four main clusters according to their centrality and level of development (Figure 6). According to this map, the concepts of "interior design," "interior design education," and "environment" located in the lower right region are the most fundamental and consistent research areas. This indicates that interior architecture studies are shaped around approaches focused on space, environment, and education.

The concepts of "performance," "stress," and "culture" in the upper right section are driving themes with both high centrality and high development. Accordingly, psychological, cultural, and behavioral themes have gained importance in interior architecture research and are seen as studies that guide the field. The concepts of "art," "emotions," and "model" in the upper left represent studies that are original but have a limited scope of influence. Accordingly, it has been observed that studies focusing on the emotional and artistic dimensions of interior architecture have a limited relationship with the discipline's general research framework. However, it has been observed that the "COVID-19" theme has risen periodically but has not fully established itself in the general research field. The themes located in the lower left region cover both emerging and declining topics due to their low centrality and development values. Accordingly, considering the intensities, the concepts of "design education," "creativity," and "technology" have been prominent and developing research areas in the field of interior architecture in recent years. When the thematic map is evaluated overall, it is seen that the field

of interior architecture has been shaped around education, environment, culture, and user experience.

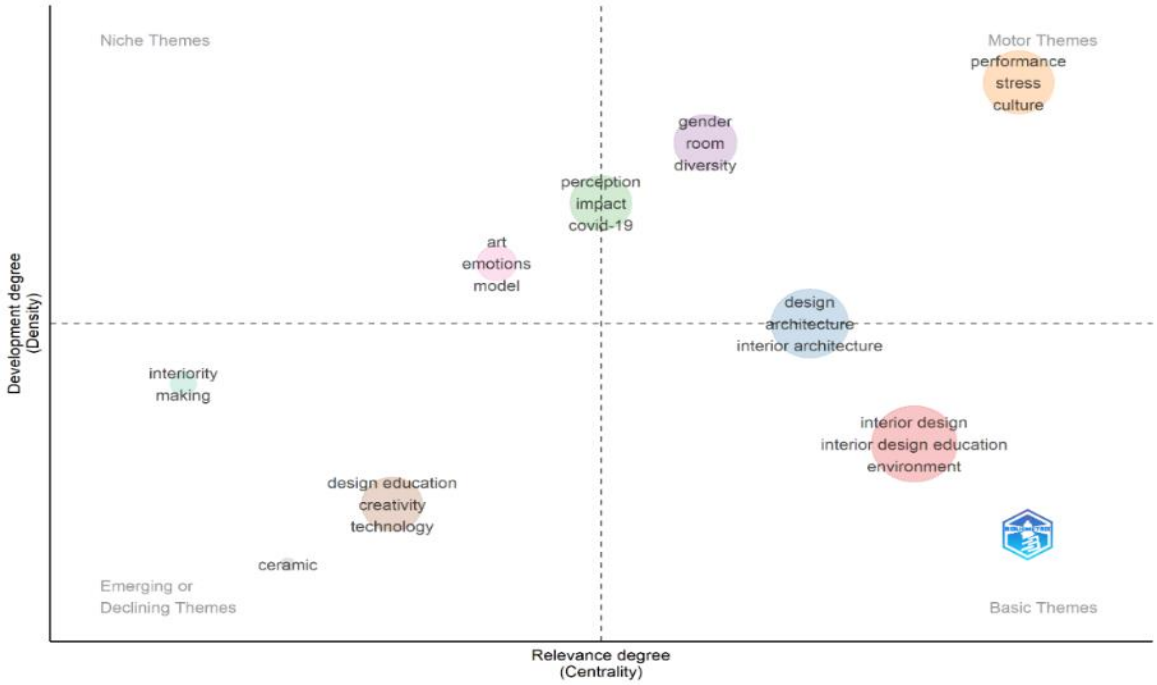


Figure 6. Thematic map of interior design study areas

The journal citation network map created using VOSviewer (Figure 7) shows which journals academic publications in the field of interior design are concentrated around and the levels of interaction between journals. Upon examining the map, it is seen that the Journal of Interior Design has established strong citation relationships with other publications and occupies a central position. The journal with the strongest connection to the Journal of Interior Design is Archnet-IJAR: International Journal of Architectural Research. This finding indicates that there is a direct citation exchange (referencing/citing each other) between the two journals. The other journals on the map interact with interior design literature to a relatively limited extent. Overall, it was observed that academic production in the field of interior design is concentrated around a limited number of journals and, consequently, bibliometric visibility is limited.

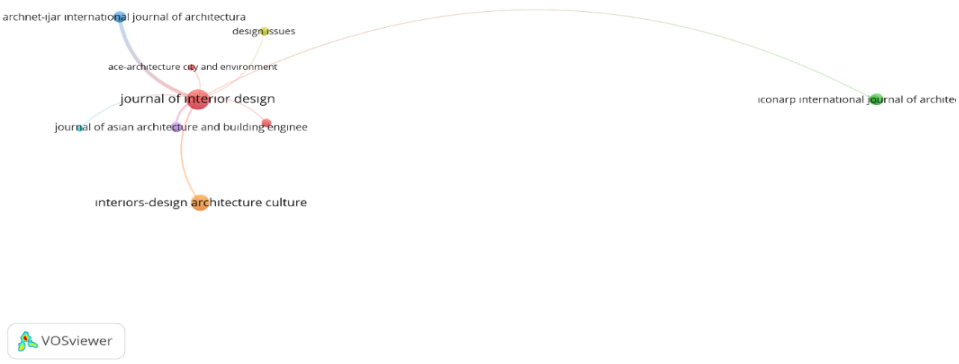


Figure 7. Journal citation network analysis

When examining the conceptual structure map provided in Figure 8, it can be seen that research themes in the field of interior architecture are concentrated in different clusters. The concepts of design education, creativity, artificial intelligence, and technology, located in the upper right section of the map, represent current and innovative research trends in the field. The clusters of design pedagogy, BIM, and visualization, located in the lower right section, represent research that addresses the integration of digital tools and visualization techniques into educational processes. The concepts of home and perception, located on the left side of the map, represent less connected themes in the research network. Overall, it can be seen that the bibliometric structure in the field of interior architecture is grouped into two main clusters: technology and education-focused design research, and user experience and perception-focused themes.

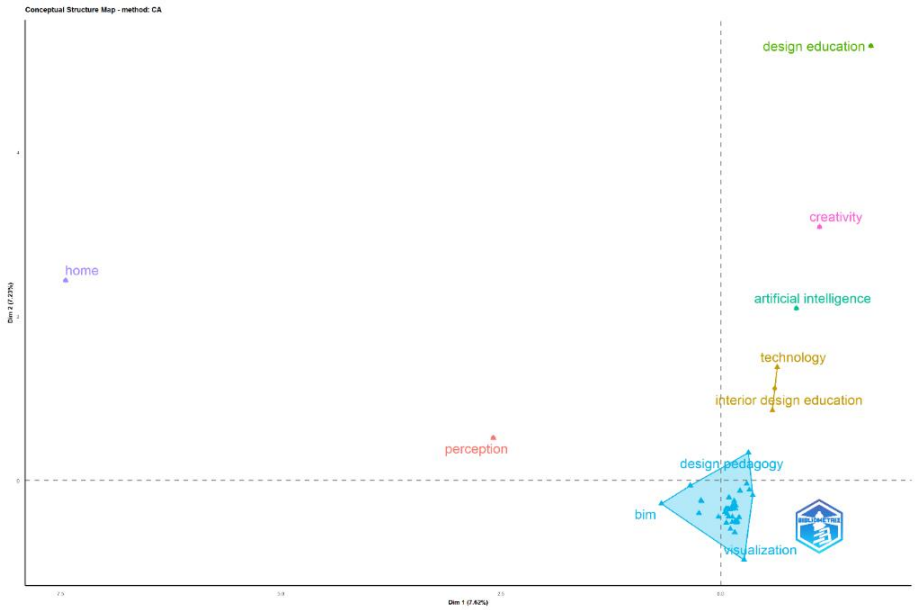


Figure 8. Conceptual clustering-based bibliometric factor analysis

The top 10 most cited articles indicate that research in interior architecture is concentrated around specific topics (Table 2). The highest number of citations was found in VR-based design research. Artificial intelligence, environmental design, education, and user experience topics are also among the highly cited studies. In this context, it is seen that the citation distribution is generally high in technology and experience-focused studies.

Table 2. Top 10 most cited articles

	Article title	Year	Citation
1.	Virtual environments for design research: Lessons learned from use of fully immersive virtual reality in interior design research	2020	48
2.	Application of AI methods in the clustering of architecture interior forms	2017	24
3.	Surroundings and Environments in Fourth Order Design	2019	23
4.	Understanding Spatial Ability in Interior Design Education: 2D-to-3D Visualization Proficiency as a Predictor of Design Performance	2019	21
5.	Spatial User Experience: A Multidisciplinary Approach to Assessing Physical Settings	2020	20

6.	Diy Biophilia: Development of the Biophilic Interior Design Matrix as a Design Tool	2019	19
7.	The 8-Hour Challenge: Incentivizing Sleep during End-of-Term Assessments	2019	16
8.	Silver and Gold Leed Commercial Interiors: Certified Projects	2019	16
9.	Assessing Architectural Color Preference After Le Corbusier's 1931 Salubra Keyboards: A Cross Cultural Analysis	2021	13
10.	Virtual Reality Versus Real- World Space: Comparing Perceptions of Brightness, Glare, Spaciousness and Visual Acuity	2022	12

4. Conclusion and Recommendations

This study, which evaluates the perspective on the last decade of article studies in the field of interior architecture, indicates that the increasing research output points to the discipline's development at both the academic and professional levels. However, the fact that the majority of the studies are published in journals within the A&HCI scope indicates that theoretical and interpretation-based, qualitative research trends are prominent in the discipline's research methodologies. The fact that publications in the field of interior architecture are largely concentrated in the Journal of Interior Design and Interiors: Design Architecture Culture indicates that the field is limited in terms of journal diversity. However, it is clear that English plays a decisive role in international academic interaction. The global representation of the field has been largely limited to the United States. It is clear that interior architecture research has evolved from aesthetic and spatial themes towards technology, education, and sustainability between 2015 and 2025. In addition, concepts such as artificial intelligence and digitalization have emerged as new research trends in the discipline in recent years.

The central and advanced research areas in the discipline have been topics focused on education, environment, culture, and user experience. However, it is clear that interior architecture research, which has been shaped around pedagogical-technological and space-human centered topics, has recently come to the fore with technology-education based studies. In citation analysis, it is evident that the most cited studies are concentrated around technology and user experience-focused research.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Attiwill, S. (2004). Towards an interior history. *Idea Journal*, *5*(1), 1-8.

Eyüboğlu, H., & Büyükçam, S. F. (2022). Lisans ve lisansüstü derslerle Türkiye'de güncel iç mimarlık eğitimi. *Yakın Doğu Üniversitesi Yakın Mimarlık Dergisi*, *6*(2).

Jones, L. (2008). *Environment and Interior Design*. Fairchild Books

Kaptan, B. B. (2003). 20. Yüzyıldaki toplumsal değişimler paralelinde iç mekan tasarımı eğitiminin gelişimi, Sanatta Yeterlilik Tezi, Anadolu Üniversitesi, Sosyal Bilimler Ensititüsü, Eskişehir.

Kilmer, R., & Kilmer, W. O. (2014). *Designing Interiors* (2nd ed.). Wiley.

López, D. E. R. (2023). Interior design as a relegated discipline in the academic and professional stage in Colombia. *Journal of Interior Design*, *48*(2), 95-100.

Pottgiesser, U. (2011). Interior design as an academic discipline in Germany. *Journal of Interior Design*, *36*(4), 5-14.

Şekerci, C., & Oral, M. (2023). İç mimarlık eğitim müfredatının oluşturulmasında güncel yaklaşımlar. *Sanat Yazıları* (*48*), 215-226.

Tate, A., & Smith, C. R. (1986). *Interior design in the 20th Century.* New York: Harper and Row Publishers.

Vischer, J., & Poldma, T. (2003). Growing a discipline: evolving learning practices in interior design. *Idea Journal*, *4*(1), 173-184.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

In Search of Thermal Comfort: Forgotten Design and Planning Principles for Cities

Nursevil YUCA[1]*

ORCID 1: 0000-0002-7985-7706
[1]Research Assistant, Van Yuzuncu Yil University, Faculty of Architecture, Department of Landscape Architecture, Van-Türkiye
nursevilyuca@yyu.edu.tr **(**Responsible Author)

Feran AŞUR[2]

ORCID 2: 0000-0001-9480-5536
[2] Assoc. Prof. Dr., Van Yuzuncu Yil University, Faculty of Architecture, Department of Landscape Architecture, Van-Türkiye
feranasur@yyu.edu.tr

Abstract

With rapid urbanization, building density has increased, reducing open and green spaces and natural habitats. Although urbanization offers diverse employment, transportation, and social opportunities, it has also led to declining thermal comfort due to urban heat islands and extreme weather events, negatively affecting urban quality of life. Since thermal comfort is closely linked to well-being, studies focusing on mitigating the urban heat island effect and enhancing thermal comfort have gained growing attention.

This study reviews recent research on thermal comfort across various climate zones and analyzes the design and planning decisions that influence it. Findings indicate that key strategies such as providing shading, considering wind direction, selecting appropriate surface materials, and integrating water elements are essential for achieving outdoor thermal comfort. However, despite their long-standing recognition, these principles are often neglected in modern urban design. Therefore, this study highlights the need to revisit and integrate these fundamental yet overlooked design principles to promote thermally comfortable and sustainable urban environments.

Keywords: Thermal comfort, UHI, urban design, urban planning, climate change

1. Introduction

The duration, frequency, and timeframe of outdoor space use in cities, as well as the age group using it, depend on the city's climate. While outdoor use is more common in cities with more livable climates, recent changes in climate and weather conditions have affected individuals' health and comfort, leading to a decline in outdoor use.

A brief look at the causes of this problem: While rapid urbanization driven by global needs was initially minor, over the last 50-60 years, it has rapidly altered the unique fabric of cities. Open and green spaces, which provide outdoor living areas for other living creatures, have been unintentionally destroyed and replaced by unplanned urban development, and this trend continues to this day (Sirakaya et al., 2018). Especially over the last 30 years, people in countries affected by war and weather disasters have abandoned their homes and begun to crowd into other cities. This, in turn, has led to increased urbanization and increased human activity in these cities. This has led to an increase in the Urban Heat Island effect (UHI) (Chen et al., 2022; Guo et al., 2022; Yuca, 2025), which occurs when urban areas are warmer than surrounding rural and suburban areas. Consequently, the adverse effects of climate change are felt more intensely in cities.

The IPCC's (Intergovernmental Panel on Climate Change) latest assessment report, published in 2022, asserts that rising temperatures in urban areas are directly linked to increased threats to human health (IPCC, 2022). In line with this alarming information, Article 13 of the United

Nations' Sustainable Development Goals emphasizes the need for urgent measures to combat climate change and mitigate its effects. The most crucial step in this process is to reduce the heat impact in cities.

Therefore, in recent years, numerous studies on thermal comfort in urban microclimates have been conducted in academia to mitigate the effects of global climate change and create healthy cities (Jin et al., 2020; Gachkar et al., 2021). All of these studies have concluded that there is a direct relationship between climate conditions and the use of outdoor spaces (Deng and Wong 2020; Karimi et al., 2021). Thermal comfort is the degree to which people are satisfied with the climatic conditions of their environment (Yan et al., 2021). People avoid using outdoor spaces in very hot, very cold, windy, or humid environments because they experience thermal discomfort (Ahmed et al., 2024). However, it is known that outdoor use is higher in more sustainable, healthy cities where climate conditions are more livable and air quality is high (Russo, 2024). In this context, one of the most essential steps in creating healthy cities is to provide suitable climatic conditions in outdoor public spaces where people can spend time, relax, and communicate. The thermal comfort of these spaces is the most important environmental factor affecting individuals' participation in outdoor activities (Geng et al., 2022). Comfortable urban open spaces help promote outdoor activities, social interactions (Lai et al., 2020a), and sustainable urban development (Tian et al., 2022).

Public spaces are often the first thing that comes to mind when creating healthy, sustainable cities. While public spaces usually come to mind first, streets are the primary link between urban outdoor spaces, connecting open green spaces, squares, and gathering areas. While streets are often associated with vehicular traffic, they also serve as community hubs for activities such as walking, cycling, providing transportation to public spaces, socializing, shopping, and more (Lee and Mayer, 2018). Therefore, in the context of designing healthy cities, promoting walkability between interconnected areas and ensuring both sustainability and well-being are key priorities (Necira et al., 2024). Adverse thermal comfort conditions due to excessive heat stress are a critical barrier to walking and can significantly impact a person's desire to walk and time spent walking (Suwanmanee et al., 2024). This, in turn, can impair walkability, street livability, and urban vitality (Arif and Yola, 2021; Oppermann et al., 2021; Tumini et al., 2016). Therefore, many studies have been conducted to assess and improve outdoor thermal comfort in streets to improve sustainable, healthy urbanization and walkability (Boussaidi et al., 2023; Siqi et al., 2023). These studies also evaluated street dimensions related to walking-related thermal comfort, including land-use differences, street connectivity, street inclination, human-scale issues, and transparency. In addition, recent studies have been conducted across different climatic regions worldwide to analyze and improve thermal comfort in outdoor spaces (Lai et al., 2020b; Huang et al., 2019; Nogueira et al., 2020). Some of these studies focused on measures to reduce the UHI effect caused by summer temperatures in cities (Zhen et al., 2022), while others focused on temperature changes in winter (Huang and Peng, 2020) or stable temperature changes occurring throughout the year (Lu et al., 2019; Zhou et al., 2019; Yuca, 2024). In these studies, the most appropriate indices were selected based on the characteristics of the study area. While the PET (Physiological Equivalent Temperature) index is generally used to determine outdoor thermal comfort, some studies also use indices such as the predicted mean vote (PMV) and the Universal Thermal Climate Index (UTCI).

On the other hand, while some of these studies utilize past climate data and field analysis (Karimi and Muhammed, 2021), many studies have recorded current climate data and generated different scenarios to improve the study area. Based on the climate changes in these scenarios,

recommendations for public space design and planning in urban areas have been made (Arrar et al., 2024; Yuca, 2025). Generally, when these studies conducted worldwide are examined, each study offers design and planning recommendations that can be implemented by the disciplines of landscape architecture, architecture, and urban and regional planning to reduce heat stress in cities. This study examines global studies and discusses these recommendations.

Thermal Comfort Studies Conducted Around the World

This section examines studies on the investigation and improvement of thermal comfort in outdoor urban environments across regions with different climates worldwide. In this context, firstly;

Karimi and Muhammed (2022) conducted a study examining outdoor thermal comfort among tourists visiting historical squares in Sevilla and Madrid (Figure 1), where high summer temperatures and occasional heat waves lead to heat stress. The research aimed to determine a reasonable and comfortable visit duration for visitors to these historical and cultural sites. For this purpose, three squares were selected from each city, and long-term climate data from previous years were analyzed to assess thermal comfort conditions in these squares. Consequently, the study used data from July 13-14, 2021, for the squares in Sevilla, and from July 10-11, 2021, for the squares in Madrid.



Figure 1. Squares where the study was carried out (Karimi and Muhammed 2022)

The study used the ENVI-met climate simulation, which is claimed to be reliable and has been used in many studies. Because the areas have no usage restrictions, the study conducted 24-hour simulations within these time intervals. Additionally, to test the accuracy of the simulation results, climate measurements were taken at a specific height on the exact dates, and the PET index, widely used in studies of outdoor thermal comfort, was used. Subsequently, to understand users' thermal sensation in each study area, surveys were conducted in two separate time periods: morning (08:00-13:00) and afternoon (16:00-21:00). The surveys lasted 5 to 7 minutes. Because the study was conducted on a hot summer day, the survey results were closer to the high end of the range.

The study found that small areas with good vegetation have better thermal comfort conditions than other areas. While squares generally fall short of the appropriate thermal comfort range during the day, PET values are better at night. Semi-open areas with adequate afforestation provide more suitable thermal comfort conditions than other city squares.

Arrar et al. (2024) conducted a study investigating pedestrian thermal comfort in the city of Kasbah, Algeria, which has a Mediterranean climate (Figure 2).



Figure 2. The 4 regions where the Algerian Kasbah was studied (Arrar et al., 2024).

The study area features a Mediterranean architecture, with residential units arranged around a central courtyard, reflecting a 1000-year-old urban design. This emphasis is highlighted because there are no high-rise buildings that affect thermal comfort, and local materials, typically terracotta and lime, are used. Areas with the highest activity levels and diverse street types were selected for the study, and climate measurements (air temperature (Ta), relative humidity (RH), wind speed (WS), and surface temperature were conducted in these four areas from August 5 to 11, 2021. Sky images were also obtained with a fisheye lens to assess sky clarity.

Using the climate data obtained in the study, thermal comfort was analyzed using the PET value, the most commonly used index for outdoor spaces. The PET value was obtained using the ENVI-met climate simulation model. Finally, 14 different models were generated in the ENVI-met climate simulation across the four study areas to improve pedestrian thermal comfort and reduce UHI impacts.

The study concluded that the cooling effect was greater in the scenario with green roofs and green walls used together. In contrast, scenarios with green roofs and increased soil surface area were practical in all four regions, with varying cooling effects. Additionally, it was concluded that afforestation scenarios provided better cooling in some regions than in others. Cool pavements can increase outdoor thermal comfort in densely populated areas by up to 14.9°C. Increasing wall albedo (wall surface) negatively impacts heat stress in densely populated areas by increasing solar radiation reflection and surface temperatures. Shading created by the reconstruction of ruined settlements has a significant cooling effect, significantly positively impacting thermal comfort. Therefore, these scenarios have substantial implications for advising decision-makers in similar Mediterranean environmental contexts to improve existing urban fabrics and enhance livability and vitality in outdoor spaces.

Ahmed et al. (2024) conducted a study examining the impact of the UHI on thermal comfort in urban open spaces in Rome, Italy, and the strategies implemented to mitigate it (Figure 3). As in other studies, this study examined the impact of urban microclimate conditions on occupants'

thermal perception using PET, PMV, and PPD (estimated percentage of dissatisfaction) values assessed via ENVI-met climate simulations.



Figure 3. Uses of studied areas (Ahmed et al., 2024)

The study first examined the current situation in the selected study area, then developed proposed designs to improve thermal comfort, and finally obtained comparative results. The study produced new designs by adopting sustainable approaches that require greater attention in urban open spaces, such as adding more vegetation, improving tree planting according to design principles, enhancing connectivity between sub-areas, changing pavement materials, adding water features, and creating more shaded areas. Microclimate models were simulated to assess the impact of the strategies used in these designs on PET, PMV, and PPD.

The study found that the redesigned project had a significant cooling effect on PET, PMV, and PPD during a summer day scenario. While the 9 a.m. simulation of the current situation showed a moderate heat stress level, with PET reaching 37.4°C, PPD reaching 73.7%, and PMV reaching 1.93, the designed project reduced morning PET by up to 19°C, PPD by 20%, and PMV by an average of 1 point, resulting in more comfortable conditions. Another finding was that at 3:00 p.m., while the current situation was extremely sweltering everywhere, with PET at 51.2°C (extreme heat stress), high dissatisfaction at 97.39% PPD, and PMV at 3.97, the simulation of the redesigned area reduced PET by up to 4°C, reducing PPD by more than 30% and PMV by more than 2 points. Finally, this study indicates that detailed redesign strategies, such as incorporating vegetation, changing tree placement, improving connections, and adding water features, can serve as a practical guide for creating urban areas with high human and thermal comfort.

Kozak & Lipecki (2025) conducted a study investigating the effects of green walls on thermal comfort and microclimatic conditions in a modern residential area in Lublin, Poland (Figure 4).



Figure 4. The studied residential area (Kozak and Lipecki 2025)

The study first defined the study area in detail (story heights, building density, and land use). The ENVI-met simulation then modeled and compared the current situation with the design incorporating green walls. The Universal Thermal Climate Index (UTCI) was used as the index in the study. Simulation results indicated that green walls caused a statistically significant but slight decrease in maximum UTCI values across the site, with a peak difference of 0.16°C recorded at 3:00 PM, the hottest hour of the day. Green walls can significantly improve the microclimate in the immediate vicinity of buildings, and UTCI differences can reach up to 3.68°C during intense solar radiation. Another finding emphasized that while green walls help mitigate extreme heat, their effectiveness alone is insufficient to achieve significant improvements in thermal comfort during heat waves, and that for maximum impact, green walls should be integrated with complementary adaptation strategies.

Thermal Comfort Studies Conducted in Turkey

Global climate change is already having adverse effects in many countries, including Turkey. Consequently, thermal comfort studies have recently started in cities with varying climate conditions in Turkey. This section examines studies conducted on the investigation and improvement of thermal comfort conditions in outdoor urban environments in Turkey.

Adıguzel et al. (2022) conducted a study in the Toroslar Neighborhood of Çukurova District, located in the northern part of Adana, where high-rise and dense construction is prevalent (Figure 5). In this study, instantaneous measurements of temperature and relative humidity were taken using a portable climate measurement device around Hayal Park at 07:00, 14:00, and 21:00 on Tuesday, August 20. Thermal comfort zones were determined by measuring temperature and relative humidity at 25 different locations in the study area.



Figure 5. Measured points in the study (Adıguzel et al., 2022)

The study area was then imported into ArcGIS for GIS analysis, and temperature and relative humidity distribution maps were created. Analysis of the distribution maps revealed that areas outside Hayal Park were classified as hot at 7:00 a.m., and that green spaces positively affected thermal comfort zones. Smaller areas were classified as very hot, and by 2:00 p.m., they were fully hot. Heat stress in these areas was thought to be due to the presence of multi-story buildings in the study area, and to asphalt and concrete surfaces that increased temperatures. Consequently, the study identified uncomfortable areas and determined that the urban plan needed to be revised to bring the area within the thermal comfort range, as urban form and

settlement affect climate comfort. To achieve this, the study emphasized reducing the impact of heat on the study area by reducing asphalt and concrete surfaces and increasing the density of open and green spaces.

Ertem, Mutlu, and Yılmaz (2024) examined the effects of different green space ratios on the microclimate and outdoor thermal comfort in Erzurum, a winter city. The Yıldızkent district, a new settlement in Erzurum, was selected as the study area, and microclimate data were recorded hourly for one year with an installed climate device. Five different green space increase scenarios were then created, each with a different level of green space (10%, 20%, 30%, 40%, and 50%). A total of six different scenarios (including the current situation and the creation of five green spaces) were simulated for outdoor thermal comfort using the ENVI-met program for the hottest (summer) and coldest (winter) periods of 2021. The study found that scenarios with increased green space did not differ significantly from the current situation. Only the 10% green space ratio scenario for mean radiant temperature (Tmrt) and the 30% green space ratio scenario for PET yielded positive results in both winter and summer. The study revealed that scenarios with increased green space had a positive effect on the microclimate and led to greater outdoor thermal comfort.

Yuca (2025) analyzed the impacts of Lake Van on both regional and micro-scale climatic conditions and urban thermal comfort within the province of Van (Figure 6). For regional-scale analyses, long-term climate data from stations located in both coastal and inland districts of the lake were collected and analyzed. Temperature and PET distribution maps were created in ArcGIS. For micro-scale analyses, climate stations were established in five regions with varying distances from Lake Van and varying urban patterns, and a total of one year of meteorological data was collected through 2024. Finally, using the ENVI-met microclimate model, climate data from the two stations were used to generate 36 different climate-adaptive design scenarios for summer and winter.



Figure 6. Areas measured for 1 year in the study (Yuca, 2025).

The study's findings indicated that a climate-adaptive design scenario with 75% planting achieved successful results, reducing PET values by 0.9-1.2°C during summer noon. Furthermore, PET analyses and ENVI-met simulations revealed that vegetation density and water-surface availability are key determinants of thermal comfort, underscoring the importance of strategically integrating water and vegetation in sustainable, climate-sensitive urban open space designs.

Zeren Çetin et al. (2025) conducted a study investigating whether improving thermal conditions is feasible for achieving healthy, livable, and sustainable urban environments.



Figure 7. Sample areas with different usage patterns (Zeren Çetin et al., 2025).

In the study, two separate regions with different surface materials were determined and it was investigated how the surface temperatures of the coatings of these two areas affected thermal comfort, especially in the summer months when heat stress is high (Figure 7). The study was conducted on September 10, 2022, at Cumhuriyet Park in the Yurt neighborhood of Adana province's Çukurova district in Türkiye's Eastern Mediterranean Region. Surface temperatures were measured by an unmanned aerial vehicle from 20 different locations. A detailed surface temperature map was also created using a thermal camera.

The study found that water surfaces had the lowest recorded temperature, while dark concrete surfaces had the highest. The findings highlight the importance of selecting surface materials to shape thermal conditions and improve thermal comfort in urban open and green spaces. The importance of carefully selecting surface materials in urban design and planning is emphasized, as is the need to create more livable, high-quality, sustainable cities. It is also suggested that increasing water surfaces, green cover, and vegetation in cities with high summer temperatures, such as those in the Mediterranean region, will positively impact thermal comfort.

Considerations for Climate-Livable Cities

With urbanization accelerating globally, including in Turkey, high-density urban development models have intensified the impact of climate change in cities while increasing the frequency of extreme weather events (Wei et al., 2023). Consequently, climate change, one of the most significant global challenges of our time, is emerging, and its most important impacts are being felt in cities. Due to the increasingly adverse climate conditions on the health of people living there and the time spent outdoors, recent efforts to mitigate climate change at the micro-scale have increased. These studies generally examine the perceived temperature range during outdoor time and how urban spaces should be designed to enhance the quality of time people spend outdoors.

This study examines several studies conducted on this topic from around the world and in Turkey. The results of these studies generally show that in areas with high climate stress and intense heat, planting significantly reduces perceived temperature, making areas more livable. When we examine other application principles that improve thermal comfort conditions from the results obtained from the studies reviewed above;

• Partially open spaces are characterized by better thermal comfort compared to surrounding urban settlements when more technical planting is implemented.

• Green roofs and green walls designed in cities have little effect when used alone, but are more effective when used together.

• Tree planting densities and combinations (depending on the species used) do not have the same impact in every residential area, providing better thermal comfort in some settlements.

• Urban areas can experience adverse thermal conditions due to the application of incorrect planting techniques, and thermal comfort can be improved by applying planting design principles in these areas.

• Cool pavements used in outdoor spaces increase thermal comfort.

• Dark-colored flooring, where it is heavily used, negatively impacts thermal comfort because it causes heat accumulation.

• Caution is needed when increasing the albedo of exterior walls, as it increases solar reflection and surface temperature.

• Reconstructing unused, dilapidated residential areas according to thermal comfort standards can positively impact thermal comfort in the surrounding regions.

• Water elements used in accordance with urban design and planning principles can increase thermal comfort.

The studies examined have shown that differences in urban geometry and climate mean the results of each study are not fully applicable to other areas. However, in general, the same methods can be applied to settlements with similar urban geometry, density of use, and climatic characteristics, as shown in previous studies.

Recently, as academics in Turkey have recognized the importance of this topic, studies have increased, and studies are still ongoing. Examining the results of these studies, it has been concluded that the correct application of the design and planning principles learned and taught since undergraduate education in the discipline of Landscape Architecture actually positively impacts thermal comfort conditions. Unfortunately, these planning and design principles, neglected during rapid urbanization, have negatively impacted outdoor thermal comfort in our lives today and exacerbated the effects of climate change, making these issues a pressing concern. Therefore, reframing the planning and design principles of landscape architecture in line with current urbanization trends is a critical necessity for creating sustainable, climate-sensitive urban environments.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Adiguzel, F., Cetin, M., Doğan, M., Güngör, S., Kose, M., Bozdogan Sert, E., & Kaya, E. (2022). The assessment of the thermal behavior of an urban park surface in a dense urban area for planning decisions. *Environmental monitoring and assessment*, 194(7), 519.

Ahmed, N. M., Altamura, P., Giampaoletti, M., Hemeida, F. A., & Mohamed, A. F. A. (2024). Optimizing human thermal comfort and mitigating the urban heat island effect on public open spaces in Rome, Italy through sustainable design strategies. *Scientific reports*, 14(1), 19931. https://doi.org/10.1038/s41598-024-65794-8

Arrar, H. F., Kaoula, D., Santamouris, M., Foufa-Abdessemed, A., Emmanuel, R., Matallah, M. E., ... & Attia, S. (2024). Coupling of different nature base solutions for pedestrian thermal comfort in a Mediterranean climate. *Building and Environment*, 256, 111480.

Arif, V., & Yola, L. (2021). The impact of Sky view factor on pedestrian thermal comfort in tropical context: A case of Jakarta sidewalk. In *Sustainable Architecture and Building Environment: Proceedings of ICSDEMS 2020* (pp. 27-33). Singapore: Springer Singapore.

Boussaidi, K., Djaghrouri, D., Benabbas, M., & Altan, H. (2023). Assessment of outdoor thermal comfort in urban public space, during the hottest period in Annaba City, Algeria. *Sustainability*, 15(15), 11763.

Chen, S., Yang, Y., Deng, F., Zhang, Y., Liu, D., Liu, C., & Gao, Z. (2022). A high-resolution monitoring approach of canopy urban heat island using a random forest model and multi-platform observations. *Atmospheric Measurement Techniques,* 15(3), 735-756.

Cheung, P. K., & Jim, C. Y. (2018). Global pattern of human thermal adaptation and limit of thermal neutrality: systematic analysis of outdoor neutral temperature. *International Journal of Climatology,* 38(14), 5037-5049.

Deng, J. Y., & Wong, N. H. (2020). Impact of urban canyon geometries on outdoor thermal comfort in central business districts. *Sustainable Cities and Society*, 53, 101966.

Ertem Mutlu, B., & Yılmaz, S. (2024). Determining the Effects of Different Green Space Ratios on Outdoor Thermal Comfort Using ENVI-met Analysis: The Case of Erzurum. *Journal of Adnan Menderes University, Agricultural Faculty, 21*(1).

Gachkar D, Taghvaei SH, Norouzian-Maleki S (2021) Outdoor thermal comfort enhancement using various vegetation species and materials (case study: Delgosha Garden, Iran). *Sustain Cities Society.* 75(8):103309. https://doi.org/10.1016/j.scs.2021.103309.

Geng, Y., Hong, B., Du, M., Yuan, T., & Wang, Y. (2022). Combined effects of visual-acoustic-thermal comfort in campus open spaces: A pilot study in China's cold region. *Building and Environment,* 209, 108658.

Guo, F., Wang, Z., Dong, J., Zhang, H., Lu, X., Lau, S. S. Y., & Miao, Y. (2022). Spatial differences in outdoor thermal comfort during the transition season in cold regions of China. *Buildings,* 12(6), 720.

Huang, Z., Cheng, B., Gou, Z., & Zhang, F. (2019). Outdoor thermal comfort and adaptive behaviors in a university campus in China's hot summer-cold winter climate region. *Building and Environment,* 165. https://doi.org/10.1016/j.buildenv.2019.106414.

Huang, H., & Peng, M. (2020). The outdoor thermal comfort of urban square: A field study in a cold season in Chongqing. In *IOP Conference Series: Earth and Environmental Science* (Vol. 467, No. 1, p. 012215). IOP Publishing.

IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. https://doi.org/ISBN 978-92-9169-161-6.

Jin, H.; Liu, S.; Kang, J. (2020). Gender differences in thermal comfort on pedestrian streets in cold and transitional seasons in severe cold regions in China. *Build. Environ.* 168, 106488.

Karimi A, Mohammad P, Gachkar S, Gachkar D, García-Martínez A, Moreno-Rangel D, Brown RD. (2021). Surface urban heat island assessment of a cold desert city: a case study over the Isfahan metropolitan area of Iran. *Atmosphere,* 12(10):1368.

Karimi, A., Mohammad, P. (2022). Effect of outdoor thermal comfort condition on visit of tourists in historical urban plazas of Sevilla and Madrid. *Environ Sci Pollut Res*, 29, 60641–60661. https://doi.org/10.1007/s11356-022-20058-8

Kozak, M., & Lipecki, T. (2025). The impact of green walls on outdoor thermal comfort in residential areas under warm weather conditions: A case study. *Urban Climate,* 62, 102541.

Lai, D., Chen, B., & Liu, K. (2020a). Quantification of the influence of thermal comfort and life patterns on outdoor space activities. In *Building simulation*, 13(1)113-125, Beijing: Tsinghua University Press.

Lai, D., Lian, Z., Liu, W., Guo, C., Liu, W., Liu, K., & Chen, Q. (2020b). A comprehensive review of thermal comfort studies in urban open spaces. *Science of the Total Environmen*t, 742, 140092.

Lee, H., & Mayer, H. (2018). Thermal comfort of pedestrians in an urban street canyon is affected by increasing albedo of building walls. *International journal of biometeorology*, 62(7), 1199-1209.

Lu, M., Hou, T., Fu, J., & Wei, Y. (2019). The effects of microclimate parameters on outdoor thermal sensation in severe cold cities. *Sustainability,* 11(6), 1572.

Necira, H., Matallah, M. E., Bouzaher, S., Mahar, W. A., & Ahriz, A. (2024). Effect of street asymmetry, albedo, and shading on pedestrian outdoor thermal comfort in hot desert climates. *Sustainability,* 16(3), 1291.

Nogueira, M., Lima, D. C., & Soares, P. M. (2020). An integrated approach to project the future urban climate response: Changes to Lisbon's urban heat island and temperature extremes. *Urban Climate,* 34, 100683.

Oppermann, E., Kjellstrom, T., Lemke, B., Otto, M., & Lee, J. K. W. (2021). Establishing intensifying chronic exposure to extreme heat as a slow onset event with implications for health, wellbeing, productivity, society and economy. *Current Opinion in Environmental Sustainability,* 50, 225-235.

Russo, A. (2024). Urban green spaces and healthy living: A landscape architecture perspective. *Urban Science,* 8(4), 213.

Siqi, J., Yuhong, W., & Hien, W. N. (2023). The effect of urban greening on pedestrian's thermal comfort and walking behaviour. In *E3S Web of Conferences,*36, 05013. EDP Sciences.

Sirakaya, A., Cliquet, A., & Harris, J. (2018). Ecosystem services in cities: Towards the international legal protection of ecosystem services in urban environments. *Ecosystem Services,* 29, 205-212.

Suwanmanee, N., Kronprasert, N., Sutheerakul, C., Arunotayanun, K., & Rinchumphu, D. (2024). Investigation of outdoor thermal comfort for campus pedestrian walkways in Thailand. *Sustainability*, 16(2), 657.

Tumini, I., Higueras Garcia, E., & Baereswyl Rada, S. (2016). Urban microclimate and thermal comfort modelling: strategies for urban renovation. *International Journal of Sustainable Building Technology and Urban Development,* 7(1), 22-37.

Tian, Y., Hong, B., Zhang, Z., Wu, S., & Yuan, T. (2022). Factors influencing resident and tourist outdoor thermal comfort: A comparative study in China's cold region. *Science of the Total Environment*, 808, 152079.

Venhari, A. A., Tenpierik, M., & Taleghani, M. (2019). The role of sky view factor and urban street greenery in human thermal comfort and heat stress in a desert climate. *Journal of Arid Environments,* 166, 68-76.

Wei, R., Yan, J., Cui, Y., Song, D., Yin, X., & Sun, N. (2023). Studies on the specificity of outdoor thermal comfort during the warm season in high-density urban areas. *Buildings,* 13(10), 2473.

Yan, Y., Xu, Y., & Yue, S. (2021). A high-spatial-resolution dataset of human thermal stress indices over South and East Asia. *Scientific data*, 8(1), 229.

Yuca, N. (2025). *The impact of lakes on urban thermal comfort: A case study of Lake Van* (Doctoral dissertation, Van Yüzüncü Yıl University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture). Council of Higher Education Thesis Center. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=945254

Zeren Cetin, I., Adiguzel, F., Sandal, E. K., & Dinc, Y. (2025). Enhancing bioclimatic conditions in urban open spaces through surface material selection: The case of Adana (Turkey). *Environment, Development and Sustainability,* 1-16.

Zhen, M., Zou, W., Zheng, R., & Lu, Y. (2022). Urban outdoor thermal environment and adaptive thermal comfort during the summer. *Environmental Science and Pollution Research,* 29(51), 77864-77883.

Zhou, Z., Deng, Q., Yang, W., & Zhou, J. (2020). Effect of seasonal adaptation on outdoor thermal comfort in a hot-summer and cold-winter city. *Advances in Building Energy Research,* 14(2), 202-217.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Climate-Concerned Urban Furniture in the Urban Landscape

Feran AŞUR[1]*

ORCID 1: 0000-0001-9480-5536
[1]Assoc. Prof. Dr., Van Yuzuncu Yil University, Faculty of Architecture, Department of Landscape Architecture, Van-Türkiye
feranasur@yyu.edu.tr (Responsible Author)

Nursevil YUCA[2]

ORCID 2: 0000-0002-7985-7706
[2] Research Assistant, Van Yuzuncu Yil University, Faculty of Architecture, Department of Landscape Architecture, Van-Türkiye
nursevilyuca@yyu.edu.tr

Abstract

Climate change is causing an increase in the frequency and severity of climate-related hazards, particularly extreme heat events, floods, forest fires, forest fire smoke, and ozone air pollution. Today, cities, public spaces, and infrastructure assets such as street furniture are forced to adapt to this change. Smart street furniture in the urban landscape can be defined as urban accessories that meet new urban needs and contribute to sustainability through technological advancements. Sustainability and climate change are inextricably linked, and mitigation and adaptation strategies can contribute to sustainability.

Many global cities have developed ambitious green and sustainability strategies and plans to achieve their goals of mitigating climate change. This paper focuses on street furniture, which plays a crucial role in urban landscapes to enhance urban livability under changing climate conditions. This study examines examples of various street furniture designs within the framework of current street furniture design, sustainability and climate change, and climate anxiety and adaptation. As a result, it has been demonstrated that new technologies and attractive aesthetic designs in urban furniture can increase the livability and effectiveness of existing services such as solar energy, smart technology, and thermal regulation in the urban landscape.

Keywords: Climate change, urban furniture, urban landscape, sustainability

1. Introduction

Human activities, which accelerated with the industrial revolution, are causing global warming and climate change. Climate change projections produced with scenarios predicting greenhouse gas emissions indicate that these changes will continue on the same trajectory into the future (Şerifzade 2022). Cities' climates have a structure that directs, directly affects, and changes the planning, design, and usage processes of the city. Urban furniture, an integral part of the urban landscape and the functional use of public spaces, must also adapt to this change. Smart urban furniture, which has a significant impact on the urban landscape, can be described as urban accessories that respond to new needs in cities with the development of technology and contribute to the sustainability of the city.

Urban furniture is defined as equipment or structures in public spaces that have no specific user base, have open-space functionality, and generally provide fixed services (Najafidashtape, 2018). Urban furniture is a uniquely designed product placed in public spaces such as streets, avenues, roads, parking lots, and squares. It meets needs such as seating, protection, shelter, transportation, orientation, lighting, waste collection, rest, and entertainment, and provides protection from sun, wind, rain, and other external factors (Aksu, 2012). Many global cities have developed ambitious green and sustainability strategies and plans to achieve their goals of slowing climate change. This study focuses on urban furniture as a tool for improving urban livability in changing climate conditions.

Urban Furniture Design Today

The design of urban furniture, which has a wide user base, generally requires three factors. These factors are: functional, psychological, and technological. Functional criteria include sizing appropriately for users' anthropometric characteristics and ease of use. Psychological criteria include considering the diverse cultural characteristics of societies. Technological criteria include producing urban furniture using durable materials and technologies appropriate for function and form (Hacıhasanoğlu, 1991).

In recent years, due to the climate and environmental challenges experienced in urban environments, in addition to the aforementioned basic criteria, urban furniture design has been prioritized to support urban living conditions and ensure sustainability. In this context, it is expected that urban furniture will adapt to changes within the scope of environmental design and develop innovative solutions to provide healthy and sustainable living conditions.

Urban furniture with durable, aesthetic, and flexible designs offers a solution in this regard in the urban landscape. In this solution, biophilic design offers an interesting intersection between sustainable materialism and beauty (International Living Future Institute, n.d.). Biophilic design is the integration of nature into built environments. Biophilia is the idea that humans are instinctively connected to nature and that increasing natural elements in urban environments enhances their mental well-being (McCain, 2020). In the context of street furniture in urban landscapes, biophilic design elements can include planting trees, shrubs, or flowers next to benches. This also means that natural shapes, patterns, and colors can be incorporated into designs.

Sustainability and Climate Change

Sustainability can be defined as a process that ensures the coordinated and prudent use of all resources—social, cultural, natural, human, and scientific—(Galdwin, 1995). Sustainable development is a multifaceted approach to creating a built environment that considers economic, social, and environmental concerns.

Sustainable development is a key component of any strategy to support the planet's growing population and can be achieved by constructing new infrastructure and buildings that reduce environmental impact by reducing carbon pollution. Sustainability and climate change are inextricably linked, and mitigation and adaptation strategies can facilitate sustainability.

Mitigation aims to reduce and offset greenhouse gases that trap heat in the atmosphere (NASA, n.d.). For urban furniture, mitigation strategies include reducing vehicle dependency by increasing access to sustainable transportation through public transportation and active modes of transportation such as walking or cycling. Mitigation strategies will also include the use of greener construction practices such as recycling, lighter-weight buildings, and zero-emission buildings. Adaptation is an approach that must be agile and flexible to adapt to the unpredictable weather events brought on by climate change. Adaptation offers the City an opportunity to examine how street furniture, a key element of public infrastructure, can be integrated into community resilience (City of Vancouver, 2024).

Climate change is causing an increase in the frequency and severity of climate-related hazards, particularly extreme heat events, floods, wildfires, wildfire smoke events, and ozone air pollution. These events cause emergencies resulting in illness, injury, and, for some, death (Vancouver Coastal Health, n.d.). By using both mitigation and adaptation strategies to guide

the management of public spaces and infrastructure assets such as street furniture, cities can see the impact of immediate and long-term resilience in action. Climate resilience addresses approaches and trends in street furniture and social amenities related to sustainability and equity. These approaches represent both mitigation and adaptation strategies.

2. Examples of Urban Furniture Designs Concerned with Climate Concern and Adaptation

This section examines some examples of urban furniture designed to support sustainability in today's cities, driven by climate concern and adaptation. Smart technology can be integrated into urban furniture to provide services such as Wi-Fi, emergency buttons, wayfinding, or charging stations.

Transportation Stops

The opportunity for cities to install data sensors at public transit stops means generating qualitative data that will inform planning decisions and aid climate adaptation. For example, if an air pollution sensor indicates high levels at a particular intersection, trees or shrubs can be planted or air filters installed in that area.

A 2020 study, "Thermomodulating Effects of Bus Stops and Tree Shade on Public Transit Ridership," examined the effects of both temperature and shade on public transit ridership in cities across the United States, particularly in Austin, Texas (Lanza and Durand, 2021). The authors found that, despite the decline in ridership in many cities due to high temperatures, sheltered bus stops carried more passengers on these hot days than sheltered stops on cold and heavy rainy days. Trees can be planted at bus stops to provide shade, considering shade as a type of infrastructure from every perspective, or urban furniture can be designed to provide shade (Flores, 2019). Trees are excellent shade sources, contributing to rainwater management, filtering air, providing shelter for biodiversity, blocking winds, and contributing to human well-being through biophilia (TerraMai, n.d.). Additionally, there are many approaches to adapting urban furniture through technological interventions. For example, in extremely hot climates, misting systems are an option for transit shelters, ideally in addition to shade. Fogging requires connection to a water source, which presents a challenge in cities experiencing drought (City of Phoenix, n.d.). The Phoenix shelter (Figure 1) is one example, providing misting, ventilation, and shade.



Figure 1. A transit shelter with a fogging feature in Phoenix (City of Phoenix, n.d.).

In Chongqing, China, foggers designed to spray cooled mist at bus stops to cool bus passengers. In Victoria, British Columbia, foggers were installed on fire hydrants (Chan, n.d.). The "Vegetal Bus Stop" is one example of a smart bus stop (Figure 2). The stop was designed to support the growth of declining vegetation in urban areas. The street furniture, which can be used as a bus or tram stop, is considered a symbolic piece of urban furniture that is effective in encouraging public transportation use, thus limiting the greenhouse effect and gas emissions. The design also incorporates environmentally friendly solutions such as rainwater collection and the use of low-consumption lighting (designboom, n.d.).

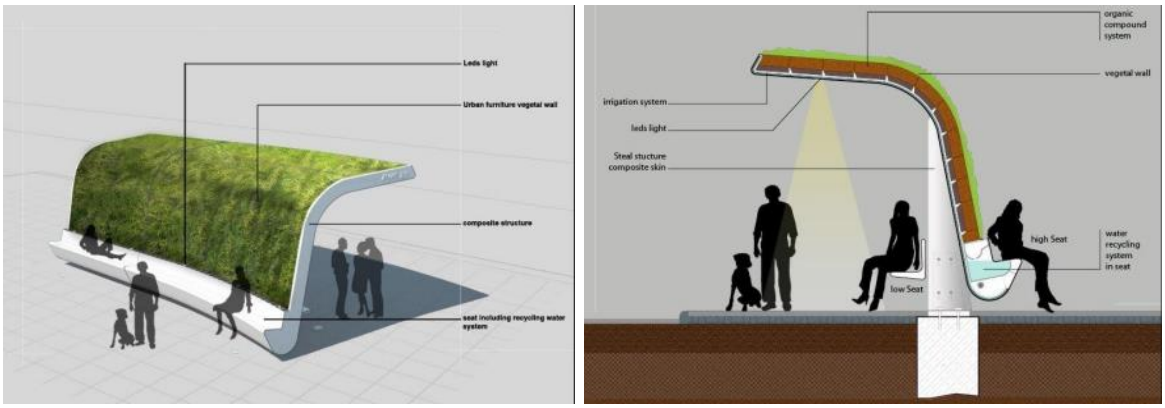


Figure 2. The appearance and operation of the "Vegetable Bus Stop" smart bus stop (designboom, n.d.).

Green and Cool Roofs

An effective way to reduce urban temperatures on unused roofs. There are two popular strategies: green and cool roofs. A green roof is a permanent rooftop vegetation system or a type of vegetation. In addition to reducing the urban heat island effect, these roofs can support biodiversity, absorb pollutants and CO2, and increase rainwater retention. Cool roofs are made of highly reflective materials and are very effective at cooling the interior of a building.

According to the authors of the book Energy and Buildings, cool roofs provide three times more effective cooling than green roofs and are generally more cost-effective than green roofs. However, cool roofs require more maintenance than green roofs because they require frequent pressure washing to maintain their solar reflectance (Sproul et al., n.d.). Derby, England, uses the roofs of bus shelters (Figure 3) to create areas for native plants that will attract bees and other pollinators (Derby City Council, n.d.).



Figure 3. A green roof installed on a transit shelter in Derby, England.

One of the biggest advantages of solar-powered street furniture is that it doesn't require electrical wiring connected to the public grid. As batteries and technology improve each year, even dark and rainy climates will benefit from solar energy (BC Hydro-Power Smart, n.d.). They also require regular maintenance, which can become a significant expense if subject to constant vandalism. Some cities are using solar energy at public transit stations. For example, Edmonton has had solar-powered public transit stations since 2012 (City of Edmonton, n.d.).

For example, the Telford transit station (Etesian Green Shelters, n.d.) is powered by both wind and solar energy. The station will be grid-independent and will generate enough electricity to power both its lights and advertising panels.

Seating and Smart Charging Units

The "Smart Tree" smart seating element is another example of an application developed by the same company (Figure 4). The seating element was inspired by nature and designed like a smart tree. This urban furniture piece, which features smart benches, also provides users with the opportunity to sit in the shade under a tree (Strawberry Energy, n.d.).



Figure 4. "Smart Tree" smart seating (Strawberry Energy, n.d.).

The smart seating element, called "Digital Break," is an example of urban furniture that offers flexible use, is suitable for working with a laptop, provides internet access, and provides news and city information via its digital screen (Figure 5). The green roof on its eaves is intended to create the illusion of a garden in the urban environment (Dezeen, n.d.).



Figure 5. The "Digital Brake (Escale Numérique)" smart bench (Dezeen, n.d.).

The "Artificial Tree" seating unit is another urban furniture unit developed to filter polluted air in cities (Figure 6). In addition to serving as seating and lighting, the urban furniture can also emit fresh scents and natural sounds, and its digital display can provide access to information in the city (Jordi Hans Design, n.d.).



Figure 6. "Artificial Tree" smart seating and lighting application (Jordi Hans Design, n.d.).

The other product is called City Tree. This particular product claims to have the nitrogen dioxide absorption capacity equivalent to 275 trees. The seating also includes Wi-Fi, charging, and solar-powered sensors that can detect a lack of humidity and, when necessary, activate a water pump located behind moss walls, cooling the area within a 5-meter radius. The product is currently being piloted in Paris, Oslo, Berlin, and Brussels, where nitrogen levels have decreased by 15%. Brussels, experiencing higher than normal temperatures, required additional water for its irrigation system after sensors detected low humidity.

Similarly, Canopee, shown in Figure 7, uses live plants in locations where trees are unsuitable. This particular product also creates a canopy with a minimal footprint. Canopee has been installed in cities such as Paris, Marseille, Bordeaux, and Nantes, as well as in Spain, Morocco, the Gulf States, and most recently, Australia. The system also collects rainwater, and irrigation is controlled remotely using humidity sensors. The product is also solar-powered (Plastics Le

Mag, n.d.). This design would be useful in areas with high pollution, where shade is needed, and where the area would benefit from biophilic elements.



Figure 7. A canopy creates a self-contained canopy with integrated irrigation.

Sidewalks

According to the C40 leadership group, cool sidewalks could be considered along bus routes and in waiting areas. This approach to heat adaptation aims to create cool streets by reflecting heat and solar radiation from the sidewalk. The theory is that reflective paint will redirect radiation, thus cooling the urban heat island. This strategy is being explored by the Los Angeles Department of Streets. In 2017, they launched a pilot program using solar reflective paving on residential blocks (Figure 8). The goal is to reduce the citywide average temperature by 1.7°C by 2035.

This strategy is used in conjunction with cool roofs and green infrastructure. A study on this program, "Solar Reflective Pavements—A Policy Solution for Heat Mitigation?", found that paving alone is ineffective and requires additional shade interventions to maximize its impact (Li et al., 2020).

The findings also show that asphalt concrete reduces heat transfer compared to cement concrete in the late afternoon, but increases human heat load. Critics of the plan cite reflective energy absorbed by people walking on it, which is up to 7°C warmer than asphalt (Bloomberg, 2019). The surface appears to work best in conjunction with additional strategies, such as shade from tree canopy.



Figure 8. Solar reflective pavements showing the difference between absorbent dark asphalt and light-colored reflective pavement (Bloomberg, 2019).

Car and Bicycle Rental Elements

The "Cigogne Bicycle Shelter," featuring smart bicycle charging elements, is designed to provide a safe space for bicycles and protect them from adverse weather conditions and vandalism (Figure 9). This area, which holds 20 bicycles, also offers services such as electric bicycle charging and tire inflation. These modules aim to facilitate and support cycling within the city. The shelter developed by French rail vehicle provider Altinnova is an example of a project designed to reduce urban air pollution and encourage cycling (Paris de l'Avenir, n.d.).



Figure 9. Example of a bicycle storage unit (Bike Box, n.d.).

Smart Waste Collection Systems and Trash Cans

It has been noted that in traditional urban waste collection systems, route planning without knowing the needs at the station leads to problems such as wasted labor and time and increased greenhouse gas emissions. As a solution, smart trash cans and waste system solutions are being developed and implemented in some cities. Smart trash cans, with features such as a sensor indicating when they are full, counting the amount of use or damage to a piece of furniture, or adjusting the lighting, will not provide effective solutions in public spaces. Smart waste collection systems prevent unnecessary traffic of waste collection vehicles in the city, thus

reducing carbon emissions (Demir, 2018). The "Ecube Lab" smart waste booths are one of the smart energy applications in Amsterdam (Figure 10). Trash is compressed in the compression chambers of solar-powered waste containers, the fill level is displayed, and ultrasonic technology can detect all types of materials (Noe, 2020).



Figure 10. Operation of the "Ecube Lab" smart waste collection booth (Noe, 2020).

3.Conclusion and Suggestions

Climate change significantly impacts people and will continue to do so on a larger scale. The city has developed numerous plans and policies to mitigate its impacts now and in the future. All departments should consider how they contribute to sustainability and climate resilience. Sustainability, a dual approach of mitigation and adaptive strategies, is crucial in building climate resilience. Mitigation will include prioritizing carbon strategies and carbon sequestration elements such as vegetation.

Another mitigation strategy is to increase bus ridership and active transportation by making these experiences more accessible and improving the visual quality of the landscape. Adaptive strategies include cooling measures such as shade and mitigating the effects of extreme heat events by reducing solar radiation. Creating shade will help protect the most vulnerable in our city from the effects of the Urban Heat Island Effect. In the absence of vegetation, artificial shade elements protect people from rain and sun.

New technology and attractive aesthetic designs in urban furniture can increase the livability and effectiveness of existing services, such as solar energy, smart technology, and thermal management. Creating comfortable spaces where people want to spend time will increase resilience by building community and providing infrastructure that supports all aspects of urban life. Some suggestions for this include:

• Sourcing sustainable materials if existing assets need to be replaced.

• Collaborating: Investigating how sustainability and embodied carbon strategies influence street furniture procurement, design, and installation.

• Conducting more detailed reviews of material options to achieve the target.

• Conducting a shade and rain cover audit that considers both artificial and natural shade elements.

• Continue exploring smart technology and how it can be used. Integrating Wi-Fi and charging stations into street furniture to improve the user experience.

• Focusing on equality for all segments of society regarding social accessibility.

• Utilizing concepts such as biophilia and placemaking to improve spaces to encourage active transportation and public transportation use for social resilience.

Examples of climate-concerned street furniture approaches can be seen in many global cities. According to a literature review, sustainability and climate resilience have been cited as important components of street furniture strategies for many cities. Street furniture is a vital part of urban life and can be an integral part of cities' climate resilience and sustainability.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Aksu, V. Ö. (2012). Kent Mobilyaları Tasarımında Özgün Yaklaşımlar. *İnönü Üniversitesi Sanat ve Tasarım Dergisi*

BC Hydro- Power Smart. (n.d.). Solar power. https://www.bchydro.com/powersmart/residential/building-and-renovating/switch-to-solar-energy.html

Bike Box. (n.d.). *Street Box collection.* https://www.bike-box.nl/collections/street-box

Bloomberg. (2019, October 3). *Reflective pavement may be less cool than it seems. Bloomberg.* https://www.bloomberg.com/news/articles/2019-10-03/reflective-pavement-may-be-less-cool-than-it-seems

Chan, A. (n.d.). *Victoria opens 14 misting stations amid high-temperature warnings*. CTV News Vancouver Island. https://vancouverisland.ctvnews.ca/victoria-opens-14-misting-stations-amid-high-temperature-warnings-1.6001725

City of Edmonton. (n.d.). *Solar bus shelters. Change for Climate.* https://changeforclimate.ca/story/solar-bus-shelters

City of Phoenix. (n.d.). *Misted bus shelter installed near Uptown Phoenix.* https://www.phoenix.gov/newsroom/public-transit/367

City of Vancouver. (2024, March 13). *Climate Change Adaptation Strategy (2024–2025).* City of Vancouver. https://vancouver.ca/files/cov/climate-change-adaptation-strategy.pdf

Derby City Council. (n.d.). *Bee-friendly bus shelters coming to Derby.* https://www.derby.gov.uk/news/bee-friendly-bus-shelters-for-derby/

Designboom. (n.d.). *Vegetal bus stop.* https://www.designboom.com/project/vegetalbus-stop

Dezeen. (n.d.). *Escalenumerique by Mathieu Lehanneur and JCDecaux.* https://www.dezeen.com/escalenumerique-by-mathieu-lehanneur-and-jcdecaux/

Etesian Green Shelters. (n.d.). *UK's first wind and solar powered bus shelter arrives in Telford*. https://egshelters.com/uks-first-wind-and-solar-powered-bus-shelter-arrives-in-telford/

Flores, J. (2019, October 24). *LA's answer to scorching sidewalks? umbrellas.* Curbed LA. https://la.curbed.com/2019/10/24/20927608/umbrellas-bus-steps-los-angeles-shade

Galdwin, Kennely, J., Thomas N., ve Krause, T.-S. (1995). Shifting paradigms for sustainable development: Implications for management theory and research. *Academy of management Review.*

Hacıhasanoğlu, İ. (1991). *Mimari Tasarım-Kent Mobilyası tasarımı*. 3. Uluslararası Yapı ve Yaşam Kongresi Bildiri Kitabı. s. 326-329.

International Living Future Institute. (n.d.). *Biophilic design initiative. International Living Future Institute*. Retrieved August 8, 2025, from https://living-future.org/biophilic-design-initiative/

Jordi Hans Design. (n.d.). *Artificial tree*. https://jordihansdesign.com/portfolio/artificialtree/

Lanza, K., & Durand, C. P. (2021). Heat-moderating effects of bus stop shelters and tree shade on public transport ridership. *International Journal of Environmental Research and Public Health*, 18(2), 631. https://doi.org/10.3390/ijerph18020631

Liebenberg, A., & Mulhall, B. (2022). Explorıng the Opportunıtıes For Street Furnıture to Contrıbute to Clımate Resılıence and Sustaınabılıty.

Li, H., Meier, F., Lee, X., Chakraborty, T., Liu, J., Schaap, M., … & Baklanov, A. (2020). Solar reflective pavements—a policy panacea to heat mitigation? *Environmental Research Letters,* 15(10), 104017. https://doi.org/10.1088/1748-9326/ab87d4

McCain, M. (2020, June 23). *Bringing the outdoors in: The benefits of biophilia.* NRDC.

Najafidashtape, A. (2018). *Mimarlık ve Yaşam Dergisi.* s. 63-74.

NASA. (n.d.). *Climate change adaptation and mitigation. NASA*. Retrieved August 8, 2025, from https://climate.nasa.gov/solutions/adaptation-mitigation/

Noe, R. (2020, August). *Amsterdam's Smart System of Underground Garbage Bins*, 08.08.2025 tarihinde: https://www.core77.com/posts/102208/Amsterdams-Smart-System-ofUnderground-Garbage-Bins.

Paris de l'Avenir. (n.d.). *Blog – English*. Retrieved from https://www.parisdelavenir.paris/en/blog en

Plastics Le Mag. (n.d.). *Urban Canopée: Cooling down the city by greening up.* https://plastics-themag.com/Urban-Canopee:-cooling-down-the-city-by-greening-up

Sproul, J., et al. (n.d.). Economic comparison of white, green, and black flat roofs in the United States. *HEATISLAND*. https://heatisland.lbl.gov/publications/economic-comparison-white-green-and

Strawberry Energy. (n.d.). *SmartBench*. https://strawberrye.com/smartBench.html

Şerifzade, T. (2022*). Sürdürülebilir kent mobilyaları tasarımı üzerine bir inceleme: Bakü örneği* (Master's thesis, Bursa Uludag University (Türkiye).p

TerraMai. (n.d.). *How biophilic design is making humans happier.* https://www.terramai.com/blog/biophilic-design-making-humans-happier/

Vancouver Coastal Health. (n.d.). *Community health and climate change. ArcGIS StoryMaps.* https://storymaps.arcgis.com/stories/7bf7141bb6fd41fb9b61a02cfbc61ecd

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Daylight Utilization in Architectural Structures

Zübeyde ÇİÇEK [1*]

ORCID 1: 0009-0001-4879-7026
[1] KTO Karatay University, Department of Architecture, Faculty of Fine Arts and Design, Konya-Türkiye
zubeydee.cicekk@gmail.com (Responsible Author)

Halil SEVİM[2]

ORCID 2: 0000-0002-0211-3397
[2] Assistant Professor., KTO Karatay University, Department of Architecture, Faculty of Fine Arts and Design, Konya-Türkiye
halil.sevim@karatay.edu.tr

Abstract

Daylight is a major factor in the architecture of any building. It does more than just lighting the building, as it affects the building's look, interior design, visual comfort, energy efficiency, and in fact, each stage of the whole design process. From an architectural point of view, daylight is a major factor in energy-saving. When natural light is used effectively, the need for artificial lighting is minimized by the user, thus the consumption of electricity is lessened and the designer is able to achieve the goal of creating a sustainable design. Proper daylight in a room is beneficial for the psychological and physiological health of the users, and it also helps their biological rhythms to be regulated.

Therefore, in order to substantially improve the efficiency of the light, that is, the amount of light entering the room, leading figures in modern architecture such as Le Corbusier, Tadao Ando and Renzo Piano have in a very considered manner utilises a variety of opening elements such as windows, skylights, light shelves, and light tubes in their works. This utilisation ensures that daylight reaches interior spaces to the maximum extent, increases visual comfort, decreases the need for using artificial lighting, elevates the aesthetic value of the space, and enriches the user experience. Comparative studies on the openings used have been conducted to provide a comprehensive understanding of the effective role of daylight in the design process.

Skylights and roof lights are designed to allow direct daylight to get in, whereas light shelves and light tubes are used to transport light to the back areas of the room. Subsequently, interiors are more evenly lit, color perception is improved and the feeling of space is greatly increased. Overall, it is a significant study that presents a compelling perspective on the importance of daylight.

Keywords: Modern architecture, daylight, housing

1.Introduction

1.1. The Historical Development of Light

In looking at the historical background, it can be stated that the first artificial light source discovered was fire. Over the years, due to technological developments and environmental conditions, some artificial lighting elements were encountered that were used at the user's desire and purpose and that were portable. Initially, people tended to the development of a portable light source by using torches. In later periods, lighting tools that were user-adaptable to geographical, seasonal, and climatic conditions were developed.

In antiquity, lamps and candles based on animal fats tended to be widely used. The Ancient Egyptians and Romans made their contributions to lighting technology with the introduction of candles from beeswax and animal fats. These developments were followed by gas lamps, leading to significant innovations in urban lighting. Subsequently, the invention of electrical lighting systems, fluorescent lamps, and light-emitting diodes (LED) introduced another significant energy efficiency in the area of lighting.

Today, smart lighting systems, sensor-equipped lamps, and artificial light sources using solar energy are widely used (Özkum, 2011). Figure 3 presents an overview of the development of light.



Figure 1. Colour temperature and white balance (Erikli & Yıldırım, 2021)

2. Types of Lighting

2.1. Types of Lighting Based on Light Source

Light is an essential form of energy, not only for the process of vision but also for the sustainability of life, technological advancements, and day-to-day requirements. Light is incredibly relevant to a space. Based on usage intentions, spatial dimensions and user needs of an indoor or outdoor space, the lighting in a space can be split into two categories natural and / or artificial light sources. Natural lighting depends solely on day lighting; whereas, artificial lighting is one of the inventions created by the hands of man. Each of these two concepts exists together in various sections below.

2.1.1. Natural Lighting

Natural lighting refers to natural light that arrives on Earth through rays produced by the sun. Sunlight contains ultraviolet rays, and also contains visible light. Sunlight, in fact, is the primal source of natural lighting that regulates biological rhythms and provides efficiency in energy-saving lighting options. It can also contribute to healthier and more liveable architecture. Daylight can be integrated into architectural spaces in a controlled manner. Natural lighting is a mix between sunlight and sky light and varies according to seasons, weather and time of day. The defining characteristic of daylight is that it is not stagnant, it is dynamic by continuously changing. This dynamism creates diversity in terms of light intensity, colour, contrast, richness and liveliness. This diversity can be observed in space and within the psyche (Özkum, 2011; Bayhan, 2018).

According to the Turkish Language Association (TDK, 2023), natural lighting can be defined as a form of lighting that is integrated with nature, while it can be said to be the opposite of artificial lighting. Natural lighting is fundamentally achieved by distributing daylight in the most effective way, and is provided in the space through openings such as windows, doors and roof lights. A natural lighting scheme that works well will, to a very large extent, eliminate the need for lighting during daylight hours altogether, including regardless of the building material. Natural lighting—which has been used since ancient times to the present day—is seen most impressively in the Pantheon Temple in Rome. The only lighting available in the building was a circular opening at the top. In modern architecture Louis Kahn's Bangladesh Parliament Building was designed with the intention of bringing natural lighting into the space. Adequate natural lighting enhances visual comfort as users will become aware of their surroundings and

be able to move about. Similarly, a good function of natural light will reduce the use of artificial lighting by about 70% and reduce energy use. It is significant, considering lighting uses 25% of a daily energy use, to note attention to natural lighting (Etli, 2013).

Sunlight is a form of directional light that will vary in direction throughout the day, creates sharp and definite shadows, and shifts from orange to white in tone. The sun, as a natural light source, produces light with a colour temperature of about 1800 K during sunrise and sunset and between 5000–5800 K at midday. The primary benefit of using a natural form of lighting is that it allows us to see things in their true texture, warmth, and purest form (Özkum, 2011). Example of natural lighting, shown in Figure 2.



Figure 2. Natural Lighting (Personal Archive)

In designing an architectural space, the atmosphere of the location is as critical to the light you are layering into the space. Based on the orientation of daylight on the surface of the earth, and depending on the latitude and longitude of the specific location, spaces are exposed to different qualities of light and quantity of light, which directly impact the identity of the space. Therefore, in space design, the intended use of the buildings, where you are located, the climate and seasonal conditions must be considered. Daylight in architecture is important, both in terms of aesthetics and function.

2.2.2. Artificial Lighting

Artificial lighting refers to electrical systems with artificial light sources designed to illuminate spaces without relying on daylight. Such provided lighting utilizes a range of light sources, including lamps, LED replacements, fluorescent lamps, and bulbs. In concerning the lighting process created in these spaces, artificial lighting is employed in environments deemed inadequate for daylight provision. In indoor spaces where daylight lighting and distribution are limited, artificial lighting technology has sought to create user preference in a wide range of factors relating to human psychology, including light intensity and colour temperature.

Artificial light has become an integral part of modern existence for animal and plant life and overarching production solutions that improve functionality across a multitude of areas of production. Advances in technology have brought about a notably more efficient, longer-lasting, and environmentally sounding artificial lighting system application. Such applications

are used in spaces with poor daylight or underground (tunnels, basements, caves, etc.), spaces where an improved productive working environment is required, garden lighting, ornamental/decoration lighting that can add aesthetically pleasant enhancements to art or in built form to interiors, stage lighting used in concerts, affected theatres, and alternative event events, health and therapeutic applications, lighting and artificial lighting application in the entertainment industry, advertising - most recently including the recent advancements in visual arts through new technologies. Figure 3 shows a visual diagram of artificial lighting.



Figure 3. Artificial Lighting (Personal Archive)

As Le Corbusier stated in 2000, 'Architecture is the appropriate and beautiful game of volumes assembled by light. Everything around us, is a unity, with light and shadow.' (Fitoz, 2002)

Methods of Utilising Daylight in Buildings

Daylight Openings in Buildings

Daylight openings are openings in the building envelope through windows or roofs that allow daylight to be brought into the indoor space. These openings maximize both visual comfort and energy efficiency. Several techniques have emerged that encourage effective daylight use, such as light shelves, light tubes, and various types of glass are now more commonplace than before.

When designing day lighting systems, it is important to consider the location of the building, including the geographical and climatic aspects. Moreover, considering the elements of the design techniques that will be used will be useful in this assessment. (Yıldırım, 2021; Erikli, 2021)

Windows

Buildings are sleeves designed to insulate humans from outside conditions. However, humans need light, air and also interaction with the environment in order to exist on this planet. In that sense, windows that started out as structural elements have transformed into elements with

infrastructural qualities without prominent considerations in design, due to technology. (Karalurt, 2008).

Windows are apertures in the exterior walls of buildings that admit light, air, and views into the inner space. Supported by various components, such as frames, glass, and curtains, windows also perform functions of insulation, security, and connecting areas (Bulut, 2001). Windows, which are one of the primary elements of natural lighting design, are placed according to climate and light direction (Yener, 2008; Yıldırım, 2021; Erikli, 2021).

Windows at eye level, located at the eye level of a sitting or standing person, provide a pleasant view of the outdoor scenery. Windows at eye level enhance the visual interaction with nature which improves user performance, relaxes the eye muscles, and provides psychological relief. Typically preferred in living areas, windows at eye level provide support for natural light to be distributed homogeneously throughout the space. Its brightness level may be high in the areas proximate to the window while being lower in the depths of the space. Therefore, proper shading elements must be designed to minimize the negative effects of direct sunlight. The sun's changing position throughout the day and the year is a determining factor for developing shading strategies for the window orientation as required for energy efficiency and higher user comfort (Yener, 2008).

To sum up, windows are not just an opening letting in light and air, but also significant elements to integrate light and air and aesthetics and energy performance in architecture. Thoughtfully integrated, windows can improve the quality of a space and comfort of the user. Figure 4 represents the window appearance and Figure 5 represents the plan and section distribution of the window.



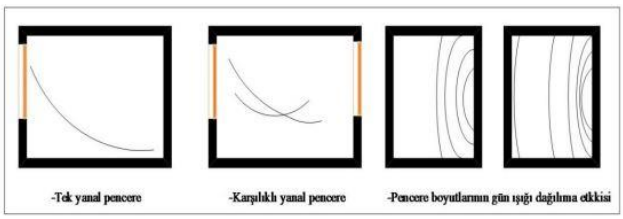


Figure 4-5. Window appearance and daylight distribution in plan and section (Özhancı & Özyılmaz, 2013)

Roof Skylights

A roof skylight refers to a horizontal or sloped opening in roofs of buildings; this includes openings which are continuous, lanterns, as well as sloped windows meant to bring daylight aesthetically into spaces from above. Their primary purpose is to not only bring daylight through above as well as allow the light to be modulated to ensure the best use of natural day-lighting (Tekbıyık, 2018).

Roof skylights are often placed on sloped roofs and are common in the form of single transparent openings in saw tooth forms. The daylight and its distribution to the aesthetic space depend both on the size and placement of the skylights. While certainly common and seen in industrial spaces, they're also a common option in spaces with large volume, such as schools, hospitals, and the lobby of a building. In some designs roof skylights can only provide natural lighting, whereas some roof skylights can also provide a natural ventilation option by contributing to clean air-flow (Tekbıyık, 2018).

Alternatively, skylights are sections that have glazing on all sides to provide light from multiple directions, but they may contribute to glare because of these qualities. In sunnier climatic regions, skylights that are orientated north-south may be better than horizontal openings. In contrast, east-west oriented skylights provide a more balanced amount of light throughout the day. (Tekbıyık, 2018). An example of a roof skylight is shown in Figure 6.

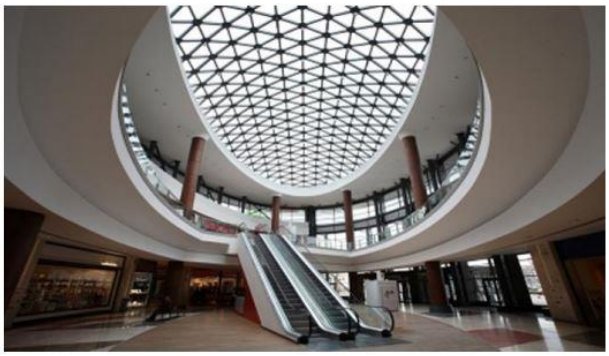


Figure 6. Continuous roof skylights example (Tekbıyık, 2018)

Advanced (Contemporary) Daylighting Systems

Light shelves

A light shelf consists of a horizontal architectural feature typically situated on the interior or exterior sides of the window and is intended to inhibit daylight or direct daylight onto the ceiling. The light shelf system could be designed to be part of the façade or constructed as a retrofitted element free-standing on top of the façade. Light shelves can mitigate the harshness of sunlight on areas immediately near a window while reflecting light up to the ceiling for illumination across the room allowing daylight to be utilized effectively. By manipulating and distributing sunlight, the daylight level at the edge of the window is lowered while a higher daylight level is achieved in the depth of the room. This also yields homogenized light distribution across the space as illustrated in Figure 7 (Tekbıyık, 2018).

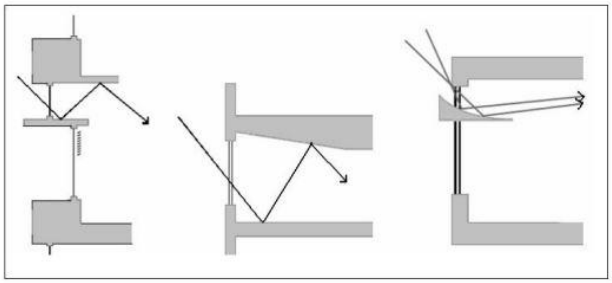


Figure 7. Bringing natural light into the space (Tekbıyık, 2018)

It is acknowledged that the angle of sunlight, especially areas that face north from the south, enables better control of daylight; creating a significant benefit in terms of architectural design. In addition, the use of atriums along with daylight from skylights within the roof are also significant in bringing natural daylight into a space and providing passive cooling; promoting the maximum utilisation of daylight in the space (Tekbıyık, 2018). For an illustration of this condition see Figure 8.



Figure 8. Shading elements applied to the transparent upper coverings of atriums (Tekbıyık, 2018)

Light Tubes

Light tubes are systems designed to facilitate the entry of daylight through openings in the roof that can be transmitted to the interior space using pipe-shaped elements covered with reflective materials at some angles. These systems, called light tubes or sun tubes, are particularly effective in public buildings and spaces where direct daylight is unable to reach. They provide daylight equally in the space to ensure balanced lighting of the space in open-plan offices. Light tubes also reduce reliance on artificial lighting, thus providing energy consumption savings and improved energy efficiency (Tekbıyık, 2018). An example of this is illustrated in Figure 9.

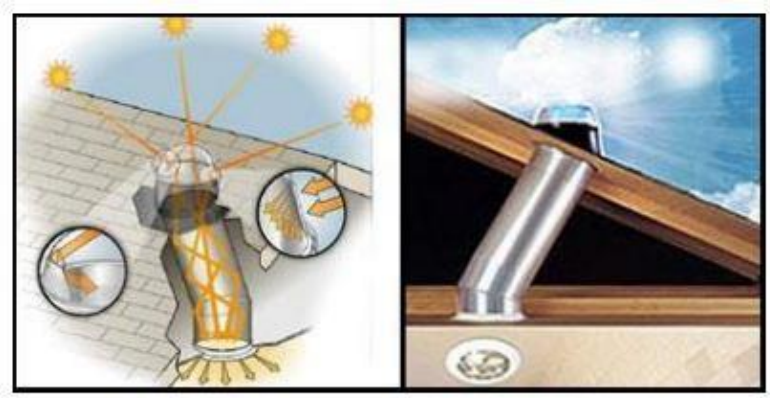


Figure 9. Light Tube (Tekbıyık, 2018)

Architectural Works By Le Corbusier, Tadao Ando and Renzo Piano

A key reason for choosing architects like Le Corbusier, Tadao Ando, and Renon Piano is because they have derived innovative principles from their focus on daylight efficiency in their architectural work. Le Corbusier, Tadao Ando, and Renzo Piano are widely recognised as leading architects of the modern era, using daylight design for symbolic and functional purposes. Both Le Corbusier and Tadao Ando created projects that articulated a holistic design

by using daylight in a way that combined beauty and function. These examples were a rich process of architecture, which developed different modalities in regard to climate conditions, building materials and the effects of daylight in interior spaces. The examination of the design principles of Le Corbusier, Tadao Ando, and Renzo Piano aims to give a different view of modern architecture and their effective use of daylight in the process of design.

Le Corbusier

Le Corbusier regards daylight as an ongoing cycle of sunrise and sunset, which he characterizes as one of the basic determinants of life. In line with this viewpoint, he employs certain design parameters to provide an effective use of daylight in his early designs, such as the Villa Falet, Villa Stotzer, Villa Jaquemet, Villa Jeanneret-Perret and Villa Favre-Jacot design cases. These approaches can be condensed into the following parameters:

- Maximize the potential of natural light: Use maximum openings on the south side; Design rooms that can collect daylight from one or two sides;
- Use L shaped corner windows, to maximize daylight entry from different angles;
- Use narrow long rectangular windows in horizontal bands;
- Use leaf shaped decorative window;
- Provide shade by using wide overhang;
- Use glass doors to enhance daylight indoor,
- Use courtyards and roof gardens to extend daylight;
- Use windows, fitted in circular projections, create light-shadow contrasts in to the interior space.

The examples of villa Le Corbusier has shown his architectural approach of daylight as a functional and aesthetic aspect (Kaya et al., 2021). The building is shown in Figure 10.



Figure 10. Le Corbusie Villas (Kaya vd., 2021)

Le Corbusier Villa Savoye

In the year 1928, Corbusier designed a vacation house for a client in the countryside close to the town called Poissy in France. This vacation house is called Villa Savoye, and it is designed in a way that offered Corbusier the opportunity to express his 'Five Principles' of modern architecture in a building. The first principle is that the project is elevated off the ground with the use of pilotis, which are columns. Second, the non-load bearing walls are true to the plan's design. Third, the principle of a load bearing structure that is independent of the façade walls. Fourth, the inclusion of ribbon windows that help illumination the building. And finally the fifth principle, the flat roof above that embraces both the building and garden. The plan of the house is designed on a square grid system and the upper floor is rectangular in shape. Overall, the building is 480 square metres of usable space and primarily uses reinforced concrete, plus the stair cases to the upper floor are circular (Varol, 2019).

Repeated ribbon windows were implemented in Villa Savoye, and open courtyards and concealed wall apertures also helped create spatial depth. The upper floor skylight and garden provide access to natural light to the interior. The light passing through the windows diffuses through the space, creating the light shelf effect and increasing spatial dynamism. Light tubes were not used. Villa Savoye is shown in Figure 11 (Kaya et al., 2021).



Figure 11. Le Corbusier Villa Savoye (Kaya et al., 2021)

La Tourette Monastery

La Tourette Monastery, situated in Lyon, France, was designed to accommodate 1,000 people. The structure consists of 100 cells, a library, a roof garden, a church, and classrooms. The monastery demonstrates the principles of Corbusier's five points of modern architecture. One principle is the structure being lifted off the ground via pilotis. The façade of the structure is made up of ribbon windows, a green roof, and clerestory windows.

The plan is a U-shaped mass that encircles the courtyard. The rectangular shape is supported by reinforced concrete load bearing elements and consists of glass surfaces with in its façade. The courtyard allows for a direct link between the outside world and the church (Varol, 2019). The adobe employs daylight and color, creating a spirit like atmosphere. The building features horizontal light shelf like openings and daylight is directed and carried to the lower spaces with upper level skylights. This method serves as a possible method, similar to the light tube processes seen in Le Corbusier.



Figure 12-13. Le Corbusier's La Tourette Monastery (Source: Varol, 2019)

Tadao Ando Azuma House

The Azuma House, also known as the Row House, was built in Osaka in 1976 and is an architectural work by Japanese architect Tadao Ando that represents a unique aspect of Japanese architecture. The two-story reinforced concrete structure is organized in three separate elements within an urban context: the front element, the courtyard, which is open to the sky, and the back element.

Ando's approach to daylight in his architectural designs is unique in terms of sparse and controlled application of daylight within his spaces. The controlled treatment of daylight is preferred for the interior atmosphere and to add richness to the space (Cengiz, 2022). The Azuma House, influenced by Japanese culture and Zen Buddhism, is intended to create an opportunity between humans and nature. In this cultural change, large glass openings were designed to allow daylight into the interior of the structure (Kaya et al, 2021).

The light courtyard, located toward the middle of the structure, allows natural daylight to enter the interior space without difficulty. Together with the glass openings on the opposite building facade, the courtyard creates an opportunity for daylight to enter deep into the space. Matt surfaces reflecting daylight can create a unique light-shadow relationship in the interior (Cengiz, 2022). The images of Azuma House by Tadao Ando in Figures 14-15. There isn't any skylight or light shelf in the building's interior, but the daylight enters vertically from the courtyard, creating a natural 'light tube effect' in the space.



Figure 14-15. Tadao Ando Azuma House. (Cengiz, 2022)

Tadao Ando Koshino House

The Koshino House, which was designed by Tadao Ando, is located in the city of Ashiya, Japan. The building is constructed on a slope and is made entirely of concrete. The Koshino House is a building that is a part of the landscape and is located in the rural countryside. (Kaya et al., 2021) The design makes extensive use of long and narrow windows that through the west façade create a contrast of light, with illumination and shadow filling the interior space. The openings in the roof take advantage of daylight entry into the building. The roof opening provides an aesthetic appearance to the design of the structure. (Cengiz, 2022) The Koshino House, designed by Tadao Ando, allows natural light to come to the interior by using a skylight that suspends between the concrete walls. In some instances, Tadao Ando's Koshino House has resulted in light that strikes and confronts the wall, creating a shelf-like effect. This is shown in Figures 16-17. The tube effect of light is observed at the ceiling height, where the light approaches downward.



Figure 16-17. Tadao Ando Koshino House (Cengiz, 2022)

Chichu Art Museum (Naoshima, 2004)

In 2004, architect Tadao Ando created an art museum on Naoshima Island in Japan that rests under a slope and has a total area of 2,300 m². The architectural approach behind this design seeks an interface that integrates nature. The project integrates views, light, and airflow into the design. The roof and windows are designed to allow natural light to enter the interior space. The underground aspect of the design also responds to the environmental aspects of the site. This is emphasized through the minimal use of materials and the use of natural materials providing harmony with the environment. The museum is designed using square, hexagonal, and triangular forms. The idea behind the design was to create varied impressions in the interior spaces (Park & Kang, 2021).

The most notable characteristic of the museum is the intention and moderation in the use of natural light. The skylights that let light through the upper ceiling of the gallery and reflective surfaces that help diffuse light across the spaces have made the use of the “light shelf” possible.



Figure 18. Chichu Art Museum, (https://avauntmagazine.com/chichu-art-museum)/



Figure 19. Chichu Art Museum, (Park & Kang, 2021)

In certain areas of the museum, significant openings function as 'light tubes'. Especially in the cylindrical voids with high ceiling heights, sunlight that comes from the ceiling helps ensure that the light is distributed evenly in the space (Park & Kang, 2021). Pictures of the Chichu Art Museum can be found in Figure 18 and Figure 19.

California Academy of Sciences, Renzo Piano, 1997, San Francisco, USA

Renzo Piano created the California Academy of Sciences in 1997, located in San Francisco, United States. The project utilized sustainable design solutions such as a natural ventilation system, green roofs, solar panels, recycled materials, aquarium, exhibit spaces, and planetarium (Özhan, 2017). The building features two domes with a total area of 3,500 m² of natural green cover. The round lighting elements hung on the domes work similarly to light tubes (Figure 20).

The building also has a terrace garden, as well as daylight, and additionally employs a rainwater harvesting system, further increasing energy efficiency. The full/empty surface relationships are particularly impactful in the overall design of the project. Renzo Piano utilized circular transparent glass openings in the dome and roof sections of the design to provide natural light to the internal spaces. The light entering the spaces through these means allows sunlight to travel in the interior spaces from the offices to the aquarium and rainforest, producing a light tube effect (Gürel & Eryılmaz, 2021).

Both the glass surfaces and the metal panels of the façade and sun-shading elements function as light shelves. The design of the system reflects daylight from the sky down to the ceiling on the interior, allowing for an equal distribution of daylighting internally.

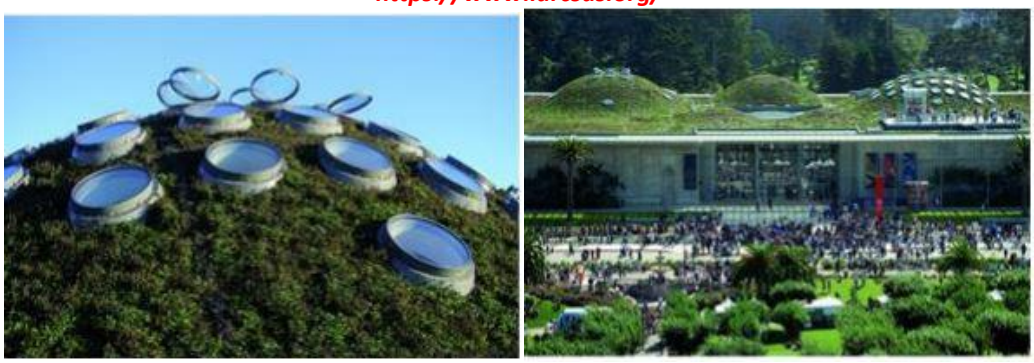


Figure 20. California Bilim Akademisi, Renzo Piano, 1997, San Francisco, ABD (Gürel& Eryılmaz, 2021)

Jean-Marie Tjibaou Cultural Centre (New Caledonia, 1998)

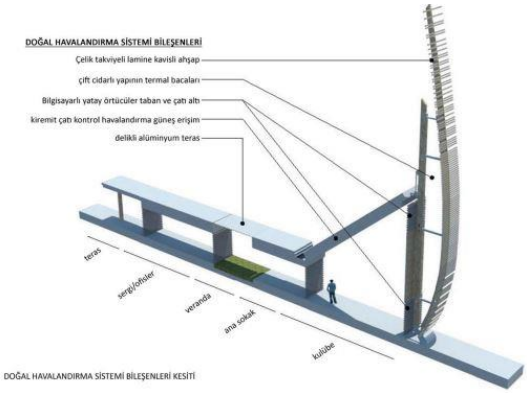
Renzo Piano constructed the Jean-Marie Tjibaou Cultural Centre in New Caledonia in 1988, designed as large huts arranged with a settlement pattern within the natural landscape. The centre is designed with shadovoltaic glass shutters that introduce daylight to the interior in a controlled manner, as well as introduce natural ventilation while providing energy savings by reducing heat loss during winter. These shadovoltaic glass shutters contribute to the sustainability target of reducing energy usage overall.

The pavilions are designed to provide both natural daylight and natural ventilation to the interior, utilizing sloped roof details and panel systems. The roof openings supply natural daylighting to the interior, but also seem to diffuse natural daylighting in a controlled way throughout the space. The openings also function as thermal chimneys for thermal control of the conditioned interior space. Shown in Figure 21.



Figure 21. Jean-Marie Tjibaou Cultural Centre, New Caledonia, 1998 (Bedir & Mayuk, 2019)

The systems of the Jean-Marie Tjibaou Cultural Centre rely upon contemporary construction techniques but are intended to be sustainable and energy efficient. The building employs skylights, light shelves and light tube effects to provide greater visual comfort through the optimized use of daylight in the interior space.



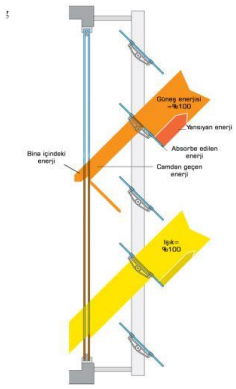


Figure 22. Facade Detail Cut, (Bedir & Mayuk, 2019) **Figure 23.** Shadovoltaic Shutter Cross-section, (Bedir & Mayuk, 2019)

Kimbell Art Museum Pavilion (Fort Worth, Texas, 2013)

Renzo Piano's architecture incorporates light as not just an aspect of a project, but part of the essence of the place. a strong illustration of this is the Kimbell Art Museum Pavilion project in Fort Worth Texas. Piano considered Louis Kahn's Kimbell Art Museum building from 1972, a concrete vaulted and dimly lit building, and designed an adjacent one that incorporates transparency and engages with daylight (ArchDaily).

The new Pavilion portion contains gallery spaces, classrooms, studio spaces, an auditorium, library and car park. In the gallery spaces, the roof system of the Kimbell Pavilion is made of tensioned fabric surfaces with incorporated wooden beams, glass panels and aluminium louvers which allow controlled daylight within the space. The daylight provided by this system can be supplemented with artificial lighting located behind the fabric walls when needed.

Glass panels supported by steel make up the roof system of the building, which is designed as an integrated part of the sunshades. This provides the roof with the ability to transfer daylight into the building while it has a climate control strategy that acts as an energy saving strategy. The panels of fabric on the surface of the roof act as a light shelf allowing light in to the interior evenly and gently.

The building does not have a light tube system but, like a light tube system, the vertical daylight transmission of the roof allows for reflected surfaces to reflect day light ultimately into the space. The use of light coloured wood, concrete and glass surfaces creates a better reflection of light within the space. Connected to Piano's design is landscape design and the landscape design affords the architectural integrity of the building (ArchDaily)



Figure 24. Kimbell Art Museum Pavilion Fort Worth, Texas, 2013 (ArchDaily)



Figure 25. Kimbell Art Museum Pavilion Fort Worth, Texas, 2013 (ArchDaily)

This research looks at nine significant works by important architects of modern architecture. This includes Villa Savoye, Villa Jaquemet, La Tourette Monastery, Azuma House, Koshino House, Chichu Art Museum, California Academy of Sciences, Jean-Marie Tjibaou Cultural Centre, and Kimbell Art Museum. The window, skylight, light tube, and light shelf systems shown to be effective in allowing the emergence of natural light in the space were examined in these nine structures.

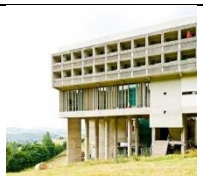
The research concluded that the architect used a different relationship to light. At Villa Savoye by Le Corbusier, the architect ensured intense daylight streamed into the interior of the house via long ribbon windows, enclosed courtyards, and roof gardens. In Villa Savoye, the openings used in the staircases and ramps provided diffuse light for the interior space without a direct light tube effect. While light shelves were not used in Villa Savoye, the use of white surfaces and the ceiling expanded strongly for an indirect system of diffusing light. At Villa Jaquemet, there was purely façade windows admitting direct light into the interior, while all three artificial lighting systems (skylights, light tubes, light shelves) were not used in the house. At La Tourette Monastery, the architect used windows and skylights to allow in natural light. The indirect flow of light into the spaces was analogous to light shelf and light tube systems.

Tadao Ando's residential projects exhibit surfaces that utilize expansive glass openings to create a pronounced light-shadow interplay inside space. Rooftop openings also possess an aesthetic function in the space. The window system is typical in various works of Ando's including Koshino House, Azuma House and Chichu Art Museum. Koshino House and Chichu Art Museum also have skylights in their roofs. In Chichu Art Museum, light entering the building diffuses into the interior, demonstrating a principle of a light shelf with reflective surfaces. In this case, however, there is no particular system as a light tube. Koshino House demonstrates interior light reflected off a wall to create a light shelf appearance; also, daylight coming from an adjacent courtyard penetrated the interior vertically establishing a natural light tube appearance (Futagawa, 1991).

Projects such as the California Academy of Sciences, Jean-Marie Tjibaou Cultural Centre and the Kimbell Art Museum, designed by Renzo Piano reveal the simultaneous use of window system, skylight, light shelves, and light tube systems. These building designs capture the same goal of providing controlled amounts of natural light into the space while supporting energy efficiency and climatic comfort (ArchDaily, 2014). A comparative analysis of the architects' works is focused on in Table 1.

To summarize, most of the surveyed buildings have made use of natural lighting elements such as large glass windows, skylights, light shelves, light tubes and light wells. Nevertheless, daylight was perceived not merely as a technical lighting element but a design element that also enhances the aesthetic and symbolic values of the space.

Table 1. Analysis of architectural works by Le Corbusier, Tadao Ando and Steven Holl

Name of the Building	Location and Year	Projects	Window	Skylight	Light Shelves	Light Tubes
Villa Savoye	France 1931		+	+	+	
Villa Jaqumel	New York 2011–2017		+	+		
LaTourette Manastırı	France		+	+	+	+
Koshino House	Japonya 1984-1985		+	+	+	+

Azuma House	Japonya 1993		+			+
ChichuArt Museum	2004, Japonya		+	+	+	
California Academy of Sciences	1997, San Francisco, ABD		+	+	+	+
JeanMarie Tjibaou	1988, Yeni Kalendoya		+	+	+	+
Kimbell Art Museum	Fort Worth, Texas,		+	+	+	+

Conclusion

Daylight is now a defining criterion at every scale, from massing to architectural design, to interior organisation to the greater design. The relationship between natural daylight, the building envelope, opening ratios, material qualities and facade components contributes to a significant relationship between these critically deliberated design elements. Climate-based location will signify the importance of natural daylight controls as a part of project-based work. If considering ultraviolet rays of daylight during hot midday hours, passive design and structural interventions draw interaction from many strong design structural components seen in courtyards, eaves and grilles used in windows and walls.

Proper manipulation of natural light promotes visual comfort in a space and satisfies and nurtures the psychological and physiological needs of users. Daylight enhances mental and psychological balance with human biological clock through vitality, dynamism and richness in space. The use of daylight as a symbolic architectural element in religious, cultural and social buildings through history suggest that light is more than an architectural element in light; it is an architectural language of universal significance.

The advancements in technology have recently opened possibilities for the efficient and sustainable use of daylight. Smart facade concepts, strategic shading strategies and consideration in openings permit daylight to be delivered to every point within the building in

an efficient manner. These technological advancements will undoubtedly continue to make daylight a design variable in architecture of the future.

Daylight is not just an opportunity for illumination, but rather a means of design that expresses aesthetic, symbolic and functional values of a space. The intentional and thoughtful use of light will play an intricate role in the development of environmentally, socially and economically sustainable future buildings and spaces - both on individual scales and in urban levels.

Acknowledgements and Information Note

I would like to thank my valuable advisor Dr. Halil SEVİM, Assistant Professor, who shared his knowledge and experience with me in my undergraduate and postgraduate education and never withheld his academic support he provided me with knowledge and experience of the thesis process, as well as thanks to faculty members of the Faculty of Fine Arts at KTO Karatay University; I am grateful for everything.

I wish to express my deepest gratitude to my dear family, who have always supported me throughout my educational journey and made me feel that I am always with their presence by my side.

References

Bayhan, D. (2018). *A study on the effect of applications creating daylight effect in enclosed spaces without daylight on user perception* [Unpublished master's thesis]. Istanbul Technical University.

Bedir, Z., & S. G. M. (2019). Jean-Marie Tjibaou Cultural Center as a local and innovative building and the examination of its details. *Online Journal of Art and Design*, 7(5), 343–254.

Bulut, Ü. (2001). Development of window frames – Design, production, and application errors in wooden and polymer (PVC) window frames [Unpublished master's thesis]. Istanbul Technical University.

Cengiz, M. S. (2022). Use of daylight in houses and villas from modern architectural buildings. *European Journal of Science and Technology,* (38), 247–258. https://doi.org/10.31590/ejosat.1113599

E., Ö. (2011). *The effects of natural and artificial lighting on human psychology* [Unpublished master's thesis]. Marmara University.

Etli, P. D. (2013). *The role and importance of light in architectural offices within the scope of sustainable architecture* [Unpublished master's thesis]. Anadolu University.

Fitoz, İ. (2002). *A lighting design model for "artificial light" as a determinant factor in space design* [Unpublished master's thesis]. Mimar Sinan University.

G., T. (2018). *The use of renewable energy resources in sustainable architecture, application methods in public buildings and examination of examples* [Unpublished master's thesis]. Fatih Sultan Mehmet Vakıf University.

J., G., & D., İ. E. (2021). Evaluation of ecological buildings in terms of basic design criteria. *Landscape – Journal of Education, Science, Culture and Art*, 3(1), 1–21.

Karakurt, H. S. (2008). *Evaluation of the thermal performance of window systems depending on frame options* [Unpublished master's thesis]. Istanbul Technical University.

Kaya, Y. E., Çelikel, S. B., & Özturan, Ö. (2021). Openness to the spiritual in Tadao Ando's architecture: Examples of Azuma House, Church of the Light, and Water Temple. *Journal of Architecture and Life*, 6(2), 503–518. https://doi.org/10.26835/my.901204

M. E. Ç., & Ü. T. A. (2021). Daylight redirection systems. *Journal of Architectural Sciences and Applications,* 6(1), 59–76.

Özhan, M. Ö. (2017). *Sustainability in the construction industry and energy-efficient housing design* [Unpublished master's thesis]. Haliç University.

Tekneci, Ö. (2023). *The effect of artificial light use on spatial perception in contemporary art production* [Unpublished master's thesis]. Sakarya University.

Y., A. K. (2008). Methods of utilizing daylight in buildings: Roof techniques. *Journal of Plumbing Engineering,* (108), 231–241.

Yıldırım, B., & M., E. (2021). Principles of lighting and natural lighting according to the buildings where it is used. *Online Journal of Art and Design*, 9(2).

E. J. P., & Andeunikang. (2021). Sublime experience for sustainable underground space: Integration of the artists' works in Chichu Art Museum. *Sustainability,* 13(6653), 2–15. https://doi.org/10.3390/su13126653

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Examination of Lighting Use in Exhibition Spaces within the Context of Refunctioned Museum Buildings Through Sample Studies

Kübra CİVELEK KALINCA [1]*

ORCID 1: 0009-0009-8308-7634
[1]Master's Student, Firat University, Institute of Science, Department of Architecture, Elazığ-Türkiye
cvlkubra@gmail.com (Responsible Author)

Menşure Kübra MÜEZZİNOĞLU [2]

ORCID 2: 0000- 0001-5808-6618
[2]Assoc. Prof. Dr., Firat University, Faculty of Architecture, Department of Interior Architecture, Elazığ-Türkiye
mkmuezzinoglu@firat.edu.tr

Abstract

The conversion of buildings with different functions into museums constitutes a significant field of study from architectural, cultural, and functional perspectives. Today, adaptive reuse practices contribute not only to the preservation of the historical identity of buildings but also to meeting contemporary functional needs. In this process, beyond the architectural features and spatial qualities of the building, the development of lighting solutions that support its new function plays a critical role. Particularly in buildings converted into museums, lighting is a decisive factor in terms of artifact conservation, the perceptibility of exhibition spaces, and the enrichment of visitor experience. Lighting design varies depending on the original characteristics of the building and the functional context to which it is adapted. In this regard, examples of military, religious, educational, administrative, residential, and industrial buildings converted into museums constitute the main focus of this study. Within the scope of the research, selected cases from both national and international contexts were classified according to their functional transformation and evaluated in terms of natural and artificial lighting systems. Data obtained through extensive literature review were systematically analyzed by applying the SWOT analysis method for each building type. These analyses reveal the strengths and weaknesses, as well as the opportunities and threats associated with the use of lighting in the adaptive reuse process. The findings demonstrate that in projects where different building typologies are transformed into museums, lighting is not merely a technical requirement but also a strategic design element that shapes the perceptual, cultural, and aesthetic values of space. In this respect, the study aims to provide guiding recommendations for the development of lighting strategies in future adaptive reuse projects.

Keywords: Lighting, re-functioning, cultural buildings, museum

1. Introduction

The inability to sustain a building's original function due to environmental, functional, or economic reasons necessitates its reevaluation for a different purpose. Adaptive reuse (refunctioning) not only preserves the existing building stock but also reduces negative impacts on the natural environment, generates economic benefits, and contributes to cultural and historical continuity (Aydın & Yaldız, 2010). For this process to be conducted effectively, the spatial qualities and physical characteristics of the building must be carefully analyzed. Particularly in buildings converted into museums, lighting constitutes a critical design parameter in terms of both the success of the exhibition function and the effective use of the space.

Throughout history, adaptive reuse has been one of the most frequently employed methods for preserving various types of buildings and transmitting them to future generations (Kaymakçı, 2022). Through functional transformation, buildings gain extended lifespans while simultaneously strengthening their significance in collective memory (İslamoğlu, 2018). In this

context, museums stand out as institutions that preserve and exhibit works of culture, art, science, and history (Özcan & Çağlar, 2020). Thus, buildings that have lost their original function are not only preserved through adaptive reuse but also become significant focal points that contribute to the touristic and cultural identity of cities (Kaymakçı, 2022).

At this point, lighting emerges as an element that both supports the new function of the building and shapes the visitor experience. Architect Tadao Ando's statement, "In all my works, light is an important control element" (ArchDaily, 2011), highlights the determining role of light in spatial perception. Human beings are constantly interacting with factors such as light, color, sound, temperature, and scent in their environments. Among these, light is the fundamental component of visual perception and the central element of lighting design (Okutan, 2012). The International Commission on Illumination (CIE) defines lighting as "the application of light to ensure the proper perception of the environment and objects" (Ünver, 2002, as cited in Öksüz, 2024). Hence, lighting is not merely a technical necessity but also a strategic design tool that supports the aesthetic, functional, and psychological dimensions of space (Kasap, 2016; Öksüz, 2024).

The multifaceted impact of lighting is directly related to the types of light used. Based on their sources, lighting systems are classified as natural or artificial; based on their purposes, as physiological or decorative; and according to the method of light distribution, as direct, semi-direct, semi-indirect, indirect, or homogeneous (Kasap, 2016; Öksüz, 2024). Natural lighting, with its dynamic structure dependent on sunlight, enables the most realistic perception of objects and spaces, while artificial lighting provides controllable and flexible illumination at the desired time and intensity. Therefore, balancing natural and artificial light in museums is of critical importance for both the conservation of artifacts and the enhancement of the visitor experience.

In the early stages of museology, artifacts were displayed under intense light; however, it was later understood that such exposure could cause irreversible damage to the objects. Today, controlled artificial lighting systems have become prominent for the purpose of artifact conservation (Yöndem & Akyol, 2017). In this context, four fundamental principles of museum lighting have been identified: (1) preventing glare to ensure clear visual perception, (2) protecting artworks from harmful radiation, (3) supplementing daylight with artificial lighting, and (4) revealing the formal, chromatic, and material properties of objects (Kurtay et al., 2003).

These principles become particularly sensitive in historical buildings. In the process of adaptive reuse, lighting design is expected to be consistent with the original character of the structure. Factors such as the building's function, volume, orientation, window openings, interior materials, and environmental conditions (light levels, surrounding natural or artificial barriers) should be evaluated together (Öksüz, 2024). In this way, lighting becomes an integrated element that both preserves the historical atmosphere of the building and supports its exhibition function.

Various types of buildings around the world and in Turkey have been converted into museums. However, these buildings have generally been examined from architectural or functional perspectives, while comparative studies focusing specifically on lighting remain limited. Although studies such as those by Çetin (2021) and Akyürek (2022) have made valuable contributions in certain respects, no comprehensive research has systematically compared different building types in terms of lighting. Therefore, this study examines museums converted from military, religious, educational, governmental, residential, and industrial structures,

analyzing the functional effects of existing and added lighting systems through the SWOT analysis method, identifying their strengths and weaknesses, and developing recommendations for future applications.

2. Materials and Methods

In this study, various building typologies that have been adaptively reused to serve as museums were evaluated based on the natural and artificial lighting strategies employed in their exhibition spaces. The aim is to present a comparative analysis of the lighting solutions adopted by buildings with different historical and spatial characteristics after being transformed into museums. In doing so, the study discusses the role of lighting in maintaining the balance between preservation and utilization, as well as in shaping the visitor experience.

Three main criteria were adopted for the selection of case studies:

- Diversity: Examination of different typologies with distinct original functions, such as military, religious, educational, governmental, residential, and industrial buildings,
- Accessibility: Focus on buildings that are documented in the literature or whose visual and technical data are available,
- Lighting Solutions: Inclusion of cases where both natural and artificial lighting applications in exhibition spaces could be observed.

Based on these criteria, the selected case studies were first introduced in relation to their historical background and architectural features, and subsequently classified according to the types of lighting used in their exhibition areas. During the analysis, factors such as the integration of daylight, window and roof openings, types of artificial lighting (e.g., spotlights, LED systems, track lighting), and their effects on exhibited artifacts were taken into consideration. These evaluations constitute the first phase of the research. In the second phase, a SWOT analysis was conducted for each building group, identifying their strengths, weaknesses, opportunities, and threats. Accordingly, the study not only examines the technical aspects of lighting design, but also evaluates its impact on visitor experience, spatial perception, and artifact conservation in a holistic manner. The buildings examined in this research are presented in Table 1, which classifies the museums according to their original functional typologies. This classification facilitates the systematic presentation of the analyses in the subsequent sections and enables comparative evaluations among different building types.

Table 1. Buildings Refunctioned as Museums

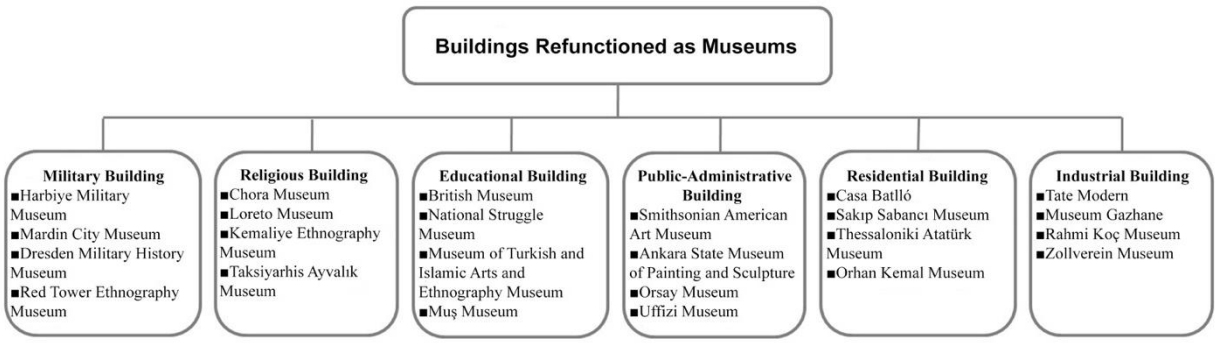


Table 1 illustrates the scope of the selected examples included in this study. According to the table, although each group of buildings possesses distinct spatial characteristics, lighting

emerges as one of the most critical design parameters in the process of transformation into a museum. In the following sections, the buildings listed in the table are examined individually in the context of natural and artificial lighting strategies, and their strengths and weaknesses are discussed through SWOT analyses.

3. Findings and Discussion

In this section, examples of buildings that have been adaptively reused as museums—originally functioning as military, religious, educational, governmental, residential, and industrial structures—are analyzed in terms of the use of artificial and natural lighting within their interior exhibition spaces.

3.1. Examples of Buildings Refunctioned from Military Structures into Museums

This subsection examines the lighting design elements used in the interior exhibition areas of buildings that have been refunctioned from military structures into museums (Table 2).

Harbiye Military Museum (Harbiye School): The building complex of the Harbiye Military Museum, originally known as Harbiye Mektebi, was constructed in successive phases between 1844 and 1893. Following a restoration process initiated in 1967, the building was opened as a museum in 1993 (Erkal, 2020; Çoruhlu, 1994; Zorlu, 2021). Natural light enters the interior through courtyard windows and roof skylights, while the exhibition areas utilize recessed and track spotlights, LED lighting within display cases, and accent lighting (Figure 1). However, reflections are observed on some display case glasses, and the showcase lighting systems operate on a timed basis, activated by visitor-controlled push buttons (Doğruer, 2020).



Figure 1. Exhibition Areas of the Harbiye Military Museum (Askerî Müze, 2014)

Sakıp Sabancı Mardin City Museum (Mardin Barracks): The barracks, dating from 1887–1891, were converted into a museum in 2009 following a comprehensive restoration (Düzenli & Düzenli, 2020). During the restoration, a controlled exhibition design was implemented using a suspended ceiling and spot lighting, while natural light was maintained at a supportive level (Figure 2).



Figure 2. Exhibition Spaces of the Sakıp Sabancı Mardin City Museum (Author's personal archive, 2025)

Dresden Military History Museum (Armory): The armory, constructed between 1873 and 1876, was reopened in 2011 with Libeskind's extension (Arslan, 2023; Özalp & Halaç, 2024). Large arched windows introduce natural light, while ceiling-mounted track spotlights allow flexible focusing, and linear LEDs provide general illumination (Figure 3).



Figure 3. Exhibition Spaces of the Dresden Military History Museum (Libeskind, 2011; ArchDaily, 2011)

Kızılkule Ethnography Museum (Watchtower): The tower, dating back to 1226, was converted into an ethnography museum following its restoration between 1951 and 1953 (Ticaret & Odası, 2016; Kültür Portalı, 2013). Limited daylight enters through niche windows, while light sources placed at the base of the walls provide texture emphasis and directional guidance. Long-term preservation considerations should be applied to objects exposed to direct sunlight (Figure 4).



Figure 4. Exhibition Spaces of the Kızılkule Ethnography Museum (Arkeogezgin, 2017)

Table 2 presents examples of former military buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 2. Comparative Summary of Military Buildings Converted into Museums

CONVERTED BUILDING TYPE		MILITARY BUILDINGS			
BUILDING NAME		Harbiye Military Museum	Sakıp Sabancı Mardin City Museum	Dresden Military History Museum	Kızılkule Ethnography Museum
CONSTRUCTION YEAR		1846	1891	1876	1226
CONVERSİON YEAR		1993	2009	1897	1953
LOCATION		İstanbul/Turkey	Mardin/ Turkey	Dresden/Germany	Antalya/ Turkey
ORIGINAL FUNCTION		Military School	Cavalry Barracks	Armory	Watchtower
CURRENT FUNCTION		Military Museum	Mardin City Museum	Military History Museum	Ethnography Museum
LIGHTING	ARTIFICIAL LIGHTING	-Recessed spotlights -Movable spotlights -LED lights	-Spotlights	-Track spotlights - Linear fixtures	-Fixed spotlights
	NATURAL LIGHTING	Daylight is incorporated through windows and ceiling skylights and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.

According to Table 2, military-origin buildings, despite differences in period and morphology, tend to adopt similar lighting principles in their conversion into museums. In the artificial lighting layer, track, recessed, and fixed spotlights combined with linear LED solutions are predominant; this approach enables object-focused emphasis and flexible staging. Natural light is mostly introduced through windows and, where applicable, ceiling skylights, and is systematically supplemented by artificial lighting to maintain stable exhibition conditions. Considering the "Construction Year" together with the "Conversion Year" indicates that design decisions are influenced by the balance between preservation requirements and the integration of contemporary fixtures. In massive, low-opening typologies (e.g., towers), limited daylight results in the prominence of grazing light and localized accentuation, whereas in wide-span buildings such as barracks or armories, selective spot lighting is applied over a base of homogeneous daylight. Overall, the trend suggests that a hybrid (natural + artificial) lighting scheme enhances exhibition legibility while supporting the building's original atmosphere.

3.2. Examples of Buildings Converted from Religious Structures into Museums

This section examines the lighting elements used in the interior exhibition spaces of buildings that have been repurposed from religious structures into museums (Table 3).

Chora Museum (Church): The Chora Church, which transitioned from a monastic structure to a mosque, was converted into a museum following restoration that began in 1948 and was completed in 1958 (müzeler.org., n.d.). In this museum, where the historic building itself is also exhibited, general illumination is provided with low-color-temperature lighting, while the frescoes are illuminated with high color-rendering, warm spotlights. These are filtered and directed to ensure the long-term preservation of the paints (Önsoy, 2002) (Figure 5).



Figure 5. Chora Museum (Kariye Camii, t.y.)

Loreto Museum (Church): The construction of the basilica began in 1468 (Bellitalie, 2021). In the church lighting design, spatial elements were emphasized through varying light levels and color temperatures; the ceiling was highlighted with daylight-like illumination, while bright objects were lit in a way that minimized glare differences (Figure 6). In the building, which has been converted into a museum, lighting solutions featuring motion sensors, warm-colored light, and artifact-safe technologies were implemented to ensure both artifact preservation and energy efficiency (Önsoy, 2002).



Figure 6. Loreto Museum (iStockphoto, 2017; Bellitalie, 2021; DZ Architecture Agency, t.y.)

Kemaliye Ethnography Museum (Church): The museum was opened in 1999 through the adaptive reuse of the Surp Kiyork Church, originally constructed in 1870 (Engin, 2023). In the exhibition areas, linear LED luminaires were employed in addition to natural lighting; daylight was enhanced through large arched windows, while artificial lighting served a complementary function (Figure 7).



Figure 7. Exhibition Areas of the Kemaliye Ethnography Museum (Engin, 2023)

Taksiyarhis Ayvalık Rahmi M. Koç Museum (Church): The Taksiyarhis Church was transferred to the Rahmi M. Koç Museum and Culture Foundation in 2011 and was opened as a museum in 2014 (Akan, 2020). The circular chandeliers on the ceiling provided both decorative and functional effects through uniform light distribution; while the arched windows allowed natural light to enter, artificial lighting enhanced overall visibility. In the glass display cases, point-source lighting highlighted the details of the exhibited artifacts, whereas indirect lighting on the columns and upper sections accentuated the architectural elements (Figure 8).

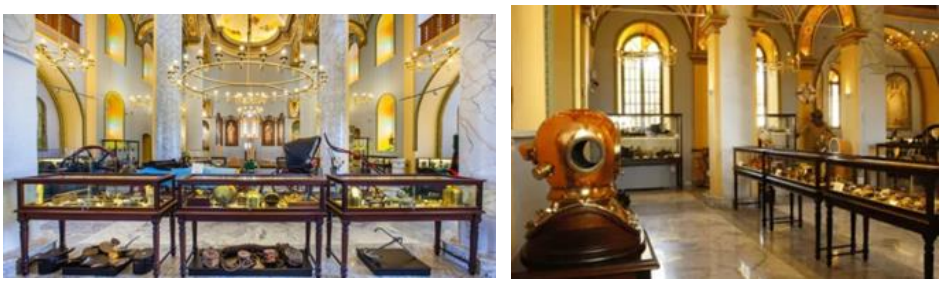


Figure 8. Interior Views of the Ayvalık Rahmi M. Koç Museum (Ayvalık Belediyesi, t.y.)

Table 3 presents examples of former religious buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 3. Comparative Summary of Religious Buildings Converted into Museums

CONVERTED BUILDING TYPE		RELIGIOUS BUILDINGS			
BUILDING NAME		Kariye Museum	Loreto Museum	Kemaliye Ethnography Museum	Taksiyarhis Ayvalık Rahmi M. Koç Museum
CONSTRUCTION YEAR		4.YY	1468	1870	1462
CONVERSİON YEAR		1958	-	1999	2014
LOCATION		İstanbul/Turkey	Italy	Erzincan/ Turkey	Balıkesir/ Turkey
ORIGINAL FUNCTION		Church	Church	Church	Church
CURRENT FUNCTION		Museum	Museum	Ethnography Museum	Museum
LIGHTING	ARTIFICIAL LIGHTING	-Filtered and directional spotlights	-Sensor-based lighting fixtures -Parabolic reflector devices -Track-mounted spot lighting	-LED luminaires	-Point-source and indirect lighting elements
	NATURAL LIGHTING	Daylight is incorporated through windows and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.	Daylight is incorporated through windows and is supplemented by artificial lighting.

According to Table 3, in museums converted from religious buildings, daylight generally serves as a primary source of ambient illumination, entering the space mostly through window openings and balanced by layers of artificial lighting. Due to conservation requirements (particularly concerning wall paintings, ornamentation, and wooden or textile surfaces) daylight has been directed, filtered, and limited, while exhibition legibility has been achieved through accent and indirect artificial lighting solutions. A comparative analysis of the examples reveals that in Kariye, filtered and directional spotlights enhance the perception of polychrome surfaces; in Loreto, sensor-supported systems, parabolic reflector devices, and track-mounted spotlights establish a dynamic balance between energy efficiency and conservation. In Kemaliye, linear LED fixtures are employed as a complement to daylight, whereas in Taksiyarhis, point-source and indirect lighting enhance both the emphasis on architectural elements and the visibility of the collection. These findings indicate that within religious typologies, hybrid (natural + artificial) lighting strategies represent a preferred, flexible, and controllable approach-supporting both artifact conservation and spatial interpretation/visitor experience.

3.3. Examples of Buildings Converted from Educational Structures into Museums

In this section, the lighting elements used in the interior exhibition spaces of buildings that have been adaptively reused from educational facilities into museums are examined (Table 4).

British Museum: British Museum was founded in 1753 (Buyurgan & Şener, 2023). Between 1994 and 2000, the courtyard was enclosed with filtered glass, creating a new exhibition area and protecting the collections from external factors. Daylight was controlled through filters and supplemented with UV-free fluorescent lamps and fiber-optic systems to provide suitable illumination for the artifacts. In the exhibition design, appropriate light levels and brightness contrasts were employed to direct visual attention toward the displayed objects (Önsoy, 2002) (Figure 9).

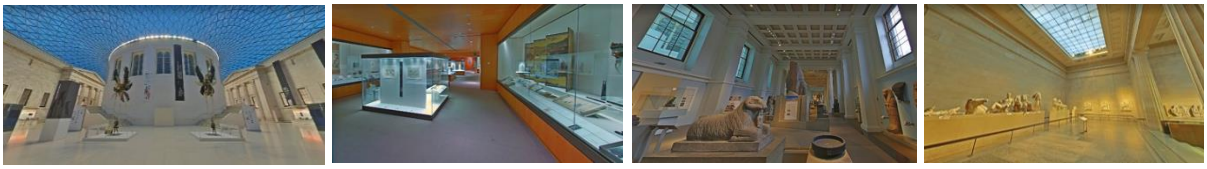


Figure 9. Exhibition Areas of the British Museum (Google Arts & Culture, t.y.-a)

National Struggle Museum (Kayseri High School): The Kayseri High School building was restored in 2012 and reopened as the National Struggle Museum in 2016 (Güner, 2017). In the museum's spatial design, the main hall was characterized by dark tones to create a dim and contemplative atmosphere, while circulation routes were emphasized through the use of materials and lighting. In the west wing, natural light was blocked, and specialized lighting systems were implemented for photographs, models, and objects. The floor was illuminated with low-level LED units, while general lighting was provided by spotlights (Figure 10). To enhance the impact of projections, a dark environment was maintained, and directional signage was supported with illuminated panels (Akyürek, 2022).



Figure 10. Exhibition Spaces of the National Struggle Museum (Akyürek, 2022)

Erzurum Yakutiye Madrasa Museum of Turkish-Islamic Art and Ethnography (Madrasa): Constructed between 1310 and 1311, the madrasa has been repurposed as the "Erzurum Yakutiye Madrasa Museum of Turkish-Islamic Art and Ethnography" following restorations carried out in 1995 and 2005 (Temur & Açıcı, 2022). In the museum layout, spotlights placed at the bases of columns highlight architectural details and guide visitor circulation. Natural light entering through the ceiling opening is supplemented with artificial lighting, while the artworks displayed on the walls are accentuated with focused illumination. Daylight is controlled for conservation purposes, and in the glass display cases, spotlights are used to provide targeted lighting (Figure 11).



Figure 11. Erzurum Yakutiye Madrasa Museum of Turkish-Islamic Art and Ethnography (Kültür Portalı, 2013; Erzurum Büyükşehir Belediyesi, t.y.)

Muş Museum (Primary School): Originally constructed in 1937 as Atatürk Primary School, the building was opened as a museum in 2021. The exhibition areas include glass display cases, informational panels, and appropriate lighting systems (Engin, 2024). Ceiling-mounted spotlights emphasize the display cases and wall visuals, while natural light is controlled using curtains (Figure 12).



Figure 12. Interior Views of the Muş Museum (Engin, 2024)

Table 4 presents examples of former educational buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 4. Comparative Summary of Educational Buildings Converted into Museums

CONVERTED BUILDING TYPE		EDUCATIONAL BUILDINGS			
BUILDING NAME		British Museum	National Struggle Museum	Erzurum Yakutiye Madrasa Museum of Turkish-Islamic Art and Ethnography Museum	Muş Museum
CONSTRUCTION YEAR		-	1904	1311	1937
CONVERSİON YEAR		1753	2016	2005	2021
LOCATION		London/England	Kayseri/Turkey	Erzurum/Turkey	Muş/Turkey
ORIGINAL FUNCTION		Academy Building	High school	Madrasa	Primary School
CURRENT FUNCTION		Museum	Museum	Ethnography Museum	Museum
LIGHTING	ARTIFICIAL LIGHTING	-Point-source and indirect lighting elements -Spotlights	-Specific spot -LED lighting	-Focused spotlights - LED lighting	-Focused spotlights -LED lighting
	NATURAL LIGHTING	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.	Daylight is supported by artificial lighting in some exhibition areas through window openings.	Daylight is supplemented with artificial lighting via ceiling openings.	No natural daylight is used in the exhibition areas.

According to Table 4, lighting strategies in buildings originally constructed for educational purposes are based on a hybrid (natural + artificial) approach that aligns with exhibition scenarios and conservation requirements. In the British Museum, daylight provided through windows and ceiling openings is balanced with point-source and indirect artificial layers, establishing both ambient illumination and artifact emphasis. In the National Struggle Museum, daylight is used selectively and in a limited manner; in certain spaces, a dark-box approach combined with specific spotlights and LED solutions reinforces narrative focal points. In the Yakutiye Madrasa, ceiling openings serve as the primary source of daylight, while a combination of focused spotlights and LEDs enhances visual legibility in the exhibition. In the Muş Museum, natural light is avoided in the exhibition areas, and controlled, artifact-adapted staging is achieved through focused spotlights and LEDs. Overall, the trend indicates that the combined use of controlled/filtered daylight with targeted artificial lighting simultaneously supports legibility, visitor guidance, and conservation objectives.

3.4. Examples of Buildings Converted from Public/Administrative Structures into Museums

In this section, the lighting elements used in the interior exhibition spaces of buildings that have been adaptively reused from public/administrative facilities into museums are examined (Table 5).

Smithsonian American Art Museum (Patent Office Building): Opened as a museum in 1968, the Patent Office Building was designated as the National Museum of American Art in 1980 and renamed the Smithsonian American Art Museum in 2000 (Cook, 2019). Natural light is provided through ceiling and wall windows, while indirect lighting creates spatial uniformity. Track-mounted spotlights provide individual emphasis on each artwork, highlighting sculptures and paintings in particular (Figure 13)



Figure 13. Exhibition Areas of the Smithsonian American Art Museum (Google Arts & Culture, t.y.-b)

Ankara State Museum of Painting and Sculpture (Turkish Hearths Headquarters): Constructed between 1927 and 1930 as the Turkish Hearths Headquarters, the building was converted into a museum in 1975 (Başkan, 1989). In the exhibition areas, oil paintings are illuminated with LED luminaires that provide high color rendering and daylight-like quality, ensuring a uniform light distribution with a low UGR value (Eryurt, 2017). Ceiling-mounted spotlights are angled to focus on the paintings, while linear LEDs and light sources beneath semi-translucent panels create soft, homogeneous general illumination. Vertical roller blinds are used to control the intensity of natural light and reduce glare (Figure 14).

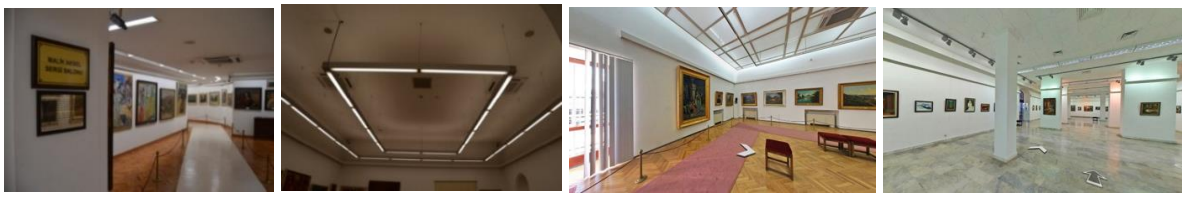


Figure 14. Museum exhibition hall and the lighting sources employed (Eryurt, 2017; Resim ve Heykel Müzesi, 2014)

Orsay Museum (Train Station): Located in Paris, the Orsay Museum opened in 1986 following the conversion of the former Gare d'Orsay train station (Güven, 2022). The main entrance is illuminated through a skylight and facade windows, while the galleries are supplemented with LED and spotlight systems (Çetin, 2021). Specialized lighting is employed for the artworks, and natural and artificial light are used in combination through ceiling openings (Yılmaz, 2024) (Figure 15).



Figure 15. Exhibition Areas of the Orsay Museum (Divisare, 2018)

Uffizi Museum: Initiated under the patronage of the Medici family in 1560 and completed in 1581, the Uffizi Palace originally housed the family's art collections and was opened to the public in 1789, serving as a model for subsequent galleries (Aslanoğlu, 2014). Natural light is controlled through semi-translucent glass panels and windows, while the exhibition areas employ linear LED fixtures, movable spotlights, and point-source lighting (Figure 16).

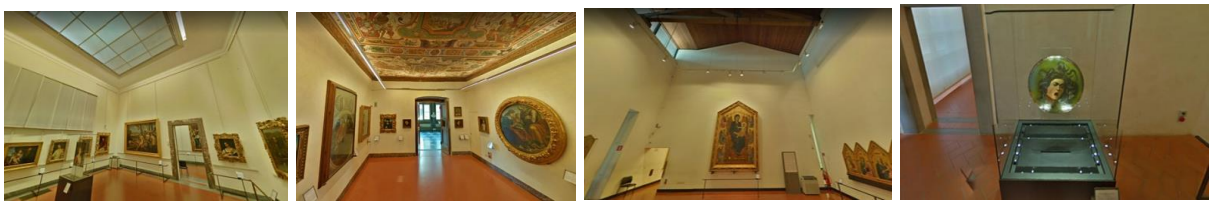


Figure 16. Exhibition Areas of the Uffizi Museum (Google Arts & Culture, t.y.-c)

Table 5 presents examples of former public/administrative buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 5. Comparative Summary of public/administrative Buildings Converted into Museums

CONVERTED BUILDING TYPE		PUBLIC/ADMINISTRATIVE BUILDINGS			
BUILDING NAME		Smithsonian American Art Museum	Ankara State Museum of Painting and Sculpture Museum	Erzurum Yakutiye Madrasa Museum of Turkish-Islamic Art and Ethnography Museum	Muş Museum
CONSTRUCTION YEAR		-	1930	19.yy sonları	1581
CONVERSİON YEAR		1968	1975	1986	1789
LOCATION		Washington/ABD	Ankara/Turkey	Paris/France	Florence/Italy
ORIGINAL FUNCTION		Patent Office Building	Turkish Hearths Headquarters	Train Station	Palace
CURRENT FUNCTION		Museum	Museum	Museum	Museum
LIGHTING	ARTIFICIAL LIGHTING	Track-mounted spotlights – Indirect lighting elements	Track-mounted spotlights – Indirect lighting elements – Linear LED fixtures	Track-mounted spotlights – LED fixtures	Spotlights – Linear LED fixtures – Point-source spotlights

NATURAL LIGHTING	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.	Daylight is supported by artificial lighting in some exhibition areas through window openings.	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.

According to Table 5, in buildings originally constructed for public and administrative use, lighting strategies are based on a balanced combination of the homogeneous daylight provided by large openings and overhead clerestories with track-mounted spotlights and linear LED layers. Daylight is controlled for glare and UV protection through curtains, diffusing panels, and semi-translucent ceiling solutions, while artificial lighting ensures artifact-focused emphasis, wayfinding, and accurate color rendering (high CRI). This approach simultaneously addresses conservation, legibility, and spatial identity. In specific examples: at the Smithsonian, daylight entering through ceiling and facade windows is directed toward the artworks using indirect lighting combined with track-mounted spotlights; at the Ankara State Museum of Painting and Sculpture, soft and uniform illumination is achieved under semi-translucent ceiling panels with high-CRI LEDs, while roller blinds control glare; at the Orsay Museum, the combination of skylights and facades is supplemented with selective spotlights for individual artworks; at the Uffizi, filtered natural light through semi-translucent surfaces is integrated with movable, point-source, and linear spotlights. Overall, the trend indicates that a hybrid (natural + artificial) lighting strategy provides a sustainable and flexible approach, supporting both artifact conservation and the visitor experience.

3.5. Examples of Buildings Converted from Residential Structures into Museums

In this section, the lighting elements used in the interior exhibition spaces of buildings that have been adaptively reused from residential facilities into museums are examined (Table 6).

Casa Batlló (Residential Apartment): Redesigned by Gaudí between 1904 and 1906, the building was transformed from a family apartment into a museum (Acar, 2017). Today, visitors experience the space through AR guides, video tours, and projection-based visualizations (Arslan, 2024). The exhibition areas offer varied spatial experiences through the use of pendant lamps, natural light, thematic lighting, and projection-supported light displays (Figure 17).



Figure 17. Exhibition Areas of Casa Batlló (Casa Batlló, t.y.)

Sakıp Sabancı Museum (Mansion): Established through the conversion of the Sabancı family's Atlı Mansion, the Sakıp Sabancı Museum opened in 2002 (Uçar, 2008). Hosting both the family collections and temporary exhibitions, the museum preserves the original layout of the mansion, with lighting provided by chandeliers and movable spotlights. In the corridors, paintings are highlighted with track-mounted spotlights, while books and calligraphy collections are displayed in low-lit cases (Özcan & Çağlar, 2020). The gallery's spacious hall

with a high ceiling is illuminated through glass ceiling details, and the exhibition areas connected to this upper level also benefit from skylight. Fluorescent strips are installed on the corridor ceilings, and the stairwell is illuminated through a combination of glass ceilings and wall-mounted fluorescent fixtures (Figure 18).



Figure 18. Interior Views of the Sakıp Sabancı Museum (Özcan & Çağlar, 2020)

Selanik Atatürk Museum (House): Originally constructed before 1870, the Atatürk House was converted into a museum and opened in 1953 (Anadol & Arıoğlu, 1981). Wall panels are made legible through uniform lighting, while images on window surfaces are covered with light-filtering materials, allowing natural light to contribute to the interior illumination. Soft ambient lighting is provided by wall sconces, and artifacts in display cases are emphasized with point-source spotlights (Figure 19).



Figure 19. Exhibition Areas of the Selanik Atatürk Museum (Arkeologlar Derneği, 2019)

Orhan Kemal Museum (Apartment): The Orhan Kemal Museum was converted from a residential apartment into a museum in 2000 to preserve the literary legacy of Orhan Kemal (Bektaş & Yalçınkaya, 2020; Çevik, 2021). The museum is organized around an object-focused exhibition and lighting strategy for items belonging to the author and his family, and due to the absence of interactive technologies, visitor engagement remains limited (İlbi, 2023). Lighting is provided through ceiling-mounted spotlights, which emphasize the objects, and natural light is blocked in favor of artificial illumination (Figure 20).



Figure 20. Exhibition Areas of the Orhan Kemal Museum (Bektaş, 2019)

Table 6 presents examples of former residential buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 6. Comparative Summary of Residential Buildings Converted into Museums

CONVERTED BUILDING TYPE		RESIDENTIAL BUILDINGS			
BUILDING NAME		Casa Battlo	Sakıp Sabancı Museum	Selanik Atatürk Museum	Orhan Kemal Museum
CONSTRUCTION YEAR		1877	-	-	-
CONVERSİON YEAR		1906	2002	1953	2000
LOCATION		Barcelona/Spain	Istanbul/Turkey	Thessaloniki/Greece	Istanbul/Turkey
ORIGINAL FUNCTION		Family Apartment	Mansion	House	Apartment Flat
CURRENT FUNCTION		Museum	Museum	Museum	Museum
LIGHTING	ARTIFICIAL LIGHTING	-Chandelier use -Projection devices	- Track/mounted spotlights -Small spotlights -Chandelier use	-Wall sconces -Spotlights -Point/source spotlights	-Spotlights
	NATURAL LIGHTING	Daylight is supplemented with artificial lighting through the use of windows in some exhibition areas.	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.	Daylight is supplemented with artificial lighting through controlled use of windows.	No daylight is used in the exhibition areas.

According to Table 6, in museums converted from residential buildings, the lighting strategy is based on a layered and controllable design that preserves the original residential atmosphere while enhancing exhibition legibility. In most examples, daylight is limited or filtered, and in smaller spaces, focused artificial lighting—such as track-mounted/small spotlights, point-source highlights, and wall sconces—is emphasized to reduce glare and reflection risks. In specific cases, at Casa Batlló, chandeliers combined with projection-supported experiential scenarios complement daylight; at the Sakıp Sabancı Museum, movable track-mounted and small spotlights are balanced with natural light from windows and ceiling openings. At the Selanik Atatürk Museum, wall sconces and point-source spotlights provide uniform legibility in conjunction with controlled window use. In the Orhan Kemal Museum, natural light is avoided entirely, with the exhibition fully illuminated by spotlights. Overall, the trend indicates that in residential typologies, the hybrid (natural + artificial) approach tends to favor artificial lighting, which consistently supports artifact conservation, visitor guidance, and the perception of close-scale interior spaces.

3.6. Examples of Buildings Converted from Industrial Structures into Museums

In this section, the lighting elements used in the interior exhibition spaces of buildings that have been adaptively reused from industrial facilities into museums are examined (Table 7).

Tate Modern Art Museum (Power Plant): Constructed between 1947 and 1963, the Bankside Power Station was closed in 1981 and reopened as the Tate Modern in 2000 following restoration work initiated in 1995 (Yiğitoğlu, 2020). Natural light is enhanced through its semi-translucent glass roof and original windows, while different ceiling heights are supported by a variety of lighting systems. The semi-translucent glass layers filter daylight during the day and are designed to be illuminated artificially at night (Jones, 2013). The space and artworks are accentuated through linear LEDs, spotlights, and stretched ceiling lighting (Figure 21).



Figure 21. Tate Modern Art Museum (Jones, 2013; Herzog & de Meuron, 2023)

Müze Gazhane (Gasworks): Established in 1891, the Kadıköy Gas Company ceased production in 1993. The Hasanpaşa Gasworks, placed under protection in 1994, was reopened as a museum in 2021. Daylight is supplemented with artificial lighting, while the space is illuminated through electro track spot systems, linear fixtures emphasizing windows, and facade light controlled with blinds (Öztütüncü, 2023). Track-mounted spotlights are used in circulation areas, and colored illuminated panels are employed at experience stations. Spatial cohesion is maintained through linear LED fixtures integrated into the suspended ceiling. The seating area shown in Figure 22 does not receive uniform light throughout the day; reflections from transparent facade surfaces reduce the visibility of objects in glass display cases, making it more difficult for visitors to focus (Öztütüncü, 2023).



Figure 22. Exhibition Areas of Müze Gazhane (Öztütüncü, 2023)

Rahmi Koç Museum (Foundry Building): Constructed in 1703, the Lengerhane Building was converted into a museum through restoration in 1994 (Akyürek, 2022). Warm tones were preferred for the chandelier suspended from the dome and general lighting to reinforce the historical atmosphere of the space (Keçeli & Doğan, 2023). Spot LEDs in display cases and linear LEDs on walls were used to highlight both the artifacts and the building materials. Natural light was limited with roller blinds, and intensive artificial lighting was applied (Figure 23).



Figure 23. Exhibition Areas of the Rahmi Koç Museum (Geziseyahat365, t.y.)

Zeche Zollverein Museum (Coal Mine): Opened as a coal mine in 1847, Zeche Zollverein was closed in 1986 and converted into a cultural and art center during the 1990s. The complex was inscribed on the UNESCO World Heritage List in 2001 and was expanded until the 2010s to include museums, exhibition areas, and educational facilities, forming a multifaceted cultural center (Graf, 2024). Strip LEDs and high-intensity spotlights were installed on structural elements at ceiling level, while natural light was kept minimal. Artificial lighting was applied intensively to maintain the industrial atmosphere; object-focused lighting emphasized the artifacts, while background and circulation areas were left in relative darkness (Figure 24).



Figure 24. Exhibition Areas of the Zeche Zollverein Museum (Varol Can, 2024; Ruhr Müzesi, t.y.; XXI, 2018)

Table 7 presents examples of former industrial buildings converted into museums, summarizing their functional history, current use, and interior lighting solutions (natural/artificial).

Table 7. Comparative Summary of Industrial Buildings Converted into Museums

CONVERTED BUILDING TYPE		INDUSTRIAL BUILDINGS			
BUILDING NAME		Tate Modern Art Museum	Müze Gazhane	Rahmi Koç Museum	Zeche Zollverein Museum
CONSTRUCTION YEAR		1963	1891	1703	1847
CONVERSİON YEAR		2000	2021	1994	1989
LOCATION		London/England	İstanbul/Turkey	İstanbul/Turkey	Essen/Germany
ORIGINAL FUNCTION		Power Plant	Gasworks	Foundry Building	Coal Mine
CURRENT FUNCTION		Museum	Museum	Museum	Museum
LIGHTING	ARTIFICIAL LIGHTING	-Linear LED fixtures -Spotlights -Stretched ceiling lighting	-Electro track/mounted spotlights -LED sources	-Fixed and movable spotlights -Linear LED sources -Chandelier	-Linear LED fixtures -Spotlights -Stretched ceiling lighting
	NATURAL LIGHTING	Daylight is supplemented with artificial lighting through the use of windows and ceiling openings.	Daylight is supplemented with artificial lighting through direct exposure and the use of windows.	Daylight is supplemented minimally with artificial lighting, with roller blinds used on the windows.	Daylight is supplemented with artificial lighting through the use of windows in some exhibition areas.

According to Table 7, lighting in buildings of industrial origin relies on a hybrid (natural + artificial) strategy to address the scale challenges created by high ceilings and large openings; however, due to conservation and control requirements, the artificial layer often predominates. At the Tate Modern, daylight filtered through the semi-translucent roof is balanced with a combination of linear LEDs, spotlights, and stretched ceiling lighting. In Müze Gazhane, facade daylight is regulated through blinds and electro track-mounted spot systems, while linear highlights enhance circulation. At the Rahmi Koç Museum, daylight limited by roller blinds, warm-toned general illumination, linear LEDs in display cases and on walls, and chandeliers reinforce the historical atmosphere. At Zeche Zollverein, limited natural light is transformed into a "textured" industrial emphasis through strong spotlights and linear LEDs. The combination of "Construction Year – Conversion Year" reflects the integration level of contemporary fixture technologies (high CRI, glare/UV control) and the balance between energy efficiency, conservation, and legibility. Overall, the trend indicates that in large-volume spaces, layered linear and spot lighting provides flexible staging and wayfinding while highlighting the building's original industrial character.

SWOT Analyses

In this study, the natural and artificial lighting decisions in the exhibition areas of museums converted from military, religious, educational, public-administrative, residential, and industrial buildings were examined. A SWOT approach was employed to discuss the relationship between design solutions and typological differences. The evaluations are presented under the headings of Strengths, Weaknesses, Opportunities, and Threats. Each typology is addressed below along with its corresponding SWOT table, followed by a brief commentary summarizing the analysis.

Table 8. SWOT analysis of lighting elements used in the exhibition areas of museums converted from military buildings

SWOT Analysis for Museums Converted from Military Buildings	Internal Factors		External Factors	
	Strengths	Weaknesses	Opportunities	Threats
Lighting in Exhibition Areas	-Unique lighting solutions emphasize the building's original atmosphere -The large interior spaces allow flexible and convenient implementation of lighting element.	-In large spaces, uneven light distribution may result in some areas being too dark while others are excessively bright. -There may be difficulties in installing lighting fixtures due to the structural characteristics of the building.	-Custom lighting designs can enhance the military character of the space	-Insufficient funding may lead to the implementation of low-quality lighting solutions

Military-origin buildings, with their large volumes and high ceilings, offer opportunities for flexible focus and layered staging through track/recessed spotlights combined with linear LED layers, significantly enhancing the legibility of exhibits. However, risks related to reflection/glare and uneven illumination require careful consideration. Anti-reflective surfaces, glare control measures, and timed or sensor-controlled circuits (e.g., within display cases) provide opportunities for both energy efficiency and artifact preservation, whereas the use of heterogeneous or low-quality fixtures may weaken the intended atmosphere and perception (Table 8).

Table 9. SWOT analysis of lighting elements used in exhibition spaces of museums converted from religious buildings

SWOT Analysis for Museums Converted from Religious Buildings	Internal Factors		External Factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Lighting in Exhibition Areas	-The use of openings of various sizes within the building enhances natural lighting and creates a more visually engaging atmosphere	-The existing lighting scheme may not adequately meet the requirements of the exhibition.	-The original lighting systems can help preserve the building's sacred or religious atmosphere.	-The original lighting systems can help preserve the building's sacred or religious atmosphere. - Wiring and installation works may compromise the structural integrity of the building.

In religious typologies, due to polychrome surfaces and ornamentation, low lighting levels, high CRI, and directed/filtered light are essential. Daylight is typically introduced in a controlled manner through window openings; sensor-assisted, indirect, or localized lighting arrangements enhance the balance between preservation and legibility. Incorrect spectral selection or excessive intensity can increase UV/thermal risks, making filtration, timing, and fixture placement critically important (Table 9).

Table 10. SWOT analysis of lighting elements used in exhibition spaces of museums converted from educational buildings

SWOT Analysis for Museums Converted from Educational Buildings	Internal Factors		External Factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Lighting in Exhibition Areas	-The clear articulation of the building's sections facilitates exhibition layout design and allows for the use of different lighting systems for each exhibition.	-Excessive and uncontrolled natural light entering through large and frequent openings may cause glare problems.	-By controlling and efficiently utilizing natural light, energy costs can be reduced.	Uncontrolled lighting may lead to the deterioration or damage of the exhibited artifacts.

Educational buildings, with their compartmentalized plans and defined circulation paths, are suitable for scenario-based lighting. A combination of filtered daylight and focused spot/LED lighting reinforces narrative focal points, while glare control-particularly in large openings-is a fundamental requirement. The "dark box" approach, employing deliberate dimming, enhances legibility and conservation in multimedia and sensitive artifact displays; uncontrolled natural light can increase the risks of glare and color distortion (Table 10).

Table 11. SWOT analysis of lighting elements used in exhibition spaces of museums converted from public-administration buildings

SWOT Analysis for Museums Converted from Educational Buildings	Internal Factors		External Factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Lighting in Exhibition Areas	-The flexibility of the building volumes facilitates the modernization of lighting systems according to the specific requirements of each exhibition.	-The difficulty of controlling light necessitates the implementation of more costly measures to ensure appropriate illumination conditions.	-Lighting can highlight the building's public identity and significance within the urban memory, thereby contributing to cultural tourism.	Improper placement of lighting elements may negatively affect spatial perception.

The large openings and clerestory windows in public-administration buildings provide uniform ambient illumination, which can be complemented with layered track spots and linear LED lighting to focus on exhibits. Diffuse panels, curtains, and translucent ceiling solutions help control glare and UV exposure, while high CRI enhances color fidelity. Misplacement of accent lighting can disrupt spatial perception, so light distribution, sightlines, and directional emphasis should be designed in an integrated manner (Table 11).

Table 12. SWOT analysis of lighting elements used in exhibition spaces of museums converted from residential buildings

SWOT Analysis for Museums Converted from Educational Buildings	Internal Factors		External Factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Lighting in Exhibition Areas	-Lighting in human-scaled buildings can create a warmer and more intimate atmosphere. -In smaller spaces, achieving homogeneous illumination is comparatively easier.	-Due to the limited height of the structure, the lighting elements may have a restricted range of effect, potentially disrupting the overall exhibition aesthetics.	-The building's windows can serve as partial light filters for the exhibition space. -Windows proportionate to the human scale are easier to control in terms of light management.	-Excessive or uncontrolled natural light may cause damage to the exhibited artifacts.

In residential typologies, while maintaining a human scale and domestic atmosphere, focused artificial lighting (small/track spots, wall sconces, localized accents) generally complements the limited daylight. In compact spaces, beam angle, fixture-to-object distance, and surface reflectivity must be carefully adjusted to mitigate risks of excessive contrast and glare. Integrating decorative fixtures with museum-grade optics enhances the balance between originality and legibility (Table 12).

Table 13. SWOT Analysis of Lighting Elements Used in Exhibition Spaces of Museums Converted from Industrial Buildings

SWOT Analysis for Museums Converted from Educational Buildings	Internal Factors		External Factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Lighting in Exhibition Areas	-Having high ceilings and larger interior spaces provides flexibility in lighting design.	-The large volumes that require illumination result in higher energy consumption for lighting.	-Natural light can be utilized to emphasize the building's original atmosphere. -The industrial character of the building can be preserved through the use of appropriate artificial lighting.	-Improper or insufficient use of light sources may adversely affect the atmosphere and the overall perception of the exhibition.

In industrial buildings, high volumes and long spans make layered linear LED and spot lighting, combined in some cases with suspended ceiling solutions, effective for scale reading and directional emphasis. Natural light is generally filtered and maintained at a supportive level; zonal or stepped dimming ensures energy efficiency and flexible staging. Incorrect or insufficient placement can create "dead zones" and perceptual disruptions in large spaces, making uniformity and glare control key performance criteria (Table 13).

Conclusion and Recommendations

This study examines the role of interior lighting within the museum conversion process of military, religious, educational, administrative, residential, and industrial buildings through a comparative framework. The findings reveal that, across all typologies, the prevailing tendency favors a hybrid lighting scheme (natural + artificial); however, the degree of control, stratification, and emphasis strategies within these hybrid systems differ significantly according to the building's original typology (Tables 2-7). In military structures, large volumes and elongated openings allow flexible scenographic arrangements through track/recessed spotlights and linear LEDs, making uniformity and luminance control critical. In religious buildings, the preservation of polychrome surfaces necessitates low illuminance levels, high color rendering (CRI), and filtered/directed light. In educational buildings, compartmentalized layouts support scenario-based configurations, occasionally embracing the "black box" approach. In public-administrative buildings, the homogeneous environment achieved through skylights is complemented by artifact-focused spot and linear lighting layers. In residential typologies, human scale is maintained through point-based highlights and the integration of decorative fixtures with museum-grade optics. In industrial structures, linear LED + spotlight systems and, in some cases, stretched ceiling solutions reinforce spatial legibility and wayfinding.

SWOT findings (Tables 8-13) confirm that lighting functions not only as a means of visibility but as a formative design parameter that simultaneously establishes the triad of conservation–legibility–identity. Strengths emphasize typology-specific spatial potentials (large volumes, skylights, defined circulation, human scale), offering opportunities for layered composition and flexible focusing. Weaknesses highlight implementation challenges such as glare/reflection,

uneven illuminance, uncontrolled daylight, and limited installation capacity. Opportunities suggest that sensor-based control, zonal or staged dimming, spectral selectivity, and anti-reflective surfaces can enhance both energy efficiency and conservation outcomes. Threats, however, stem from low-quality fixtures, inappropriate placement, and UV/thermal loads, which may compromise exhibition readability and artifact preservation. Overall, these findings emphasize the necessity of integrating measurement and verification (uniformity, luminance, lux-hour) as systematic components from the early design phase through to operation.

From a practical standpoint, the study proposes a typology-sensitive layered lighting model (ambient–task–accent) in conjunction with control and conservation protocols (filtering, shading, scheduling, sensors, zonal dimming). The role of natural light becomes safer when skylight and window systems are employed as a supportive layer, balanced with artificial components to account for diurnal and seasonal variations. The spectral content and CRI selection should be calibrated according to material sensitivity; optical and anti-reflective solutions are recommended, particularly on glazed surfaces and display cases, to mitigate reflection and glare risks. Track-based modular systems enhance sustainability by allowing quick adaptation to exhibition changes and facilitating maintenance.

The study's scope is limited by the reliance on secondary sources and visual/documentary analyses, restricting quantitative validation through on-site photometric measurements. Therefore, future research should be expanded through in-situ assessments (illuminance, glare, lux-hour) and simulation-based comparisons utilizing tools such as Radiance, DIALux, or Relux. Complementary visitor experience studies (perceived comfort, wayfinding success, eye-tracking) and energy/life-cycle analyses (impacts of control strategies on consumption and maintenance) will enable a more holistic evaluation of design effectiveness. In conclusion, through a typology-based framework and SWOT synthesis, this study advocates addressing lighting design in repurposed museums as an integrated process encompassing design–validation–operation, updating guidelines with measured and simulated data, and promoting flexible, protective, and sustainable lighting strategies in practice.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article contributed.

References

Acar, A. (2017). Visualizing knowledge through interactive design solutions in museums and exhibitions [Müze ve sergilemelerde etkileşimli tasarım çözümleriyle bilgiyi görselleştirmek]. *Hacettepe University Faculty of Fine Arts Art Writings Journal*, 36, 139–155.

Akan, A. (2020). *Taksiyarhis Church in Alibey (Cunda) Island* [Master's thesis, Bursa Uludağ University].

Akyürek, Y. (2022). *Evaluation of interior design of re-functioned historical buildings through museum examples* [Master's thesis, Cappadocia University].

Anadol, K., & Arıoğlu, E. (1981). Restoration of the Atatürk House in Thessaloniki after the June 1978 earthquake.

ArchDaily. (2011). AD Classics: Church of the Light / Tadao Ando. Accessed: https://www.archdaily.com/101260/ad-classics-church-of-the-light-tadao-ando

ArchDaily. (2011). Dresden Military History Museum / Studio Daniel Libeskind. Accessed: https://www.archdaily.com/172407/dresden%E2%80%99s-military-history-museum-daniel-libeskind

Arkeogezgin. (2017). Kızıl Kule. Accessed: https://www.arkeogezgin.com/kizil-kule/

Arkeologlar Derneği. (2019). Selanik Atatürk Evi reopened to visitors. Accessed: http://arkeologlardernegi.org/1893/selanik-ataturk-evi-yeniden-ziyarete-acildi/

Arslan, A. (2024). The Ephesus Experience Museum from the perspective of tour guides. *Journal of Turkish Social Research*, 28(3), 643–663.

Arslan, Z. (2023). *The effect of façade applications on architectural silhouette in sustainable architecture* [Master's thesis, Fatih Sultan Mehmet Vakıf University].

Askerî Müze. (2014). Sanal gezi. Accessed: https://askerimuze.msb.gov.tr/SANALGEZI/short-auto.html

Aslanoğlu, O. M. (2014). *Changing museum design approaches over time: The Mercedes-Benz Museum as a contemporary example* [Master's thesis].

Aydın, D., & Yaldız, E. (2010). Evaluation of building performance through users in adaptive reuse processes.

Ayvalık Belediyesi. (n.d.). Ayvalık Culture Portal. Accessed: https://ayvalik.bel.tr/Kultur/Detay?kulturId=f240b4f5-7761-4fc3-82b5-101b2609fe5c

Başkan, S. (1989). *Ankara State Painting and Sculpture Museum.* Ak Yayınları.

Bektaş, U., & Yalçınkaya, Ş. (2020). Building-function harmony from house to museum: The case of Beyoğlu district. *Medeniyet Art Journal*, 6(2), 80–95.

Bellitalie. (2021). Lorette. Accessed: https://www.bellitalie.org/destination/marches/lorette/

Buyurgan, S., & Şener, D. K. (2023). Contemporary exhibition methods in museums: The case of the Turkish İşbank Museum of Economic Independence. *Journal of International Museum Education*, 5.

Casa Batlló. (n.d.). Experience tour. Accessed: https://www.casabatllo.es/en/experience/

Cook, E. (2019). *The historical development of American museology and an investigation through Smithsonian Museums* [Master's thesis, Istanbul University].

Çağlar Eryurt, B. (2017). A research and conservation study on a group of oil paintings in the Ankara State Painting and Sculpture Museum collection.

Çetin, C. İ. (2021). Adaptive reuse of historical buildings as exhibition spaces: The cases of Tate Modern and Musée d'Orsay. *STAR Art and Design Research Journal*, 2(3), 227–253.

Çevik, S. (2021). Evaluation of literary spaces in Turkey in the context of modern museology. *Folklor/Edebiyat*, 27(105), 135–150.

Çoruhlu, T. (1994). Mekteb-i Harbiye. In *Istanbul Encyclopedia from Past to Present* (Vol. 5, pp. 372–374).

Divisare. (2018). Musée d'Orsay / Gae Aulenti Architetti Associati & Mariano De Angelis. Accessed: https://divisare.com/projects/383538-gae-aulenti-architetti-associati-mariano-de-angelis-musee-d-orsay

Doğruer, F. S. (2020). *Preventive conservation guide for museum designs.*

Düzenli, E., & Düzenli, H. İ. (2020). Two modern constructions in Mardin: The Mardin Barracks and its transformation into a museum. *Idealkent*, 11(30), 648–677.

DZ Architecture Agency. (n.d.). Botero Museum. Accessed: https://www.dz-aa.com/botero

Engin, H. (2023). An analysis on the contribution of Kemaliye Ethnography Museum to urban memory. *Journal of Social Sciences Research*, 13(3), 2855–2872.

Engin, H. (2024). From school building to museum: Muş Museum as a case of conservation and adaptive reuse. *Journal of Kafkas University Social Sciences Institute*, (33), 309–327.

Erkal, N. (2020). Nezih Eldem's holistic architecture: The Harbiye Military Museum and Cultural Site. *Mimarlık*, (411), 41–48.

Erzurum Büyükşehir Belediyesi. (n.d.). Virtual tour. Accessed: https://www.erzurum.bel.tr/sanaltur.aspx

Geziseyahat365. (n.d.). Rahmi Koç Museum virtual tour. Accessed: https://www.geziseyahat365.com/rahmi-koc-muzesinde-sanal-tur/

Google Arts & Culture. (n.d.-a). The British Museum. Accessed: https://artsandculture.google.com/partner/the-british-museum

Google Arts & Culture. (n.d.-b). Smithsonian American Art Museum. Accessed: https://artsandculture.google.com/partner/smithsonian-american-art-museum

Google Arts & Culture. (n.d.-c). Uffizi Gallery. Accessed: https://artsandculture.google.com/partner/uffizi-gallery?hl=en

Graf, M. (2024). Marcus Graf.

Güner, H. E. (2017). From high school to museum, from education to consumption: The transformation of Kayseri High School into the National Struggle Museum. *TÜBA-KED Journal of Cultural Inventory*, (16), 13–34.

Güven, E. B. (2022). *User–space interaction in contemporary museology* [Master's thesis, Fatih Sultan Mehmet Vakıf University].

Herzog & de Meuron. (2023). Tate Modern: Contribution to London's cultural landscape. Accessed: https://archeyes.com/the-tate-modern-herzog-de-meurons-contribution-to-londons-cultural-landscape/

İlbi, K. B. (2023). *Gertrude Stein's studio and art museology in the context of postmodern museum practices* [Master's thesis, Ankara University].

İslamoğlu, Ö. (2018). Building-function compatibility in the reuse of historical buildings: The case of Rize Museum. *Journal of History Culture and Art Research*, 7(5), 510–523.

iStockphoto. (2017). Loreto interior basilica [Photograph]. Accessed: https://www.istockphoto.com/tr/foto%C4%9Fraf/loreto-i%C3%A7-bazilikas%C4%B1-gm664637480-125226771

Jones, R. (2013). AD Classics: The Tate Modern / Herzog & de Meuron. *ArchDaily.* Accessed: https://www.archdaily.com/429700/ad-classics-the-tate-modern-herzog-and-de-meuron

Kariye Camii. (n.d.). Mimari özellikler. Accessed: https://www.kariyecamii.com/mimari-ozellikler

Kasap, M. (2016). Considering spatial lighting as a contemporary art product.

Kaymakçı, S. (2022). Examining the use of historical buildings as museums with examples from Istanbul. *Architecture and Life*, 7(2), 647–667.

Keçeli, M., & Doğan, C. (2023). Palimpsest interiors in industrial heritage: A study on Istanbul museum examples. *Architecture and Life*, 8(3), 597–623.

Kurtay, C., Aybar, U., Başkaya, A., & Aksulu, İ. (2003). Analysis of perception and lighting criteria in museums: The central hall of the Museum of Anatolian Civilizations, Ankara. *Journal of Gazi University Faculty of Engineering and Architecture*, 18(2).

Kültür Portalı. (2013). Kızılkule Ethnography Museum. Accessed: https://www.kulturportali.gov.tr/turkiye/antalya/gezilecekyer/kizilkule-etnografya-muzesi

Kültür Portalı. (2013). Yakutiye Medresesi. Accessed: https://www.kulturportali.gov.tr/turkiye/erzurum/gezilecekyer/yakutiye-medresesi

Libeskind. (2011). Military History Museum. Accessed: https://libeskind-com.translate.goog/work/military-history-museum/

Muzeler.org. (n.d.). Kariye Museum. Accessed: https://muzeler.org/kariye-muzesi--809454

Okutan, M. (2012). *A study on the stages of design, implementation, and use in lighting* [Master's thesis].

Öksüz, M. (2024). *Artistic lighting in interior architecture within the scope of adaptive reuse* [Master's thesis, Marmara University].

Önsoy, B. (2002). *Lighting in historical buildings refunctioned as museums* [Master's thesis].

Özalp, N. Ö., & Halaç, H. H. (2024, June). Analysis of additional building effects in historic buildings with visual attention software: The case of Dresden Military History Museum. In *Proceedings of ICCAUA*, 7(1), 1210–1222.

Özcan, U., & Çağlar, H. (2020). Evaluation of museum lighting in terms of users and artifacts. *European Journal of Science and Technology*, (18), 645–655.

Öztütüncü, P. D. (2023). *Examination of lighting design in refunctioned historical industrial buildings: The case of Hasanpaşa Gasworks.*

Resim ve Heykel Müzesi. (2014). Sanal tur. Accessed: https://www.360tr.com/resim-ve-heykel-muzesi-1-panorama-sanal-tur_6f5fe666c0_tr.html

Ruhr Museum. (n.d.). Ruhr Museum. Accessed: https://www.zollverein.de/erleben/ruhr-museum/

Temur, B., & Açıcı, F. K. (2022). A cultural heritage value: The Yakutiye Madrasa Turkish-Islamic and Ethnography Museum in Erzurum. *Journal of Architectural Sciences and Applications*, 7(2), 598–614.

Ticaret, A., & Odası, S. (2016). *2012 Alanya Economic Report.* Alanya Chamber of Commerce and Industry.

Uçar, N. (2008). *New icons of artistic spaces in Istanbul* [Master's thesis].

Varol Can, M. (2024). *Proposals for the transformation of coal processing facilities in Turkey into cultural and artistic venues.*

XXI. (2018). Ruhr Museum: A unique existence. Accessed: https://xxi.com.tr/i/ruhr-muzesi-benzersiz-varolus

Yılmaz, A. N. (2024). Orsay: From station to museum, from politics to art. *The Journal of Academic Social Science*, 8(8), 494–510.

Yiğitoğlu, Ş. (2020). Effects of functional change in architecture: From factory to contemporary art museum - The case of Beykoz Leather and Shoe Factory. *Architecture and Life*, 5(2), 381–402.

Yöndem, İ. A., & Akyol, A. A. (2017). The effect of lighting criteria on the preservation of materials in exhibitions: Çengelhan Rahmi Koç Museum. *Journal of Social Sciences Institute*, 12, 526–542.

Zorlu, N. (2021). Mekteb-i Harbiye in the context of Westernization and its role in architectural transformation. *BAB Journal of FSMVU Faculty of Architecture and Design*, 2(2), 185–199.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Impact of the White Cube Paradigm on Interior Design in Contemporary Art Museums: A Comparative Analysis of İstanbul Modern and New York MoMA

Sena YILMAZ [1]*

ORCID 1: 0009-0005-1766-7156
[1]Master's Student, Fırat University, Faculty of Architecture, Department of Architecture, Elazığ-Türkiye
mimarsenayilmazz@gmail.com (Responsible Author)

Menşure Kübra MÜEZZİNOĞLU [2]

ORCID 2: 0000-0001-5808-6618
[2]Assoc. Prof. Dr. Frat University, Faculty of Architecture, Department of Interior Architecture, Elazığ-Türkiye
mkmuezzinoglu@firat.edu.tr

Abstract

This study examines the influence of the White Cube exhibition paradigm on interior design strategies within contemporary art museums. To explore how this approach is interpreted across different geographical and cultural contexts, the research focuses on a comparative analysis of İstanbul Modern and the Museum of Modern Art (MoMA) in New York. The White Cube paradigm advocates for presenting artworks in neutral, minimal, and distraction-free environments, aiming to direct the viewer's attention exclusively to the artwork itself. By stripping away historical, social, and spatial references, it seeks to provide a "neutral" exhibition experience. However, the implementation of this paradigm varies significantly depending on architectural choices, geographical settings, and cultural frameworks. Employing a qualitative research methodology, this study integrates literature review, architectural plan and section analyses, and visual assessments of exhibition spaces. Key evaluation criteria include spatial organization, circulation patterns, lighting design, surface materials, wayfinding elements, and visitor interaction dynamics. Findings reveal that MoMA preserves a conventional interpretation of the White Cube paradigm, characterized by white walls, uniform lighting, simplified circulation axes, and spatial neutrality. Conversely, İstanbul Modern reinterprets the paradigm within its local cultural context, incorporating natural lighting, flexible display units, multi-functional spatial configurations, and interactive elements to create a more experiential exhibition environment. In conclusion, while the White Cube paradigm serves as a universal exhibition model, its reinterpretation across diverse cultural contexts leads to spatial diversity and design innovation. This underscores the evolving role of contemporary art museums—not merely as display venues, but as dynamic cultural spaces that shape collective memory, local identity, and visitor engagement.

Keywords: White cube paradigm, Contemporary Art Museums, İstanbul Modern, New York MoMA, interior design

1. Introduction

The spaces in which artworks are exhibited are fundamental elements that directly shape the perception, experience, and interaction of the viewer with the work. Exhibition spaces are not merely passive surfaces that serve as a backdrop for artworks; they are also active design components that produce meaning, guide perception, and shape cultural experience (Duncan, 1995). For this reason, the configuration of museum spaces has played a critical role in designing audience-centered experiences in line with contemporary understandings of art. One of the most influential approaches to emerge in this transformation process is the "White Cube" paradigm. Conceptualized by Brian O'Doherty (1986) in *Inside the White Cube: The Ideology of the Gallery Space*, this paradigm advocates for exhibiting artworks in neutral, simple, and distraction-free environments. Through white walls, homogeneous lighting, and controlled spatial arrangements, the viewer's attention is directed solely toward the artwork. Thus, the work is isolated from its historical and social context, creating a "neutral" field of aesthetic

experience. However, the White Cube paradigm is not implemented in the same way in every context. Geographic location, cultural identity, architectural choices, and curatorial strategies directly influence its spatial interpretation. Therefore, although White Cube is accepted as a universal model, it has a structure open to reinterpretation and local adaptations.

From this standpoint, the aim of this study is to examine the impact of the White Cube paradigm on the interior design of contemporary art museums. The research seeks to comparatively evaluate the reflections of the paradigm in different geographical and cultural contexts through the examples of İstanbul Modern and The Museum of Modern Art (MoMA) in New York. Within this scope, the exhibition spaces of both museums are analyzed in terms of circulation schemes, lighting strategies, and material usage. Methodologically, the study adopts a qualitative research approach. Literature review, analysis of architectural plans and sections, and visual analyses of exhibition spaces constitute the main tools of the research. This multi-layered methodological framework aims to reveal not only the theoretical but also the spatial and experiential dimensions of the White Cube.

The findings indicate that the White Cube still provides an effective framework in contemporary art museums. However, it is also evident that this framework is redefined in ways that are sensitive to local contexts. Consequently, contemporary art museums are no longer merely structures for displaying works. Beyond this, they are becoming dynamic spaces that construct collective memory, represent local identity, and establish new forms of engagement with the audience.

2. Conceptual Framework

The concept of the museum has evolved throughout history from spaces where artworks were preserved into dynamic institutions that guide cultural experience, construct collective memory, and produce identity. The term originates from the Ancient Greek word mouseîon (μουσεῖον), meaning “a place dedicated to the Muses.” Today, museums are not only spaces where works of art and science are preserved but also cultural platforms that mediate the social sharing of knowledge and support public participation (ICOM, 2006). The 18th century marks a critical turning point in the evolution of museology. The establishment of the British Museum (1753) and the Louvre Museum (1793) enabled museums to assume the functions of preserving cultural heritage and making knowledge accessible to the public (Figure 1).



Figure 1. Exterior views of the Louvre Museum and the British Museum (Nugraha, 2012; Stormnight, 2006)

Since the second half of the 20th century, museums have ceased to be merely spaces where artworks are exhibited; instead, they have transformed into multifunctional institutions that strengthen cultural identity, encourage public interaction, and adopt experience-oriented exhibition approaches. Institutions such as the Centre Pompidou (1977), Guggenheim Bilbao (1997), and Tate Modern (2000) are among the pioneering examples of this transformation (Figure 2).



Figure 2. Centre Pompidou, Guggenheim Bilbao, and Tate Modern as pioneering examples of contemporary museum practice (Faléco, n.d.; Gehry, 2015; Sudjic, 2016)

Within this transformation process, one of the most significant approaches shaping the spatial configuration of contemporary art museums has been the White Cube paradigm. Conceptualized by Brian O'Doherty (1986) in *Inside the White Cube*, this paradigm advocates the presentation of artworks through white walls, homogeneous lighting, neutral surfaces, and distraction-free arrangements. This approach transforms the gallery into a sterile laboratory-like space, aiming to grant the artwork absolute visibility and autonomy. The viewer's attention is directed solely toward the artwork; the work is perceived within a "neutral" field, isolated from historical, social, and cultural contexts. Thus, the White Cube creates an aesthetic order that detaches art from environmental factors and defines the work by its intrinsic values. However, this claim of neutrality has also been interpreted by some researchers as part of an ideological construct, suggesting that beneath the invisibility of the space lies a powerful form of guidance (Figure 3).

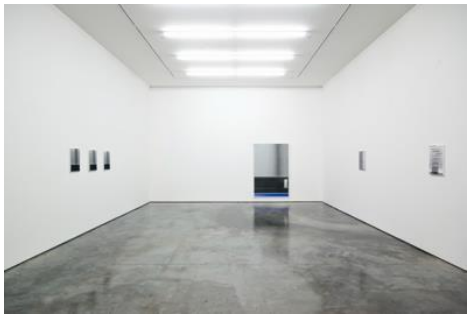


Figure 3. A typical exhibition space layout reflecting the White Cube approach (Coolimagesco, n.d.)

O'Doherty (2013) emphasizes that the White Cube is not merely a mode of display but also an ideological framework. The sterile and abstract nature of the space produces the very context that defines the object as a work of art; it detaches the viewer from environmental stimuli and invites them into a state of "pure aesthetic perception." Grunenberg (2012) describes the White Cube as "a space that presents the purity of artistic ideals within an invisible frame," while Antmen (2013) interprets it as a shell that both shapes and protects art.

The White Cube paradigm transforms not only spatial arrangements but also the relationship between viewer and artwork. Within this environment, isolated from the external world, the viewer experiences art independent of time and place. Particularly when abstract works are exhibited in such spaces, the sense of timelessness and placelessness is further intensified.

Nevertheless, the White Cube does not manifest as a uniform application in every museum. Its interpretation varies according to geographical context, cultural identity, and architectural preferences. At this point, the Museum of Modern Art (MoMA) in New York represents the

classic and canonical form of the paradigm, whereas İstanbul Modern reinterprets the approach by blending it with local context. The use of natural light, flexible display elements, and interactive arrangements with visitors in İstanbul Modern's exhibition spaces transform the paradigm into a more experiential and participatory structure (Figures 4 and 5).

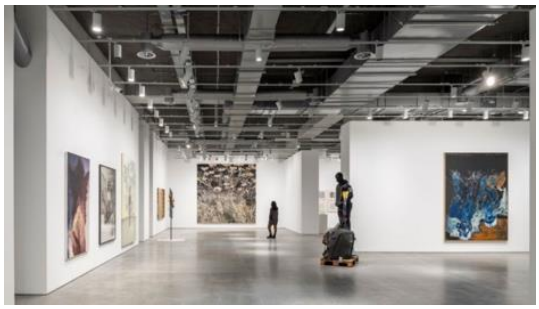


Figure 4. Exhibition layout employing the White Cube paradigm at İstanbul Modern (İstanbul Modern, n.d.)



Figure 5. Interior walls as display surfaces at MoMA (MoMA, 2025)

In conclusion, the White Cube paradigm plays a decisive role in the interior design of contemporary art museums, in the visitor experience, and in curatorial strategies. However, the paradigm's capacity to be reinterpreted across different contexts makes it less of a universal exhibition model and more of a flexible design language adaptable to local cultural dynamics. This is clearly observable in the new building of İstanbul Modern. In the structure designed by Renzo Piano, the White Cube gallery concept has been reinterpreted through a contemporary approach. The exhibition spaces were constructed with a simple, neutral, and flexible arrangement; by favoring white tones and plain forms on wall, floor, and ceiling surfaces, the design ensures that the artworks remain at the forefront (Figure 6).



Figure 6. Photography exhibition at İstanbul Modern (İstanbul Modern, 2025)

This approach, much like the ideal gallery space defined by O'Doherty (2013), aims to detach the viewer from the outside world and direct their full attention toward the artwork. At İstanbul Modern, light control, acoustic arrangements, and guiding elements are designed in ways that support this unity. In this manner, the building becomes architecturally "invisible," while the exhibition area transforms into an "artistic stage." The reinterpretation of the White Cube concept in such a way within a contemporary museum design positions İstanbul Modern not only physically but also conceptually in parallel with contemporary art museums on a global scale.

The neutrality of the walls and the overall atmosphere ensures that the artworks remain at the forefront. In particular, the orderly display of photographic and visual art pieces creates a sense of unity for the viewer; meanwhile, the glass showcases serve both as protective elements and as striking components of presentation. Lighting elements are directed specifically to highlight the artworks, while a dim overall ambiance is preferred in order to focus the viewer's attention solely on the exhibited works. The columns within the space are considered not only as structural supports but also as integral parts of the exhibition, being incorporated into the overall arrangement. In this context, the exhibition design of İstanbul Modern reinterprets the traditional "White Cube" approach through a contemporary lens, offering a simple, balanced, and interactive environment where interdisciplinary works can be displayed together (Figure 7).

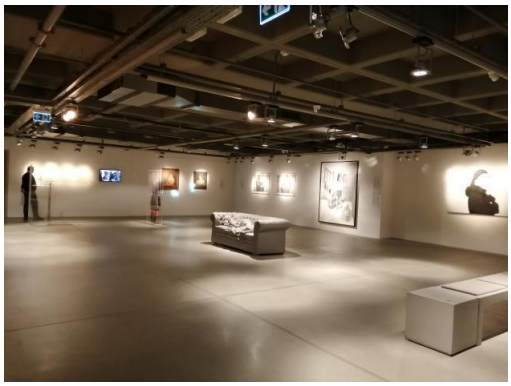


Figure 7. Photography exhibition at İstanbul Modern (İstanbul Modern, 2025)

The exhibition areas are planned with high ceilings and open spans. Gallery spaces are designed at varying heights and in flexible forms. Instead of fixed panels, movable exhibition elements and temporary walls are employed, allowing for diverse exhibition setups. In lighting design, both natural and artificial light are used together. In Renzo Piano's architecture, the relationship between interior and exterior is of great importance, and this quality is also evident within the exhibition spaces. Although the environment has been simplified in line with White Cube principles, the visual connection with the surrounding context has not been completely severed.

MoMA, however, presents a different approach. The Museum of Modern Art (MoMA) in New York adopts a simple and functional arrangement in its exhibition spaces, prioritizing the perception of artworks. The white wall surfaces, homogeneous floor coverings, and a carefully controlled balance of natural and artificial light are all designed to direct the viewer's focus directly onto the artwork. The orderly and well-spaced placement of works allows each piece to be evaluated individually, while the spatial voids create a rhythmic flow throughout the viewing process. Natural light entering through glass façades is balanced with artificial lighting

to ensure visual comfort. The interior organization of MoMA is structured around an open circulation scheme that enables visitors to move freely between artworks without requiring directional guidance. Through these features, the museum extends the White Cube approach beyond its classical boundaries, offering a modern exhibition experience that establishes a direct and uninterrupted connection between art and the viewer (Figure 8).



Figure 8. Interior walls as display surfaces at MoMA (MoMA, 2025)

In MoMA's exhibition halls, white walls and controlled artificial lighting are the defining elements. Natural light has been minimized as much as possible, thereby maintaining a uniform level of illumination throughout the entire space. The spacing left between artworks, combined with the simplicity of the environment, further highlights each piece. The White Cube approach at MoMA functions as an exhibition system that does not directly guide the viewer yet simultaneously detaches the work from its context, operating as an ideological framework. This spatial atmosphere offers the viewer an experience of "being alone with art" (Figure 9).



Figure 9. Interior walls as display surfaces at MoMA (MoMA, 2025)

3. Materials and Methods

This research was designed as a qualitative study aiming to examine the influence of the White Cube approach on the interior design of contemporary art museums. The study addresses the effects of the White Cube paradigm on the formal, functional, and conceptual configuration of exhibition spaces, focusing particularly on how this paradigm is interpreted in different geographical and cultural contexts. To this end, a comparative analysis method was adopted, and the variations of the paradigm across contexts were evaluated through the cases of İstanbul Modern and the Museum of Modern Art (MoMA) in New York.

In the first stage of the research, a comprehensive literature review was conducted. Within this framework, Brian O'Doherty's seminal work *Inside the White Cube: The Ideology of the Gallery Space* (1986) was examined in order to understand the historical development, ideological dimensions, and relationship of the White Cube paradigm with architectural design. In addition, the works of scholars such as Tony Bennett (1995), Charlotte Klonk (2009), Grunenberg (1999), and Antmen (2010) were analyzed, thereby situating the paradigm's

emergence, its role in exhibition spaces, and its effects on visitor experience within a theoretical framework.

Building upon this theoretical background, the research examined the architectural arrangements, organization of exhibition spaces, lighting strategies, material usage, and spatial configurations of İstanbul Modern and MoMA, selected as case studies. The analysis drew upon the museums' official websites, architectural drawings, exhibition catalogues, printed publications, academic articles, and theses. The use of diverse data sources allowed the study to present both the spatial characteristics and the conceptual approaches behind design decisions in a holistic manner.

In the final stage, the collected data were evaluated through the lens of comparative analysis. Within this scope, the ways in which both museums implemented the White Cube paradigm were examined in terms of circulation schemes, lighting preferences, and material usage. Thus, the impact of the White Cube paradigm in contemporary art museums has been addressed not only as a universal exhibition model but also as a flexible architectural tool adaptable to local cultural contexts.

4. Findings and Discussion

This section discusses the reflections of the White Cube paradigm in contemporary art museums through the exhibition spaces of İstanbul Modern and New York MoMA. The findings are comparatively evaluated based on the spatial organization, lighting strategies, material preferences, and curatorial approaches of both museums, while also examining the influence of cultural context on exhibition design.

4.1. The Classical Interpretation of the White Cube at MoMA

The exhibition spaces of MoMA place the artwork at the center through the use of white walls, homogeneous lighting, simple circulation axes, and an arrangement free from distracting elements. This approach directly reflects Brian O'Doherty's (1999) definition of the White Cube as an "ideological exhibition system." The principles of simplicity and clarity highlighted by Grunenberg (2012), as well as Antmen's (2013) description of the White Cube as a "protective shell for art," are observed here in their most typical form.

The exhibition areas at MoMA allow the viewer an independent circulation while simultaneously creating a decontextualized atmosphere that positions the artwork within a sterile environment. In this way, the work refers not to any social or spatial context but solely to its own aesthetic value. Thus, MoMA preserves the White Cube paradigm in its most classical and pure form, presenting an ideological stance that represents the continuity of modernist aesthetics (Figure 10).

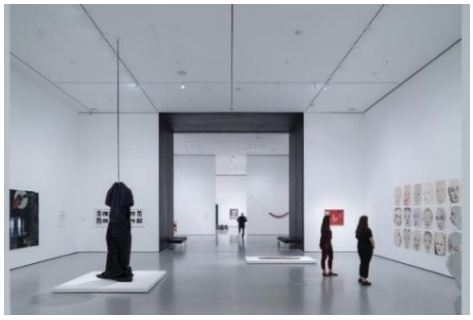


Figure 10. MoMA's New Photography exhibition (Peers, 2019)

4.2. The Experiential and Interpretive Use of the White Cube at İstanbul Modern

At İstanbul Modern, the White Cube paradigm is reinterpreted in an experiential and open-to-interpretation manner, going beyond the boundaries of its classical reading. In the building designed by Renzo Piano, galleries employ white and neutral surfaces to foreground the artwork; yet the controlled use of natural light, movable exhibition units, galleries designed at varying heights, and the integration of columns into the exhibition layout together provide the space with a multi-layered experiential dimension.

This arrangement goes beyond O'Doherty's (1999) idealized notion of a decontextualized and sterile "art space," creating instead an exhibition environment that engages more directly with the viewer. The visual relationship established with the surrounding environment and the incorporation of the Bosphorus view into the interior provide opportunities for art to form multidimensional connections with collective memory and urban identity. Thus, at İstanbul Modern, the White Cube ceases to function merely as a frame that isolates art; it transforms into an interpretive, participatory, and experiential tool of display. This not only aligns İstanbul Modern with global museum typologies but also renders it a distinctive cultural focal point (Figure 11).



Figure 11. Eye Catching / Computer video installation (Steinkamp, 2003)

4.3. Similarities and Differences Between İstanbul Modern and MoMA

Although both museums adopt the White Cube approach as a fundamental exhibition model, their modes of implementation demonstrate significant differences.

Spatial organization: At MoMA, spatial arrangement is based on white walls, homogeneous floors, and controlled circulation axes. At İstanbul Modern, by contrast, the use of flexible display elements, galleries designed at different heights, and the incorporation of columns into the exhibition design emphasize a more experiential layout (Figure 12 and 13).

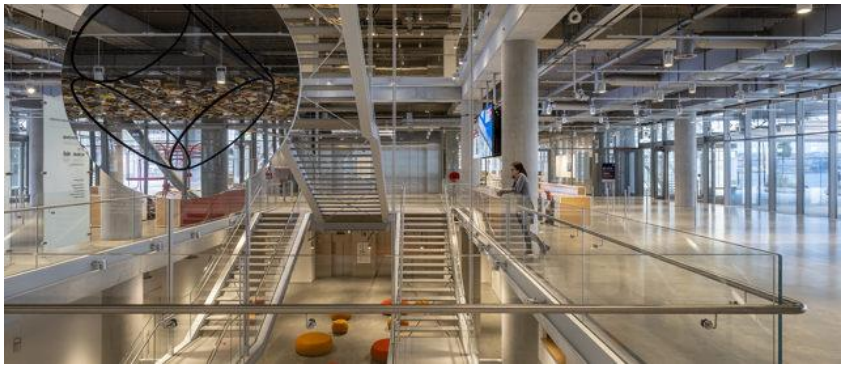


Figure 12. Foyers at İstanbul Modern (İstanbul Modern, n.d.)



Figure 13. The Museum of Modern Art (MoMA), New York (Müze Biletleri, n.d.)

Use of light: MoMA largely restricts natural light, providing artificial and homogeneous illumination. İstanbul Modern, on the other hand, incorporates natural light into the interior, balances it with artificial lighting, and creates a dynamic atmosphere (Figure 14 and 15).



Figure 14. The Museum of Modern Art (MoMA), New York (Müze Biletleri, n.d.)



Figure 15. İstanbul Modern. (Anadolu Ajansı, 2023)

Material preferences: At MoMA, white walls and matte surfaces create a sterile environment, whereas at İstanbul Modern, glass and metal panels establish a visual continuity with the surrounding environment (Figure 16 and 17).



Figure 16. The Museum of Modern Art (MoMA), New York (Müze Biletleri, n.d.)



Figure 17. Library at İstanbul Modern (İstanbul Modern, n.d.)

Curatorial strategies: At MoMA, artworks are exhibited in an independent, distanced, and neutral arrangement. At İstanbul Modern, by contrast, context-sensitive, interactive, and experiential configurations establish multidimensional relationships among art, space, and the viewer.

This comparison demonstrates that although the universal principles of the White Cube are preserved, they differ significantly in terms of spatial experience, visitor interaction, and cultural context.

4.4. The Impact of Cultural Context on Exhibition Design

Geographical, cultural, and social differences cause the White Cube paradigm to acquire distinct spatial meanings in each museum. MoMA, by adhering to the universal aesthetic principles of modernism, produces a decontextualized and timeless atmosphere through white walls, homogeneous lighting, and neutral surfaces. In contrast, İstanbul Modern draws upon its local context, incorporating the Bosphorus view, natural light, and flexible display units to create an experiential space that engages with its surroundings. While MoMA emphasizes a sterile exhibition approach independent of cultural context, İstanbul Modern develops a spatial interpretation integrated with the city's dynamic identity and collective memory. Thus, MoMA represents the continuity of universal modernist aesthetics, whereas İstanbul Modern presents an open-ended and multilayered exhibition practice that interacts with cultural context.

4.5. The Universal Model and Local Adaptations of the White Cube

Although the White Cube is recognized as a universal exhibition model in contemporary art museums, it is reshaped in every institution according to local context. The cases of İstanbul

Modern and MoMA illustrate that the paradigm is not a uniform exhibition framework; on the contrary, it can be flexibly reinterpreted according to cultural dynamics. Therefore, the White Cube functions not only as a universal aesthetic order but also as a design language capable of integrating with local identities.

Table 1. Comparative Analysis of the White Cube Paradigm at New York MoMA and İstanbul Modern

Feature	New York MoMA	İstanbul Modern
Year of Establishment	1929	2004 (new building in 2023)
Architect	Philip L. Goodwin & Edward Durell Stone (original), Yoshio Taniguchi (renovation)	Renzo Piano
Location	Manhattan, New York	Tophane, İstanbul
Building Type	Vertical, layered gallery structure	Horizontal mass connected to the sea
Gallery Layout & Spatial Configuration	Modular, enclosed, and sterile exhibition scheme; inward-looking	Flexible White Cube: contextual arrangement, galleries with varying heights
Use of Light	Controlled artificial lighting, minimal natural light	Balanced use of natural and artificial light
Façade Material	Glass, steel, and plaster surfaces	Glass and metal panels (wave/light form)
White Cube Approach	Traditional application preserving modernist aesthetics	Contemporary reinterpretation; experiential and participatory approach
Circulation Scheme	Directed, defined circulation; controlled movement	Free, non-directed circulation; flexible movement opportunities
Wall Color & Structure	Completely white, fixed panels	White surfaces supported by flexible and movable panels
Relation to the External World	Minimizes relation with the surroundings; inward-oriented spatial setup	Establishes visual connection with the city; permeable and transparent façade arrangement
Visitor Experience	Distant, sterile, and artwork-centered; viewer in a passive role	Participatory, interactive, experiential; viewer in an active role
Curatorial Strategy	Neutral presentation detaching the artwork from context; continuity of modernism	Context-sensitive, multilayered presentation; relationship among art–viewer–city
Ideological Dimension	Represents continuity of modernist aesthetics; universalist approach	Highlights local identity and collective memory; contextual approach
Level of Interpretation	Universal level; timeless and sterile exhibition concept	Localized level; exhibition concept integrated with cultural context

The comparative analysis summarized in Table 1 clearly demonstrates how the universal principles of the White Cube are rearticulated in two different museums. In the case of MoMA, the paradigm persists as a neutral and decontextualized exhibition system that represents the

continuity of modernist ideals; whereas at İstanbul Modern, the same paradigm transforms into an experiential and flexible exhibition strategy that internalizes cultural context. This reveals that the White Cube is not merely an exhibition model but also a tool that shapes the cultural identity of space, the visitor experience, and collective memory.

5. Conclusion

This study has revealed that the White Cube paradigm functions as a universal exhibition model in contemporary art museums; however, this model takes shape in different ways across institutional and cultural contexts through spatial organization, lighting, material preferences, and curatorial strategies. Initially conceptualized as an ideological framework aiming for perceptual purity by isolating the artwork from social and historical contexts, the White Cube has proven not to be a singular and absolute construct. Instead, the findings show that it is a flexible tool reinterpreted according to each institution's mission, cultural context, and architectural identity.

The case of MoMA represents the canonical and classical interpretation of the White Cube. White walls, homogeneous lighting, simplified circulation schemes, and spatial arrangements stripped of distractions place the artwork at the absolute center. This condition constitutes a direct manifestation of O'Doherty's (1999) theory of the "ideology of the gallery space." MoMA's exhibition design produces a universal sense of "timelessness" and "sterile aesthetics" by ensuring the continuity of modernist principles and the perception of art as independent from its context.

In contrast, İstanbul Modern reinterprets the same paradigm in a context-sensitive and experiential language. Renzo Piano's flexible spatial configuration, controlled use of natural light, continuity between interior and exterior through glass and metal surfaces, and the employment of movable exhibition units situate the museum in relation to its cultural and social context. Rather than isolating the artwork in a sterile environment, this approach offers a multilayered field of experience within the triangle of viewer–artwork–city. The exhibition design of İstanbul Modern transforms the White Cube from being merely a "protective shell" into a design tool that establishes active dialogue with the viewer, nourishes cultural memory, and enables public encounters.

This comparative analysis clearly highlights two dimensions of the White Cube paradigm:

- **1.Universal dimension** → A neutral system that sterilizes space, detaches art from its context, and provides the viewer with a pure aesthetic experience.
- **2.Local dimension** → Flexible and experiential applications redefined through cultural identity, geographical environment, and architectural preferences.

Therefore, the White Cube should not be regarded as a rigid and singular formula, but as a generative process of co-formation between universal principles and local contexts. The study's findings demonstrate that four design elements serve as the main levers of this co-formation:

- **Light** → At MoMA, artificial illumination creates sterile homogeneity; at İstanbul Modern, a balance of natural and artificial light produces a dynamic atmosphere.
- **Material** → At MoMA, white walls and matte surfaces dominate; at İstanbul Modern, glass and metal establish continuity with the environment.

- **Circulation** → At MoMA, undirected and simplified axes structure movement; at İstanbul Modern, flexible and experiential circulation unfolds across different heights.

- **Curation** → At MoMA, artworks are presented in an isolated, distanced, and object-centered manner; at İstanbul Modern, interactive and context-sensitive strategies allow active visitor participation.

These findings demonstrate that in contemporary art museums, the White Cube is not merely an exhibition technique but a multifaceted architectural–curatorial tool that shapes visitor experience, constructs cultural memory, and represents institutional identity. In conclusion, while MoMA's canonical implementation reinforces modernist aesthetics and object-centered perception, İstanbul Modern's experiential reinterpretation transforms space into an interface for cultural memory and public encounter. These two approaches prove that the White Cube is not a monolithic paradigm but a flexible and pluralistic design language emerging from the interaction of universal aesthetic principles and local cultural dynamics.

The results of this study contribute a new framework to the literature on contemporary museum design that goes beyond the "universal/local dichotomy." They emphasize the need to reconsider the White Cube not merely as a neutral backdrop, but as a strategic tool that directs cultural identity, collective memory, and visitor engagement. Future research may further expand this discussion by exploring how the paradigm is reinterpreted across different geographies and how it is being transformed through digital technologies such as VR, AR, and interactive exhibition design.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article contributed.

References

Anadolu Ajansı. (2023, June 20). İstanbul Modern hosted Renzo Piano, the architect of the building [News photo]. Access address (31 October 2025): https://www.aa.com.tr/tr/kultur/istanbul-modern-binanin-mimari-renzo-pianoyu-agirladi/

Barbieri, L., Bruno, C., & Muzzupappa, M. (2017). Museum experience design: Planning interactive and immersive exhibitions. In A. Marcus & W. Wang (Eds.), *Design, user experience, and usability: Theory, methodology, and management* (pp. 97–108). Springer.

Bennett, T. (1995). *The birth of the museum: History, theory, politics*. Routledge.

Bishop, C. (2012). *Artificial hells: Participatory art and the politics of spectatorship*. Verso Books.

Coolimagesco. (n.d.). Interior of white painted empty room or art gallery with skylight lighting and concrete floors [Photograph]. Dreamstime. Access address (31 October 2025): https://www.dreamstime.com/view-white-painted-interior-empty-room-art-gallery-skylight-lighting-concrete-floors-image130552416

Dinç, E. B. (2012). *Melez mekansallaşmanın dışavurumu: Salt Beyoğlu ve Salt Galata* (Yayımlanmamış yüksek lisans tezi). İstanbul Teknik Üniversitesi.

Esen, A. (2018). *Sanat müzelerinde beyaz küp bağlamının sanat mekânına ve izleyici deneyimine etkileri: İstanbul Modern örneği* (Doktora tezi). Bahçeşehir Üniversitesi, Fen Bilimleri Enstitüsü.

Faléco, O. (n.d.). Centre Georges Pompidou, Paris [Photograph]. Wikimedia Commons. Access address (31 October 2025): https://commons.wikimedia.org/wiki/File:Centre_Pompidou_(223901737).jpeg

Gehry, F. (2015). *Building art: The life and work of Frank Gehry.* Alfred A. Knopf.

Heinich, N. (1996). *The glory of Van Gogh: An anthropology of admiration*. Princeton University Press.

Hooper-Greenhill, E. (1992). *Museums and the shaping of knowledge.* Routledge.

İstanbul Modern. (2025). Exhibition hall and photography exhibition [Photograph]. İstanbul Modern. Access address (31 October 2025): https://www.istanbulmodern.org

İstanbul Modern. (2025). Library [Photograph]. İstanbul Modern. Access address (31 October 2025): https://www.istanbulmodern.org/ziyaret/kutuphane

İstanbul Modern. (n.d.). Foyers [Photograph]. İstanbul Modern. Access address (31 October 2025): https://www.istanbulmodern.org/etkinlik-alanlari/fuayeler

İstanbul Modern. (n.d.). İstanbul Modern – new building interior view [Photograph]. İstanbul Modern. Access address (31 October 2025): https://www.istanbulmodern.org

Kalyoncuoğlu, M., Güneş, E., & Memikoğlu, İ. (2021). Çağdaş sanat müzesi yapılarında iç mekân tasarımı: Müze Evliyagil örneği. *Sanat ve Tasarım Dergisi*, (28), 279–300.

Kandemir, Ö., & Uçar, Ö. (2015). Değişen müze kavramı ve çağdaş müze mekânlarının oluşturulmasına yönelik tasarım girdileri. *Sanat ve Tasarım Dergisi*, 5(2), 17–47.

Karayılanoğlu, A. G. G., & Arabacıoğlu, B. C. (n.d.). Çağdaş sanat müzelerinde "yeni" müzecilik anlayışıyla değişen iç mekân organizasyonunun İstanbul'dan örneklerle analizi [Makale].

Karayılanoğlu, G., & Arabacıoğlu, B. C. (2020). Çağdaş sanat müzelerinde iç mekân deneyimi üzerine nicel bir araştırma. *Mimarlık ve Yaşam*, 5(2), 529–549.

Klonk, C. (2009). *Spaces of experience: Art gallery interiors from 1800 to 2000.* Yale University Press.

Müze Biletleri. (n.d.). Museum of Modern Art (MoMA), New York [Photograph]. Access address (31 October 2025): https://www.muzebiletleri.com/bilet/abd/new-york/new-york-modern-sanat-muzesi-moma/

Museum of Modern Art (MoMA). (2025). Interior wall surfaces (exhibition areas) [Photograph]. Access address (31 October 2025): https://www.moma.org

Nugraha, E. (2012). Pyramid of Louvre at night [Photograph]. Good Free Photos. Access address (31 October 2025): https://www.goodfreephotos.com

O'Doherty, B. (1999). *Inside the White Cube: The ideology of the gallery space* (Expanded ed.). University of California Press.

Oskay, C. (2022). The South African National Gallery's (SANG) role in social change – Altering the "White Cube." *MSGSÜ Sosyal Bilimler Dergisi*, 1(25), 139–146.

Peers, A. (2019, October 14). The pros and cons of the new MoMA. Architectural Digest. Access address (31 October 2025): https://www.architecturaldigest.com/story/moma-expansion-redesign

Renzo Piano Building Workshop. (2023). Istanbul Modern project overview [Proje raporu]. https://www.rpbw.com/project/istanbul-modern

Şahin, B. (2024). Modern sanat müzelerinde sergileme tasarımı: OMM Modern Müzesi, İstanbul Modern ve CerModern örneği. *Bingöl Üniversitesi Teknik Bilimler Dergisi*, 5(2), 28–42.

Steinkamp, J. (2003). Eye Catching 1 [Computer video installation]. İstanbul Modern Collection. Access address (31 October 2025): https://www.istanbulmodern.org/en/collection/eye-catching-1-5-6

Stormnight. (2006, July 12). British Museum front façade [Photograph]. Wikimedia Commons. Access address (31 October 2025): https://commons.wikimedia.org/wiki/File:British_Museum_(front).jpg

Uslu, Ö., & Yalçın, G. (2020). Görsel algı bağlamında mekân tasarım bileşenlerinin incelenmesi – Adana Arkeoloji Müzesi. *Bitlis Eren Üniversitesi Sosyal Bilimler Dergisi,* 9(2), 232–244.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Squares: A Citizen-Centered Assessment of Aliağa Democracy Square in İzmir

Pelin ÖZDEN [1]*

ORCID 1: 0000-0002-5157-9919
[1]1Asst. Prof. Dr, İzmir Kavram Vocational School, Department of Architecture and City Planning, Architectural Restoration Program, İzmir-Türkiye
pelin.aykutlar@kavram.edu.tr (Responsible Author)

Abstract

The study aims to assess public space quality in Aliağa Democracy Square, located in İzmir, Türkiye, through a participatory, user-centered diagnostic process. Developed within the framework of participatory planning, the study employed spatial observation, semi-structured interviews (n=8), and structured surveys (n=60) to analyze users' everyday experiences, needs, and spatial behavior. Findings indicate that the square suffers from insufficient shaded areas, low thermal comfort during summer months (surface temperatures reaching 49°C), inadequate seating, poor maintenance, and a lack of inclusive design for elderly, children, and mobility-impaired users. Additionally, uncontrolled vehicle access and insufficient lighting have raised safety concerns. The existing water feature and street furniture were reported as dysfunctional or neglected. Most users, particularly those aged 55 and above, highlighted the need for more greenery, social spaces, and protection from extreme weather. In response, the study proposes several spatial and policy recommendations, including ecological shading elements, new seating arrangements with weather protection, accessible green areas, designated play zones, and improved urban furniture. Small-scale kiosks to support local economic activity and species-specific bird feeding stations are also suggested to improve hygiene and spatial organization. The study not only diagnoses current challenges in the square's design and use but also contributes to urban governance by offering inclusive, climate-adaptive, and user-informed strategies for sustainable public space transformation.

Keywords: Participatory planning, public space, citizen science, thermal comfort, user-centered planning

1. Introduction

In recent years, urban public spaces have gained renewed attention in the context of rapid urbanization, climate change, and growing inequalities in access to quality environments. Public squares, in particular, represent critical spatial and social nodes that reflect broader urban governance practices and serve as platforms for everyday life, democratic engagement, and socio-spatial inclusion (Carr et al., 1992; Gehl, 2010). However, many squares in contemporary cities suffer from design, maintenance, and accessibility issues that limit their potential to support inclusive and climate-adaptive urban life.

Aliağa Democracy Square, located in İzmir, Türkiye, exemplifies these challenges. While it is strategically positioned within a dense urban fabric and serves as a potential site for cultural events, informal gatherings, and social interactions, the square is currently underperforming in terms of thermal comfort, user safety, inclusivity, and ecological functionality. Surface temperatures exceeding 49°C during summer months, insufficient shaded areas, lack of barrier-free design, and degraded urban furniture significantly undermine the quality of user experience. To address these challenges, this study adopts a participatory, user-centered diagnostic approach inspired by the principles of Citizen Design Science (Müeller et. al. 2018, Özden &Velibeyoğlu, 2023). By incorporating the lived experiences of diverse users, including residents, visitors, elderly individuals, and mobility-impaired persons, this research aims to understand spatial behavior patterns, identify key barriers, and co-develop spatial improvement strategies. Drawing from structured observations, semi-structured interviews, and survey data,

the study explores how inclusive design and ecological interventions can contribute to healthier, safer, and more livable urban squares.

The research not only provides a comprehensive evaluation of the current state of Aliağa Democracy Square but also offers practical design and policy recommendations that can inform future urban regeneration projects in mid-sized cities facing similar climatic and demographic pressures. In doing so, it contributes to ongoing discussions on participatory urbanism, sustainable place-making, and citizen-led urban transformation.

2.Materials and Methods

The study employs a mixed-methods design that integrates systematic spatial observation, semi-structured interviews, and a structured on-site survey to assess user experience and public space quality in Aliağa Democracy Square, İzmir. A five-member field team from the İzmir Metropolitan Municipality and İzmir Planning Agency conducted fieldwork on August month 2025 (Figure 1).

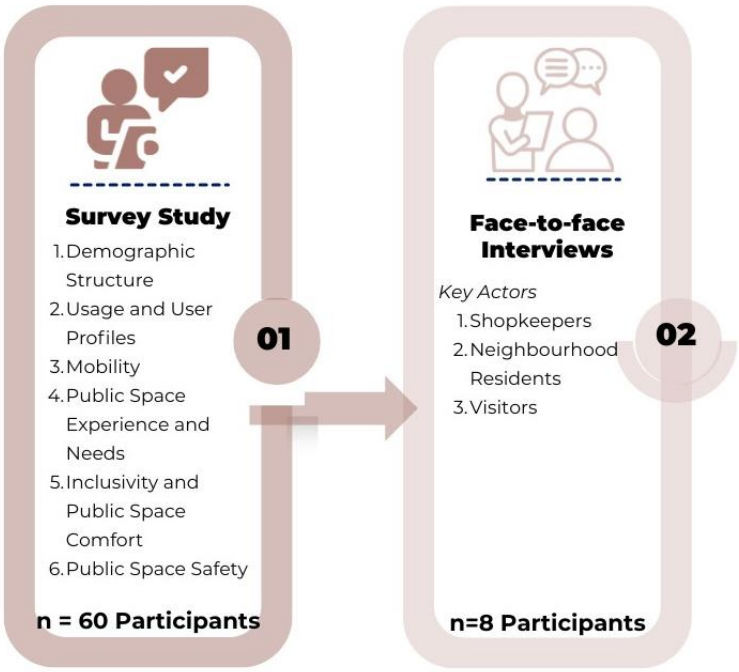


Figure 8. Methodology of the study

A concurrent triangulation strategy was adopted to enhance the validity of findings by cross-verifying qualitative and quantitative evidence (Creswell & Plano Clark, 2011). Systematic observation captured behavioral and spatial patterns in situ, interviews elicited experiential knowledge from key users, and the survey quantified usage, needs, and perceptions across a broader sample. This user-centered diagnostic approach aligns with participatory frameworks that foreground lived experience in public-space evaluation (Arnstein, 1969; Gehl & Svarre, 2013).

Spatial Context and Urban Morphology

Aliağa Democracy Square is situated within Kültür Neighbourhood, a central and densely built neighborhood in Aliağa district, İzmir. As shown in Figure 2, the square occupies a strategic

location at the intersection of major urban arteries, including Hükümet Street, İstiklal Street, and İzmir Street, and functions as both a transit node and a potential social condenser. The satellite imagery highlights two essential urban layers:

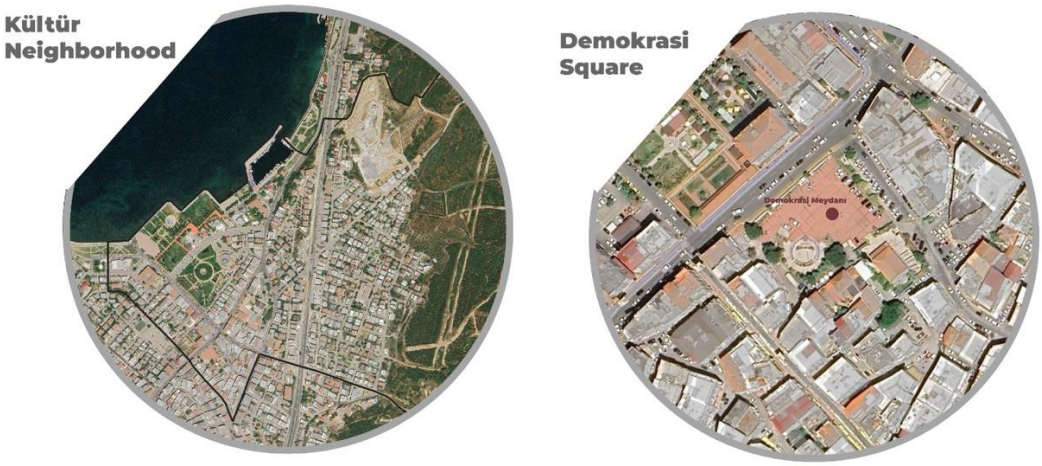


Figure 9. Spatial location and urban morphology of Kültür Neighbourhood and Aliağa Democracy Square (Source: İzmir Metropolitan Municipality Satellite Archive, 2025)

On the left, a macro-view of Kültür Neighbourhood illustrates the square's proximity to the coastal edge and the green infrastructure corridor in the north. On the right, the zoomed-in image of Demokrasi Square reveals a highly paved, compact urban texture, surrounded by civic buildings (e.g., district library, mosque), commercial units, and low-rise residential structures (see Figure 1).

This spatial duality, being embedded in a dense civic core while adjacent to natural and coastal assets, presents a unique opportunity for the square to operate as a mediator space between ecological, social, and infrastructural systems (Carmona et al., 2008). Yet, observational findings suggest that this potential remains underutilized due to the square's excessive hardscaping, lack of permeability, and poor visual legibility.

In the observed urban form, the square lacks defining edges, intuitive pathways, and inviting thresholds, which limits its symbolic and functional prominence in daily urban life. Instead of acting as a "centerpiece," the square performs more as a residual transit zone, underlining the importance of placemaking and edge activation in its future transformation (Project for Public Spaces, 2009).

The square is located within a dense urban fabric and hosts civic, cultural, and commercial functions. Following public-life study protocols, observers recorded conditions of micro-climate exposure (e.g., shade opportunities), seating supply and configuration, paving quality and accessibility, illumination, clutter and hygiene, and conflicts between pedestrian and vehicular movement (Gehl, 2010; Gehl & Svarre, 2013). Photographic documentation supported the audit of (i) neglected or dysfunctional elements (e.g., the water feature), (ii) barrier-free access constraints (damaged or uneven paving), and (iii) hygiene issues related to ad-hoc bird feeding. Observations emphasized heat-stress exposure given locally reported summer surface temperatures (~49 °C), with design implications for shade and weather protection (Nikolopoulou & Lykoudis, 2006).

Interviews: Sampling and Procedure

Eight semi-structured face-to-face interviews were conducted using purposive sampling to include key user types—shopkeepers (n=4), residents (n=3), and a frequent visitor (n=1)—representing diversity of age and gender. Purposive sampling is appropriate for capturing information-rich cases and practice-based insights (Patton, 2002). The guide probed perceived comfort (thermal and ergonomic), safety (lighting, conflicts with vehicles), inclusiveness (elderly, children, mobility-impaired users), and priorities for improvement. Interviews were recorded through detailed notes; recurring codes (e.g., “lack of shade”, “insufficient seating”, “poor nighttime lighting”, “maintenance deficits”) were identified through iterative coding to structure themes for discussion.

Survey Instrument and Administration

A structured questionnaire (n=23) was adapted from public-life survey practice inspired by Gehl’s People & Public Space studies and organized into six modules: demographics, frequency of use, mobility and access, spatial experience, inclusiveness and comfort, and safety perception (Gehl & Svarre, 2013; Gehl, 2010). The instrument comprised multiple-choice and Likert-type items, plus targeted multi-select questions to capture specific deficiencies (e.g., shade, greenery, seating). Surveys were administered on site to 60 participants using convenience sampling, a pragmatic approach in public-space intercept studies where the target population is the set of current users (Etikan, Musa, & Alkassim, 2016). Respondents represented six districts, with a majority residing in Aliağa (88%). Basic eligibility required age under 18 years old and recent use of the square. The intercept timing (mid-morning to late afternoon) was selected to capture typical daytime patterns while minimizing extreme heat exposure bias (Nikolopoulou & Lykoudis, 2006).

Data Handling and Analysis

Observation notes and photographs were compiled into a spatial audit matrix (Gehl & Svarre, 2013). Interview notes were analyzed via descriptive thematic analysis to extract recurrent constraints and user priorities. Survey data were cleaned and analyzed using descriptive statistics (frequencies, percentages) to profile users, usage patterns, perceived deficiencies, and desired interventions; cross-tabulations were used exploratorily to contextualize subgroup tendencies (e.g., age by comfort or safety perception). Methodological triangulation, comparing observational evidence with interview themes and survey frequencies, was used to consolidate convergent findings and flag discrepancies for discussion (Creswell & Plano Clark, 2011).

Ethical Considerations

All participation was voluntary, with informed consent obtained prior to interviews and surveys; data were anonymized at the point of recording. Observations were conducted in a public setting without identifying individuals, consistent with ethical guidance for public-life studies. Where visual material is used, images avoid personally identifiable information unless separate consent is documented.

3. Findings and Discussion

The findings of the study reveal a multifaceted set of spatial and experiential challenges in Aliağa Democracy Square, as perceived and experienced by users. These findings are discussed thematically under three key dimensions: (i) environmental comfort and microclimatic conditions, (ii) spatial configuration and inclusivity, and (iii) safety, accessibility, and

maintenance. The data from surveys (n=60) and semi-structured interviews (n=8), complemented by spatial observations, offer a triangulated and user-centered diagnosis of the square.

Environmental Comfort and Thermal Exposure

One of the most pressing issues reported by participants was extreme thermal discomfort, particularly during summer months. Satellite-derived thermal imaging indicated surface temperatures of up to 49°C in July 2024, aligning with observational findings of limited shade provision and inadequate microclimatic design. According to the survey, 88% of respondents stated that there is not enough shaded space in the square, while 73% reported that they could not use the space during extreme weather conditions such as heatwaves or rain.

Interviewees emphasized the absence of protective elements such as tree canopies or structural shading. Users, particularly those aged 55 and over, expressed a strong preference for shaded seating and resting areas—findings consistent with thermal comfort research in Mediterranean urban settings (Nikolopoulou & Lykoudis, 2006). This confirms the crucial role of shade in enhancing usability and inclusiveness under climate stress conditions (Johansson, Thorsson, & Emmanuel, 2014).

Spatial Configuration and User Inclusivity

The square is currently used for a variety of purposes; 57% of participants use it daily, mostly for transit, resting, or brief social interactions. However, spatial observations and interviews highlighted the inadequacy of basic urban elements. 52% of participants described seating units as dysfunctional, poorly placed, or ergonomically uncomfortable. The lack of inclusive design features such as ramps, smooth pavements, and shaded benches was especially problematic for users with mobility challenges, baby strollers, and elderly citizens.

The quality of paving emerged as a repeated concern across interviews. Observed surface degradation (e.g., cracks, slopes, water accumulation zones) limited the square's accessibility and caused safety risks. Users also pointed to a lack of greenery and ecological aesthetics, which diminishes the area's social appeal and affects its restorative potential (Kaplan, 1995). In this respect, the demand for green infrastructure (e.g., planted edges, trees, bioswales) aligns with literature emphasizing biophilic and health-oriented urban design (Beatley, 2016).

Safety, Accessibility, and Maintenance

Perceptions of safety in public spaces are shaped by both physical and social cues. In Aliağa Democracy Square, while 77% of respondents considered the square to be generally safe, 23% expressed concerns, particularly about uncontrolled vehicle entry, inadequate lighting, and presence of stray animals. Several interviewees mentioned previous incidents of vehicle conflict, particularly around pedestrian entries and paved transitions, indicating a lack of clear spatial hierarchy and protective design for vulnerable users.

Maintenance was another recurrent theme. The water feature (central fountain) was described as non-functional and unhygienic, with stagnant water and accumulated dirt. Informal practices, such as placing bowls for birds, were well-intentioned but caused sanitation concerns, as noted by both users and observers. Similarly, the lack of regular cleaning, damaged paving materials, and insufficient litter bins created a perception of neglect, affecting the users' sense of comfort and security (Carr et al., 1992).

Desired Improvements and Co-Generated Proposals

When asked about desired improvements, participants consistently prioritized:

- Shaded areas (96% mention rate)
- Increased greenery (76%)
- Better seating elements and placement (65%)
- Designated spaces for children's activities and local vendors (approx. 30–40%)

Interviewees suggested installing lightweight ecological shading structures, seasonal vegetation, weather-resistant urban furniture, and creating small-scale kiosks to promote local economic activity. These demands align with climate-adaptive, socially inclusive, and low-cost intervention strategies advocated in recent public space regeneration studies (UN-Habitat, 2020).

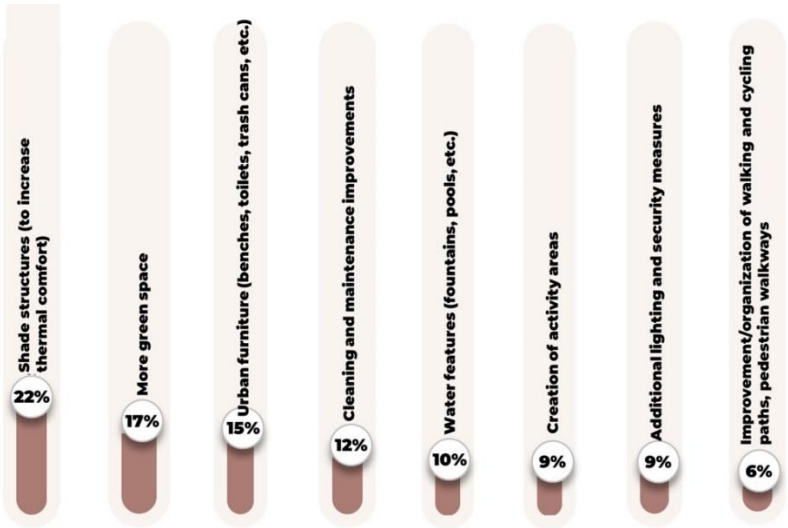
Table 1 also shows the distribution of reasons why participants could not use Democracy Square during extreme weather events. The most frequently observed problem, cited by 36 participants (80%), was the lack of overhead cover. Five participants highlighted the lack of sheltered areas against extreme weather events (11%), two participants mentioned slippery surfaces due to heavy rainfall (5%), and one participant each emphasized the lack of climate-appropriate urban furniture and infrastructure deficiencies (2%).

Table 2. Reasons for not being able to use democracy square during extreme weather events



Table 2 shows the distribution of changes participants wanted to make to make Democracy Square more attractive. The top change requested by participants to make the square more appealing is shade (improved thermal comfort), mentioned by 58 participants. Other requested changes include more green space (mentioned by 46 participants), urban furniture (mentioned by 39 participants), and improvements in cleaning and maintenance (mentioned by 32 participants).

Table 3. Distribution of participants according to the changes they want in the square



4. Conclusion and Recommendations

The study presents a comprehensive spatial and experiential evaluation of Aliağa Democracy Square, a civic public space located in the Kültür neighborhood of İzmir. By combining spatial observation, semi-structured interviews, and structured surveys, the research offers a triangulated, user-centered diagnosis of the square's current conditions and future needs. The findings highlight several persistent challenges, including poor thermal comfort, insufficient shaded and green areas, inadequate seating, maintenance deficits, and limited inclusive design features.

From a spatial justice and urban resilience perspective, the square underperforms in terms of accessibility, comfort, and social inclusion—particularly for elderly users, children, and people with limited mobility. Moreover, the lack of ecological design elements and microclimate-responsive urban furniture exacerbates discomfort, especially under increasing summer heat stress linked to climate change (Nikolopoulou & Lykoudis, 2006; Johansson et al., 2014). Despite these shortcomings, the square is intensively used by local residents and visitors, indicating its latent potential as a more vibrant and inclusive civic space.

In light of these findings, the following recommendations are proposed to guide a user-informed, climate-adaptive, and socially inclusive transformation of the square:

Design-Based Interventions

- Ecological shading structures (e.g., pergolas, tree clusters) to mitigate urban heat and improve year-round usability.
- Inclusive and weather-resistant seating arrangements, integrating shade and proximity to active zones.
- Barrier-free paving design, especially in areas with uneven or damaged surfaces.
- Green infrastructure elements, including planted borders, bioswales, and seasonal vegetation, to support visual comfort and ecological function.
- Dedicated activity zones (e.g., play areas for children, flexible kiosks for local vendors) to enhance everyday interaction and stimulate local economies.

- Species-specific bird water and feeding stations to address hygiene and spatial organization issues observed in the field.

Operational and Policy Recommendations

- Regular maintenance protocols for urban furniture, lighting, and paving.
- Introduction of participatory design workshops with community members to co-develop spatial layouts and programs.
- Integration of the square into broader green and blue infrastructure networks of the city, improving both ecological performance and connectivity.
- Institutionalization of public space monitoring tools, leveraging citizen science methodologies for continuous evaluation and adaptive management.
- Ultimately, this research underscores the value of embedding user experience, climatic responsiveness, and citizen participation in the redesign of public spaces. The case of Aliağa Democracy Square illustrates how low-cost, context-sensitive interventions, guided by local knowledge and participatory tools can transform underperforming squares into more inclusive, vibrant, and sustainable urban places.

Thanks and Information Note

The article complies with national and international research and publication ethics.

Ethics Committee approval in the study, Ethics Committee of the İzmir İnstitute of Technology dated 13.05.2025 and that it was taken with the decision no E-41752998-050.04-2500029932.

I would like to extend my sincere gratitude to Prof. Dr. Koray Velibeyoğlu, Dr. Hasibe Velibeyoğlu, Aylin Göknur and Müge Tikik for their invaluable guidance and contributions throughout the study. Special thanks are also due to all citizen participants in Aliağa who generously shared their time, knowledge, and experiences during the fieldwork.

The author declares no conflict of interest regarding the publication of this article. 1st Author %100 contributed.

References

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, 35(4), 216–224. https://doi.org/10.1080/01944366908977225.

Beatley, T. (2016). *Handbook of Biophilic City Planning & Design*. Washington, DC: Island Press.

Carr, S., Francis, M., Rivlin, L. G., & Stone, A. M. (1992). *Public Space*. Cambridge: Cambridge University Press.

Carmona, M., Heath, T., Oc, T., & Tiesdell, S. (2008). *Public Places Urban Spaces: The Dimensions of Urban Design* (2nd ed.). Oxford: Architectural Press.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and Conducting Mixed Methods Research* (2nd ed.). Thousand Oaks, CA: SAGE.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1–4. https://doi.org/10.11648/j.ajtas.20160501.11.

Gehl, J. (2010). *Cities for People*. Washington, DC: Island Press.

Gehl, J., & Svarre, B. (2013). *How to Study Public Life*. Washington, DC: Island Press.

Johansson, E., Thorsson, S., & Emmanuel, R. (2014). Strategies for outdoor thermal comfort: A review. *International Journal of Biometeorology*, 58(4), 607–625.

Kaplan, R. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2.

Nikolopoulou, M., & Lykoudis, S. (2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and Environment*, 41(11), 1455–1470. https://doi.org/10.1016/j.buildenv.2005.05.031.

Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods* (3rd ed.). Thousand Oaks, CA: SAGE.

Project for Public Spaces. (2009). *What Makes a Successful Place?* Retrieved December 1, 2022, from https://www.pps.org/article/grplacefeat.

UN-Habitat. (2020). *Streets for Pandemic Resilience*. Nairobi: United Nations Human Settlements Programme (UN-Habitat). Retrieved from https://unhabitat.org.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Comparative Performance of Adaptive Façade Systems in Different Climate Types: An Evaluation of Three Buildings

Esra Nur ARVAS [1]*

ORCID 1: 0009-0009-3905-2231
[1]Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Building Physics and Materials, Istanbul, Türkiye
20222101024@ogr.msgsu.edu.tr (Responsible Author)

Ümit Turgay ARPACIOĞLU [2]

ORCID 2: 0000-0001-8858-7499
[2] Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Building Physics and Materials, Istanbul, Türkiye
umit.arpacioglu@msgsu.edu.tr

Abstract

This study aims to examine the climate-related performance effects of adaptive façade designs by comparing the façade systems of three buildings located in regions with different climate types. The selected buildings are the Al Bahr Towers in Abu Dhabi, representing a hot–dry climate; the Information and Communication Technology Center in Lucca, representing a Mediterranean climate; and the Nordic Embassies Complex in Berlin, representing a humid continental climate. Each building was analyzed according to criteria such as façade type, movement mechanism, adaptation direction, materials used, and the level of thermal and visual comfort achieved. Based on the obtained data, the relationship between climate conditions and façade systems was evaluated, questioning the effectiveness of each façade design within its specific climatic context. The results revealed that considering climatic differences in façade design is critical in terms of energy efficiency, user comfort, and aesthetic coherence. In this context, it is emphasized that adaptive façade systems should be approached holistically in relation to local climatic data

Keywords: Adaptive façade, adaptive façade systems, climate-based design

1. Introduction

Today, environmental pollution and the disruption of the natural balance seriously threaten the sustainability of ecosystems worldwide. The future availability of existing natural resources has become a major issue discussed by experts from various disciplines. The American Institute of Architects (AIA) defines sustainability as the ability of a system to continue functioning properly even in cases of excessive consumption or depletion of essential resources. In this regard, sustainable design is recognized as an approach that aims to minimize negative environmental impacts while enhancing the quality of living environments. Within this framework, it is emphasized that energy consumption in buildings should be minimized, passive design strategies should be implemented, and structures should be designed in accordance with their local climatic context (Tatar, 2013).

In contemporary architecture, the rapid changes in environmental conditions and user needs make it essential for façade systems to be more flexible and adaptable. Adaptive façades attract attention as multifunctional systems with a high capacity to respond and adjust to external and internal conditions. These façades can effectively perform key functions such as balancing indoor temperatures, improving ventilation, generating energy, maximizing the use of daylight, and providing shading and humidity control by responding to environmental variables like weather conditions and solar radiation (Favoino et al., 2015; D. Aelenei et al., 2016).

2. Materials and Methods

The study aims to comparatively analyze adaptive building façades applied in different climate types and to determine the extent to which these systems respond to climatic conditions. Adaptive façade systems were evaluated in terms of their geographical location, climate type, and environmental responsiveness.

A literature review was first conducted to establish the classification, functions, and environmental interaction levels of adaptive façades. The systems were categorized based on criteria such as façade dynamism, response mechanism, control strategy (self-operating or user-controlled), and energy approach (passive or active). From this review, evaluation parameters were developed for use in the comparative analysis.

Three case studies representing different climatic zones were selected: Al Bahr Towers (BWh, Abu Dhabi) for the hot–arid climate, the Information and Communication Technology Center (Csa, Lucca) for the Mediterranean climate, and the Nordic Embassies Complex (Dfb, Berlin) for the humid continental climate. These examples were analyzed to assess how adaptive façade systems respond to local climatic needs through design and technological strategies.

Each building was examined according to façade type, adaptation direction, movement mechanism, response time, maintenance needs, material use, aesthetic quality, and overall performance. The analysis emphasized the façades' contributions to thermal, visual, and acoustic comfort as well as energy efficiency. The comparative approach revealed the functional, aesthetic, and technological potentials and limitations of adaptive façades under different climatic conditions, offering a foundation for future climate-responsive design decisions.

2.1 Overview of adaptive façade systems and typological classification

In architecture, the concept of "adaptive" refers to a building's capacity to change form or behavior in response to environmental variables or user needs—its ability to adjust to the surrounding context. The façade components or materials used in such buildings perceive physical data from the environment and respond accordingly. The main purpose is to enhance the building's functionality and improve its environmental performance.

In recent years, façade systems have increasingly been designed not merely as static and passive elements, but as dynamic systems containing active components that continuously interact with their external surroundings. In this context, adaptive façade systems transform the building envelope into a multifunctional interface capable of interacting with the outdoor environment. By performing functions such as thermal regulation, natural ventilation, daylight redirection, shading, humidity control, and even energy generation, they contribute to improving indoor comfort conditions. Owing to their flexible structures that can be modified according to users' needs, these systems can effectively respond to varying climatic conditions. (Favoino et al., 2015; Aelenei et al., 2016)

2.2 Typologies of adaptive façades: system characteristics and classification criteria Adaptive façade systems cannot be defined under a single universal description in the literature due to their diverse characteristics; therefore, they are categorized under various subheadings. Today, these systems are evaluated based on their integrated building technologies as well as their control and regulation mechanisms (Romano et al., 2018).

Table 1. Comparison of adaptive façade systems with different typologies *(Adapted from Romano et al., 2018)*

Façade Type	Definition / Characteristics	Adaptation Mode	Response Mechanism	User Interaction	Technology / Material
Active Façade	Systems that adapt to environmental changes to provide energy savings and comfort	Manual / Automatic	Mechanical	✓	System-based
Advanced Façade	High-performance façades integrated with energy systems and responsive building elements	Automatic	Integrated building systems	X	Responsive elements + control systems
Biomimetic Façade	Systems inspired by natural organisms and processes	Passive / Automatic	System-based	X	Biomimetic principles / systems
Kinetic Façade	Flexible and dynamic systems that change physically through motion	Automatic / Mechanical	Moving components	X	Mechanical / motorized systems
Smart Façade	Materials and systems responsive to environmental changes	Automatic	Sensor + control system	X	Material / system software
Interactive Façade	Systems shaped by human interaction, responding to both environment and users	Semi-automatic	User-triggered	✓	Responsive modules
Movable Façade	Systems that adjust position according to the sun's movement and enable renewable energy generation	Automatic	Mechanical	X	PV + sun-tracking systems
Responsive Façade	Systems reacting to environmental data through sensors, behaving according to specific stimuli	Automatic	Sensor + actuator	Partially	Responsive system components
Switchable Façade	Systems that alter the light transmittance or thermal properties of materials such as glass	Automatic	Smart glass / material	X	LC glass, electrochromic glass
Transformable Façade	Façades capable of physically changing their form	Automatic	Morphological transformation	X	Dynamic materials

The classification of adaptive façade systems has undergone a significant evolution in terms of scope and focus over time. Initially, in 2000, Fox and Yeh classified façades according to

material type, typology, and control mechanisms, focusing on the fundamental components of the system (Fox & Yeh, 1999). In 2005, Addington and Shodek advanced this classification to a more technical level by emphasizing the characteristics of smart materials and their energy interactions (Addington & Shodek, 2005). In 2009, the IEA ECBCS Annex 44 study highlighted the performance criteria of façade systems and their integration with HVAC systems, focusing on energy performance (Ayçam, 2011). In 2011, Ramzy and Fayed developed a more comprehensive model that included parameters such as movement type, control method, and cost (Ramzy & Fayed, 2011). Between 2013 and 2015, Loonen and his team expanded the classification framework by incorporating multidimensional criteria such as comfort, time scale, and visual impact. Finally, studies conducted in 2017 and 2018 proposed more systematic and holistic classification models that addressed adaptation factors, technology levels, and triggering mechanisms in detail (Basarır & Altun, 2017; Romano et al., 2018). This progression demonstrates that adaptive façades are now evaluated not only through material or functional characteristics but also in terms of performance, aesthetics, and technological integration as multilayered parameters.

The primary function of façades is to protect indoor environments from external influences and to ensure this protective function is achieved in the most efficient way (Johnsen & Winther, 2015). Adaptive façades respond to various external factors to maintain indoor comfort. These factors include the balanced use of daylight, control of outdoor temperature and humidity, the effects of climatic elements such as wind and precipitation, and the reduction of environmental noise. These parameters play a decisive role in façade design, both in maintaining thermal and humidity balance and in enhancing spatial comfort (D. Aelenei et al., 2016).

Table 2. Comparison of adaptive façade systems in different typologies (Adapted from D. Aelenei et al., 2016)

Thermal Comfort	Visual Comfort	Acoustic Comfort	Ventilation and Spatial Comfort
Maintains a balanced indoor temperature by adapting to changes in external temperature and humidity.	Controls daylight to optimize indoor illumination, reducing glare and thermal load.	Blocks environmental noise, creating a quiet and comfortable indoor environment.	Supports natural ventilation through adaptive movements against wind and precipitation.

3. Findings and Discussion

3.1 Comparative analysis of adaptive façade systems in different climate types

Although various methods are used to classify climates, one of the most widely adopted is the Köppen–Geiger system. This method defines climate zones based on temperature and precipitation data, as well as the relationship between these variables and vegetation characteristics (Öztürk et al., 2017).

In this study, three buildings with adaptive façade systems located in different climate types were selected. The Nordic Embassies Complex (Berlin, Germany) is situated in the *Dfb* climate type, which represents a humid continental climate characterized by mild summers, long and cold winters, and evenly distributed precipitation throughout the year (Köppen, 1930). The Information and Communication Technology Center (Lucca, Italy) is located in the *Csa* climate type, corresponding to a Mediterranean climate characterized by hot and dry summers, mild

and rainy winters, and seasonal variations in precipitation (Köppen, 1930). The Al Bahr Towers (Abu Dhabi, United Arab Emirates) fall within the *BWh* climate type, defined as a hot desert climate with high temperatures, minimal rainfall, and extremely dry conditions throughout the year (Köppen, 1930).

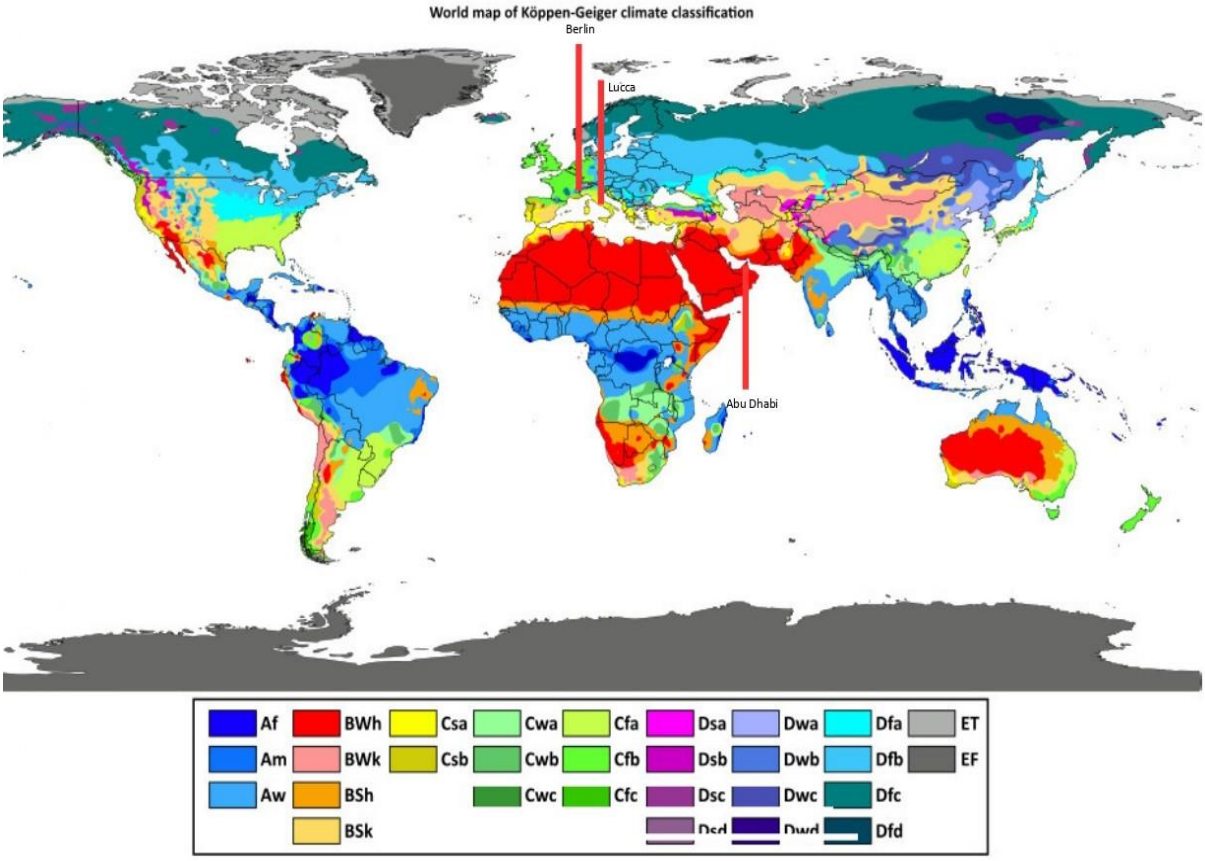


Figure 1. Locations of the selected buildings on the Köppen–Geiger climate classification map (adapted from Beck et al., 2018).

3.2 Nordic Embassies Complex (Berlin, Germany)

The architecture firm Berger and Parkkinen developed a master plan for the Nordic Embassies Complex in Berlin and led the construction of the project, which was completed in 1999. The building's plan form, characterized by sharp-angled corners, was shaped by drawing inspiration from pedestrian circulation patterns and the orientation of walkways within the urban context. The main façade of the complex is clad with horizontally arranged copper lamellas, designed to emphasize the perception of five distinct volumes corresponding to the individual embassies of each Nordic country. These lamella systems can be controlled in groups, allowing the gradual revelation of the underlying façade surface when required (Aelenei et al., 2018).

Table 3. Nordic Embassies Complex

Nordic Embassies Complex	
  **Figure 2.** The Nordic Embassies Complex in Berlin. (*Source: Nordische Botschaften. (n.d.). The Nordic Embassies in Berlin. Retrieved from https://www.nordischebotschaften.org/the-nordic-embassies-in-berlin/*)	
Climate Type	DFB
Location	Berlin, Germany
Façade Type	Active Façade
Interaction Element	Daylight
Performance Impact	Thermal Comfort, Visual Comfort, Aesthetics
Adaptation Type	Dynamic
Movement Type	Mechanical
Adaptation Tool	Façade Component
System Maintenance Frequency	Annual

3.3 Information and Communication Technologies Center

The Information and Communication Technology Center features a dynamic double-skin façade integrating photovoltaic panels and movable shading elements to improve energy efficiency. Its 50% opaque and 50% transparent modules optimize daylight, support energy generation, and enhance thermal comfort through natural ventilation. *(Sala & Romano, 2011)*

Table 4. Information and Communication Technologies Center

Information and Communication Technologies Center	
 **Figure 3.** (Sala & Romano, 2011)	
Climate Type	CSA
Location	Lucca, Italy
Façade Type	Smart Façade
Interaction Element	Daylight
Performance Impact	Thermal Comfort, Visual Comfort, Aesthetics, Acoustic Coomfort, Energy Generation
Adaptation Type	Dynamic
Movement Type	Mechanical

Adaptation Tool	Material
System Maintenance Frequency	Annual

3.4 Al-Bahr Towers

The façade of the Al Bahr Towers features a responsive system that adapts to environmental conditions. Its geometry changes according to the sun's angle, providing shading and preventing overheating by reducing direct sunlight. Controlled by sensors that monitor weather conditions, the system adjusts automatically to maintain indoor comfort and improve energy efficiency throughout the day. (Maden, 2022)

Table 5. Al-Bahr Towers

Al-Bahr Towers	
	
Figure 4. Cilento, K. (2012, September 05). *Al Bahar Towers Responsive Facade / Aedas*. ArchDaily. Retrieved December 12, 2025, from https://www.archdaily.com/270592/al-bahar-towers-responsive-facade-aedas	
Climate Type	BWh
Location	Abu Dhabi, United Arab Emirates
Façade Type	Kinetic Façade
Interaction Element	Daylight
Performance Impact	Thermal Comfort, Visual Comfort, Aesthetics, Acoustic Comfort
Adaptation Type	Dynamic
Movement Type	Mechanical
Adaptation Tool	Façade Component
System Maintenance Frequency	Annual

4. Conclusion and Recommendations

The findings indicate that façade systems are shaped according to local climatic conditions and optimized within their specific contexts.

•Nordic Embassies Building (Berlin, Dfb climate type): This structure features an active façade system designed to adapt to humid continental conditions. Reacting to solar radiation and seasonal temperature variations, the façade is composed of a steel frame and copper louvers. In addition to providing both visual and thermal comfort, the building stands out with its high aesthetic value that supports its public image and collective identity.

• Information and Communication Technology Center (Lucca, Csa climate type): Designed for the hot and dry summers of the Mediterranean climate, the smart glass façade system adjusts light transmittance to enhance both thermal and visual comfort indoors. The system also contributes to energy generation and provides acoustic comfort. This multi-layered performance transforms the façade from a passive protective element into an active energy component.

•Al Bahr Towers (Abu Dhabi, BWh climate type): Responding to the extreme heat and intense solar radiation of a hot-arid climate, the kinetic façade system consists of aluminum mashrabiya panels that dynamically filter sunlight, reducing indoor temperatures and energy consumption. The façade also achieves strong aesthetic value through its visual connection with traditional architectural elements.

Across all buildings, mechanical movement systems, minute-level response times, and annual maintenance requirements were observed. However, adaptation direction, materials used, and performance outcomes differ depending on the climatic context.

This study conducted a comparative analysis of buildings located in three distinct climate zones, each featuring different adaptive façade systems. The results reveal that façade systems are not merely aesthetic elements but dynamic components directly influencing climatic efficiency and indoor comfort.

Buildings in Dfb, Csa, and BWh climate regions developed distinct adaptation strategies to respond to local environmental conditions:

- In cold climates, façades are designed to maximize daylight use while responding to seasonal variations.
- In hot-summer climates, façades regulate light transmittance to limit heat gain and enhance occupant comfort.
- In extremely hot and dry climates, façades incorporate dynamic shading elements that block direct sunlight and reduce energy loads.

Recommendations:

1. Climate-Responsive Design: Adaptive façade systems should be designed with local climatic data in mind. Instead of a uniform approach, systems must be customized according to climate-specific performance targets.

2. Material and Technology Integration: The durability, maintenance needs, and energy performance of selected materials should be considered. Smart glazing, kinetic systems, and shading devices should be strategically integrated.

3. Aesthetic and Cultural Harmony: The visual impact of façade systems should align with the geographical and cultural context, reinforcing public perception and architectural identity.

4. Performance Monitoring and Feedback: Long-term monitoring and user feedback are essential for evaluating and improving façade system performance.

Adaptive façade systems offer holistic solutions in sustainable architecture by integrating environmental, technological, and aesthetic dimensions. Their wider and more efficient use in the future will represent a significant step toward enhancing energy efficiency and occupant comfort within architectural practice.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article contributed.

References

Addington, M., & Schodek, D. (2005). *Smart materials and technologies*. *Architecture and Urbanism, 5*(3), 8–13.

Aelenei, D., Aelenei, L., & Vieira, C. P. (2016). Adaptive façade: Concept, applications, research questions. *Energy Procedia, 91*, 269–275. Retrieved from https://doi.org/10.1016/j.egypro.2016.06.218

Ayçam, İ. (2011). *Investigation of advanced façade systems in energy-efficient office buildings*. Paper presented at the 10th National Installation Engineering Congress, İzmir, Turkey.

Basarır, B., & Altun, M. C. (2017). A classification approach for adaptive façades. In *Interdisciplinary Perspectives for Future Building Envelopes*, İstanbul, Turkey.

Fox, M., & Yeh, B. P. (1999). *Intelligent kinetic systems*. Preparation for MANSEE 99.

Johnsen, K., & Winther, F. V. (2015). Dynamic façades, the smart way of meeting the energy requirements. *Energy Procedia, 78*, 1568–1573. Retrieved from https://doi.org/10.1016/j.egypro.2015.11.199

Köppen, W., & Geiger, R. (Eds.). (1930). *Handbuch der klimatologie* (Vol. 1). Berlin: Gebrüder Borntraeger.

Loonen, R. C., Rico-Martinez, J. M., Favoino, F., Brzezicki, M., Menezo, C., La Ferla, G., & Aelenei, L. L. (2015, November). Design for façade adaptability: Towards a unified and systematic characterization. In *10th Conference on Advanced Building Skins* (pp. 1284–1294). Bern, Switzerland: Economic Forum.

Maden, F. (2022). *Tessellation-based kinetic façade designs*.

Öztürk, M. Z., Çetinkaya, G., & Aydın, S. (2017). Climate types of Turkey according to Köppen-Geiger climate classification. *Journal of Geography, 35*, 17–27.

Ramzy, N., & Fayed, H. (2011). Kinetic systems in architecture: New approach for environmental control systems and context-sensitive buildings. *Sustainable Cities and Society, 1*(3), 170–177. Retrieved from https://doi.org/10.1016/j.scs.2011.02.001

Romano, A., Angeli, P., Piovesan, S., Noventa, F., Anastassopoulos, G., Chemello, L., ... & Alberti, A. (2018). Newly diagnosed hepatocellular carcinoma in patients with advanced hepatitis C treated with DAAs: A prospective population study. *Journal of Hepatology, 69*(2), 345–352. Retrieved from https://doi.org/10.1016/j.jhep.2018.03.021

Sala, M., & Romano, R. (2011). Innovazione per l'involucro architettonico: Smart façade per edifici non residenziali = Building envelope innovation: Smart façades for non-residential buildings. *Techne: Journal of Technology for Architecture and Environment, 2*(2), 158–169.

Tatar, E., & Yamaçlı, R. (2013). Sustainability and accreditation in architectural design education: The case of Anadolu University's Department of Architecture. *The International Journal of Design Education, 7*(1), 29–44.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Technical Contributions of Civil Engineering in the Intervention Processes for the Conservation of Historical and Cultural Heritage and the Comparative Analysis of the Role of Related Courses in Architectural Graduate Programs

Pınar ARIK[1*]
ORCID 2: 0009-0008-0144-4232
[1]Erciyes University, Faculty of Architecture, Department of Architecture, Kayseri,Türkiye
pinaryildizarik@gmail.com (Responsible Author)

Hayriye Hale KOZLU[2]
ORCID 1: 0000-0001-6711-3139
[2]Assoc. Prof. Erciyes University, Faculty of Architecture, Department of Architecture, Kayseri-Türkiye
halekozlu@gmail.com

Abstact

The conservation of historical buildings is a multifaceted and multi-actor process that involves not only physical intervention but also the collaboration of various disciplines such as architecture, civil engineering, materials science, art history, and archaeology. In this context, the discipline of civil engineering plays a critical role in technical aspects such as analyzing structural systems, identifying damage, developing structural reinforcement methods, and determining appropriate intervention techniques. This study evaluates the contributions of civil engineering to the conservation of historical and cultural heritage within the framework of key principles such as authenticity, reversibility, material compatibility, minimal intervention, and sustainability. Particularly in the design and implementation phases, civil engineers are shown to actively contribute to the protection of cultural heritage through responsibilities such as preparing structural assessment reports, conducting material tests, and developing appropriate reinforcement strategies.

One of the distinctive aspects of this study is its focus on the comparative analysis of civil engineering-related courses within architectural conservation graduate programs in Turkey and Europe. Within this scope, program contents are examined to assess the extent to which interdisciplinary education is adopted and how technical knowledge is integrated into academic curricula. The findings emphasize the importance of graduate education in training conservation professionals with strong technical foundations and highlight the need for a more holistic educational approach in this field. The study ultimately aims to enhance the competencies of future conservation specialists and strengthen the visibility of civil engineering contributions in the transmission of cultural heritage to future generations.

Keywords: Historical building conservation, civil engineering, interdisciplinary approach, graduate education, structural reinforcement techniques

1.Introduction

Article 2 of the Venice Charter emphasizes that the conservation and restoration of monuments should draw upon all relevant scientific and technical disciplines (ICOMOS, 1964). This principle, while historically rooted in architecture, civil engineering, and materials science, has become even more relevant with the rapid development of technology. Today, new areas of expertise are increasingly integrated into conservation processes, enriching both the methodology and the outcomes.

In particular, software engineering has emerged as a promising field within heritage preservation. Digital tools designed for structural analysis, damage assessment, and

intervention planning provide civil engineers with valuable means to document the current condition of historic buildings and to plan appropriate engineering responses.

The 2013 declaration of ICOMOS Turkey further underlines the importance of studying load-bearing systems in conjunction with architectural documentation. It stresses that data should be gathered from historical sources, the structure itself, and through field or laboratory testing—preferably using non-destructive methods. Such assessments must also include soil characteristics and foundation structures, as they are critical to understanding the overall stability of a monument.

Earthquakes and ground movements, in particular, pose serious risks to historic buildings, often resulting in significant structural damage. This makes it essential for restoration strategies to combine traditional techniques with modern engineering solutions. Whereas earlier generations of architects relied on buttresses, ties, or partial reconstruction to address structural problems, contemporary practice now incorporates methods such as grouting, prestressing, anchorage systems, foundation enlargement, and pile foundations that reach stable soil layers (Ahunbay, 2022, pp. 92–93). Such approaches highlight that conservation is not only about safeguarding historical and cultural values, but also about ensuring structural safety and managing potential risks. Experimental studies and numerical analyses have likewise become indispensable, providing the technical evidence needed to support well-informed decisions.

For these methods to be applied effectively, however, technical expertise must extend beyond undergraduate education. It is increasingly important that engineers engaged in conservation receive interdisciplinary training at the graduate level. In both Turkey and Europe, master's programs dedicated to the preservation of historic structures now offer a growing number of courses with a civil engineering focus. This trend promises to equip future specialists with the technical competence required to meet the complex challenges of conservation practice.

2.Materials and Methods

This study employs a qualitative content analysis, focusing on a comparison of master's programs in historic preservation offered by universities in Turkey and Europe. The analysis draws on information compiled from course curricula that are publicly accessible online.

In addition, insights into engineering practices—such as the assessment of load-bearing systems, structural analysis procedures, and field observations—were gathered through a combination of literature review and an interview with Civil Engineer Volkan Aydemir, who works at the Kayseri Regional Directorate for the Conservation of Cultural Heritage.

3.Findings and Discussion

Restoration is not a simple repair task carried out with ordinary craftsmanship. On the contrary, a successful conservation process requires profound knowledge, careful observation skills, and a collaborative team approach. The planning, implementation, and monitoring of such a process cannot be achieved through theoretical knowledge alone, but must also be supported by experience and professional expertise.

As Ahunbay (2022) points out, just as a surgeon would never be authorized to perform an operation without a thorough knowledge of anatomy, an architect or engineer lacking sufficient understanding of traditional building materials, techniques, structural systems, and typologies should not be entrusted with the highly delicate responsibility of safeguarding cultural heritage.

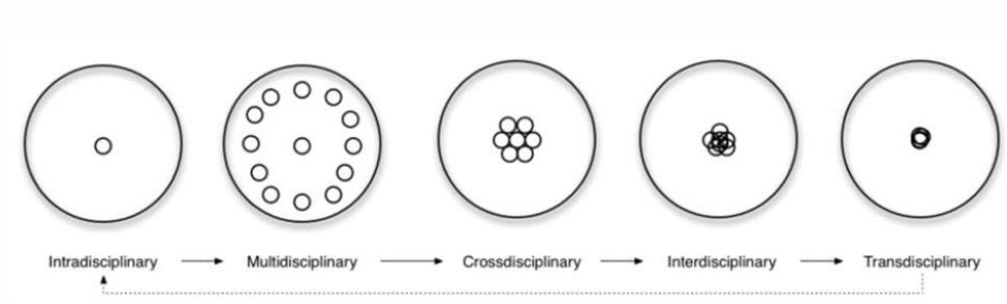


Figure 1. Diagram of Interdisciplinary Approaches (Zeigner, 1990)

In architectural practice, when sufficient communication and collaboration with other disciplines are not established, projects are often evaluated solely within the narrow framework of a single profession (an intradisciplinary approach). This frequently results in serious technical shortcomings and coordination problems during implementation. In contrast, multidisciplinary practices—where different disciplines work side by side but with limited knowledge exchange—are observed in Turkey to only a modest degree. While such an approach provides a partial basis for generating solutions, it remains insufficient for producing fully integrated outcomes.

By comparison, in advanced architectural offices, interdisciplinary collaboration is carried out more effectively. As a result, the design, engineering, and implementation stages of projects produce more holistic, reliable, and efficient outcomes.

Within this framework, the concepts illustrated in the diagram may be summarized as follows:

- **Intradisciplinary approach** refers to work conducted strictly within the boundaries of a single discipline.
- **Multidisciplinary approach** describes a model in which different disciplines work in parallel, but with limited interaction.
- **Crossdisciplinary approach** involves the borrowing of selected concepts or methods from one discipline by another, without deeper integration.
- **Interdisciplinary approach** aims to generate joint solutions through reciprocal knowledge exchange between disciplines.
- **Transdisciplinary approach** transcends disciplinary boundaries altogether, fostering the development of new areas of knowledge and methods.

This conceptual framework makes clear why interdisciplinary interaction is so vital for producing sustainable solutions in architectural and restoration projects.

3.1. Evaluating the Fundamental Principles of Historic Building Conservation from a Civil Engineering Perspective

The conservation of historic buildings involves more than preserving their aesthetic and architectural qualities; it also requires ensuring the long-term stability of their structural systems. In this regard, civil engineering provides a critical lens, examining whether proposed interventions are technically sound, structurally safe, and appropriate for the building as a whole.

From this perspective, five key principles guide the conservation process: authenticity, reversibility, material compatibility, minimum intervention, and sustainability. Each of these principles plays an essential role in shaping how engineering decisions are made, ensuring that interventions not only protect the cultural value of the structure but also secure its physical integrity for future generations.

a. Authenticity

Article 9 of the Venice Charter reminds us that restoration is not simply a technical procedure but a specialized process aimed at preserving the aesthetic and historical values of monuments. It calls for interventions to be based on authentic materials and reliable documentation. The principle that *"restoration must stop where conjecture begins"* is vital, not only from an ethical perspective but also for engineering practice. Structural interventions should always be grounded in solid technical evidence and research, leaving no space for assumptions. At the same time, any new additions should be designed to remain clearly distinguishable—both technically and visually—from the original fabric, a principle that engineers must carefully uphold in their projects.

b. Reversibility

In its 2003 document, *Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage*, ICOMOS stresses that interventions should, whenever possible, be reversible. This ensures that as new knowledge emerges, existing measures can be removed without causing harm and replaced with more appropriate solutions (ICOMOS, 2003). In practice, however, complete reversibility is not always achievable—particularly when structural safety is at stake. From an engineering standpoint, the challenge lies in striking a careful balance: protecting the authenticity of the building while ensuring the safety of those who use it. In this sense, reversibility is less an absolute rule and more a guiding principle that must be weighed against structural necessity.

c.MaterialCompatibility

Article 12 of the Venice Charter calls for missing parts of a building to be reconstructed in harmony with the existing structure, while still remaining distinguishable. For engineers, this principle translates into a conscious use of modern materials and techniques—not to imitate the historical fabric, but to ensure that interventions are deliberately recognizable. Such an approach strengthens the structural system while also safeguarding the documentary value of the monument, allowing it to be passed on to future generations with its history clearly legible.

d.Minimum Intervention

Conservation must respect the building's current state, its functions, spatial relationships, and cultural significance. As the Burra Charter puts it, the goal is to intervene "as much as necessary, but as little as possible" (Australia ICOMOS, 2013). For engineers, this principle carries considerable responsibility. Structural strengthening or repair should aim to preserve as many existing load-bearing elements as possible and to retain original materials in place. Avoiding unnecessary interventions is not only a matter of ethics but also a reflection of professional awareness. Where new structural elements are unavoidable, they should be designed in a way that avoids damaging the existing structure and leaves a clear record of their later addition.

e.Sustainability

Article 4 of the 1972 UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage places responsibility on states to safeguard their cultural heritage and transmit it to future generations (UNESCO, 1972). Within this framework, civil engineering takes on a central role. Ensuring structural safety, analyzing the properties of existing materials, and applying appropriate strengthening methods are all tasks that directly depend on engineering expertise. These technical measures contribute not only to the protection of monuments but also to their continued use and vitality—helping heritage to remain a living part of society rather than a relic frozen in time.

3.2. Roles and Responsibilities of Civil Engineers in Conservation

a. Preparation of Structural Assessment Reports

Before any intervention can take place, historic buildings must be carefully examined on site. This initial assessment involves documenting the properties of materials, identifying existing damage, and recording visible structural deterioration. When necessary, samples are taken from the building for laboratory testing to provide a clearer understanding of material performance (General Directorate of Foundations, 2021).

The type of analysis carried out depends on the building's complexity, the nature of its load-bearing system, and the characteristics of its materials. Both linear and non-linear methods, as well as static and dynamic approaches, may be employed. These analyses help to pinpoint vulnerable areas of the structure and form the basis for detailed reports outlining where and why intervention is required (General Directorate of Foundations, 2021).

At this stage, proposals for strengthening or repair are designed to respect the building's original values. Engineering solutions emphasize the preservation of existing load-bearing elements, the use of in-situ strengthening techniques, and adherence to the principle of minimum intervention. Application projects prepared in line with these structural reports aim to achieve two goals simultaneously: ensuring safety while protecting cultural heritage.

b. Supervision and Control of Implementation

Insights from Civil Engineer Volkan Aydemir of the Kayseri Regional Directorate for the Conservation of Cultural Heritage highlight the regulatory framework that guides conservation practice. According to Aydemir, two key documents shape engineering responsibilities in restoration projects.

The first is the *Guidelines for Strengthening and Repair of Historic Buildings*, published by the General Directorate of Foundations. This document provides practical guidance for protecting the authenticity of historic structures and selecting appropriate methods of intervention. The second is the *Turkish Seismic Code for Buildings* (2018), which establishes the principles and calculation methods necessary for ensuring the structural safety of historic buildings under seismic conditions.

Aydemir stresses that these two documents must be applied together. In his view, successful implementation requires balancing the ethical and cultural responsibilities of conservation with the technical demands of structural safety. This balanced approach ensures that restoration projects are both respectful of heritage and resilient in the face of physical risks.

3.3. The Role of Civil Engineering Courses in Graduate Programs on Historic Preservation: A Comparative Analysis

Graduate-level education plays a central role in preparing specialists capable of addressing the technical challenges of heritage conservation. Across Turkey and Europe, civil engineering courses are increasingly integrated into master's programs on historic preservation. These courses provide future conservation professionals with essential skills in structural assessment, materials analysis, and engineering-based intervention methods.

A comparative look at curricula reveals important differences and similarities. In Turkey, programs often focus on practical concerns such as seismic safety and repair techniques for masonry structures—reflecting the country's vulnerability to earthquakes and the prevalence of stone and brick heritage buildings. In contrast, many European programs place greater emphasis on theoretical frameworks, advanced materials research, and interdisciplinary collaboration, drawing from a broader tradition of conservation studies.

Despite these differences, both contexts highlight the same underlying need: equipping architects, engineers, and conservators with the knowledge to design interventions that are both technically sound and culturally sensitive. This integration of engineering into graduate education strengthens the professional capacity to safeguard historic buildings in a sustainable and responsible way.

Table 1. Civil Engineering–Related Courses in National and International Graduate Programs on Historic Preservation

University	Program Name	Civil Engineering Content Courses	References
Istanbul Technical University (Turkey)	Mimari Koruma Yüksek Lisans Programı (Master's Program in Architectural Conservation)	Deter. & Cons. of (Trad. Buil. Mate. Yapı ve Malzeme Bozulmaları, Güçlendirme Yöntemleri)	https://obs.itu.edu.tr/public/DersPlan/_DersGrupSearch?grupId=9756
Middle East Technical University (Turkey)	Kültürel Mirasın Korunması YL Programı (Master's Program in Conservation of Cultural Heritage)	Tarihi Yapı Sistemleri (Historic Building Systems)	https://catalog.metu.edu.tr/course.php?prog=856&course_code=8560533
Politecnico di Milano (İtaly)	Built Heritage Conservation MSc	Heritage at Risks. Managing the Effects of Seismic Actions and Traumatic Events on the Built Heritage by Digital Tools	https://www11.ceda.polimi.it/manifestidott/manifestidott/controller/MainPublic.do
TU Delft (Holland)	Master Architecture, Urbanism and Building Sciences	Building Engineering Studios	https://studiegids.tudelft.nl/a101_displayProgram.do?program_id_with_context=30250&SIS_Switchlang=en
UCL Bartlett (England)	Active parent page: The Bartlett Faculty	Historic and contemporary materials	https://www.ucl.ac.uk/bartlett/environment-energy-resources/heritage/research-

	of the Built Environment		institute-sustainable-heritage/heritage-science?utm_source=chatgpt.com
Yildiz Technical University (Turkey)	Mimarlık ABD Rölöve-Rest.Y.L. (Department of Architecture, Surveying and Restoration Master's Program)	Geleneksel Yapım Teknikleri (Traditional Building Techniques)	http://www.bologna.yildiz.edu.tr/index.php?r=program/view&id=239&aid=38
Politecnico di Torino (Italy)	Architettura per il Patrimonio	Construction Features and Consolidation of Historic Architecture Historic Architecture: Building Systems and Reinforcement Criteria	https://www.polito.it/didattica/corsi-di-laurea-magistrale/architettura-per-il-patrimonio/piano-di-studi
Mimar Sinan University of Fine Arts (Turkey)	Master's Program in Architectural Conservation and Restoration	Tarihi Yapıların Strüktürel Değerlendirilmesi ve Korunması (Structural Assessment and Conservation of Historic Buildings)	chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://msgsu.edu.tr/wp-content/uploads/2022/02/Koruma-ve-Restorasyon-Yuksek-Lisans-Programi.pdf
Roma Tre (İtaly)	Master of Science - Restoration	Strength of Materials	https://www.uniroma3.it/en/insegnamento-erogato/dipartimento-di-architettura/lm/2024-2025/master-of-science-restoration-0580707300500003/cfece609-0822-4f6e-8a7e-0687c917207d--21002096/
AA (England)	Conservation and Reuse MA/PGDip	Comparative Construction and Carbon Awareness	https://www.aaschool.ac.uk/academicprogrammes/postgraduate/conservation-and-reuse
Eastern Mediterranean University (Cyprus)	Master's Program in Conservation and Restoration	Yapıların Strüktürel Analiz ve Korunması (Structural Analysis and Conservation of Buildings) Yapılarda Malzeme Bozulması Analizi ve Korunması (Analysis and Conservation of Material Deterioration in Buildings)	https://www.emu.edu.tr/tr/programlar/koruma-ve-restorasyon-yuksek-lisans-programi-turkce-tezsiz/1688?tab=curriculum

When graduate programs in different countries are compared, it becomes clear that civil engineering courses are included in historic preservation curricula to varying degrees. In Turkey, for example, universities such as ITU, METU, YTU, and MSGSU tend to prioritize practice-oriented courses. These often address the deterioration of building materials, traditional construction techniques, and strengthening methods. While such courses are valuable, they remain largely focused on conventional practices and are not yet fully supported by analytical approaches or digital engineering tools.

European institutions present a contrasting picture. Leading universities such as Politecnico di Milano, TU Delft, UCL Bartlett, and Roma Tre University have made engineering-based content an essential part of preservation education. Their curricula include advanced topics such as structural analysis, performance evaluation, and seismic risk assessment. For instance, the

Heritage at Risk course at Politecnico di Milano allows students to explore seismic risks using digital tools, strengthening the link between conservation and engineering innovation. TU Delft's *Building Engineering Studios* and UCL Bartlett's *Historic and Contemporary Materials* courses adopt an interdisciplinary perspective that evaluates both the cultural value and technical performance of building materials. At Roma Tre University, the *Strength of Materials* course provides students with the skills to analyze material performance through fundamental engineering principles.

In the Turkish Republic of Northern Cyprus, institutions such as Eastern Mediterranean University also offer courses on structural analysis and material deterioration, further underlining the growing recognition of engineering's role in conservation education.

Taken together, these comparisons suggest that European programs use civil engineering more effectively as a tool in conservation, often supported by digital technologies and advanced analytical methods. Turkish programs, meanwhile, remain more rooted in traditional practices, with relatively limited use of numerical modeling or digital simulations. Expanding the integration of performance modeling, seismic analysis, and digital engineering tools into Turkish curricula would not only strengthen interdisciplinary collaboration but also improve the international competitiveness of these programs.

4. Conclusion and Recommendations

The conservation of historic buildings is far more than a technical exercise; it is an interdisciplinary endeavor that seeks to safeguard cultural heritage for future generations. Achieving this goal requires close collaboration and clear communication among a wide range of professionals, including architects, civil engineers, art historians, restorers, and conservation specialists. For civil engineers in particular, higher education programs that foster multidisciplinary learning are no longer optional but essential.

Equally important, the sustainable protection of heritage must extend beyond the work of experts. Broader public awareness is crucial, and the practices of countries such as Italy and the United Kingdom provide useful examples. In Italy, for instance, schoolchildren participate in field trips and on-site observation classes designed to connect them with their cultural environment from an early age. Such initiatives help instill an awareness of cultural heritage long before students choose a profession (Kishalı, 2020).

Early education of this kind lays the groundwork for future professionals—especially engineers—to adopt a holistic conservation mindset. It encourages them to value not only the structural stability of historic buildings but also their cultural meaning. This makes clear that conservation is not just about what is done on site, but also about how the next generation of experts is trained to approach their responsibilities.

A comparison of graduate programs in architecture and restoration, both in Turkey and abroad, shows that programs incorporating civil engineering and other interdisciplinary content are more effective and successful. Expanding multidisciplinary conservation education will therefore serve two purposes: it will encourage academic programs to adapt and modernize, and it will help practitioners from different fields develop a shared language. Together, these efforts will make conservation processes more coherent, effective, and sustainable.

Thanks

I would like to thank Kayseri Sugar Company for their valuable support in this study, and Civil Engineer Mr. Volkan Aydemir for generously sharing his insights during the interview process.

References

Architectural Association School of Architecture. (n.d.). *Conservation and Reuse* [Program description]. Retrieved June 19, 2025, from https://www.aaschool.ac.uk/academicprogrammes/postgraduate/conservation-and-reuse

Ahunbay, Z. (2022). *Kültür mirasını koruma: İlke ve teknikler*. İstanbul: YEM Yayın.

Ahunbay, Z. (1996). *Tarihi çevre koruma ve restorasyon*. İstanbul: YEM Yayın.

Australia ICOMOS. (2013). *The Burra Charter*.

Aydemir, V. (2025, April 10). *Regulations considered in the design and implementation control of historic buildings* [Oral interview]. Kayseri Regional Directorate for the Conservation of Cultural Heritage.

Delft University of Technology. (2025). *Heritage and Architecture MSc program* [Program information]. TU Delft Study Guide. Retrieved from https://studiegids.tudelft.nl/a101_displayProgram.do?program_id_with_context=30250&SIS_Switchlang=en

Eastern Mediterranean University. (n.d.). *Master's Program in Conservation and Restoration (Non-thesis, Turkish)* [Program information]. Retrieved June 19, 2025, from https://www.emu.edu.tr/tr/programlar/koruma-ve-restorasyon-yuksek-lisans-programi-turkce-tezsiz/1688

General Directorate of Foundations (T.C. Vakıflar Genel Müdürlüğü). (2021). *Guidelines for strengthening and repair of historic buildings*.

ICOMOS. (1964). *The Venice Charter*. Retrieved from https://www.icomos.org/charters/venice_tur.html

ICOMOS. (2003). *Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage*.

ICOMOS Turkey. (2013). *Declaration on the conservation of architectural heritage*. ICOMOS Turkey National Committee. Retrieved from http://www.icomos.org.tr/Dosyalar/ICOMOSTR_tr0784192001542192602.pdf

Istanbul Technical University. (n.d.). *Deterioration and Conservation of Traditional Building Materials* [Course description]. ITU OBS. Retrieved June 19, 2025, from https://obs.itu.edu.tr/public/DersPlan/_DersGrupSearch?grupId=9756

Jensenius, A. R. (2016). *Interdisciplinary approach* [Diagram]. Retrieved from www.arj.no/tag/interdisciplinary (Original drawing by Zeigner, 1990).

KOÜ Mim Talks. (2020, August 21). *Interdisciplinary work in historic environment and conservation – Emre Kishalı* [Video]. YouTube. https://www.youtube.com/watch?v=b2qYGt1HMQE

Middle East Technical University. (2025). *Historical structural systems* (Course code: 8560533). METU Academic Catalog. Retrieved June 19, 2025, from https://catalog.metu.edu.tr/course.php?prog=856&course_code=8560533

Mimar Sinan Fine Arts University. (2022, February). *Master's Program in Conservation and Restoration* [Program description]. MSGSU Bologna Information System. Retrieved June 19, 2025, from http://www.bologna.yildiz.edu.tr/index.php?r=program/view&id=239&aid=38

Politecnico di Milano. (n.d.). *Architectures and materials for historic heritage* [Course description]. CEDA. Retrieved from https://www11.ceda.polimi.it/manifestidott/manifestidott/controller/MainPublic.do

UNESCO. (1972). *Convention concerning the protection of the world cultural and natural heritage*.

Università degli Studi Roma Tre. (n.d.). *Master of Science Restoration (0580707300500003)* [Program description]. Retrieved June 19, 2025, from https://www.uniroma3.it/en/insegnamento-erogato/dipartimento-di-architettura/lm/2024-2025/master-of-science-restoration-0580707300500003/cfece609-0822-4f6e-8a7e-0687c917207d--21002096/

University College London. (2025). *Heritage science*. Bartlett Faculty of the Built Environment, UCL Institute for Sustainable Heritage. Retrieved June 19, 2025, from https://www.ucl.ac.uk/bartlett/environment-energy-resources/heritage/research-institute-sustainable-heritage/heritage-science

Yıldız Technical University. (n.d.). *Graduate Program in Conservation and Restoration, Department of Architecture* [Program information]. Bologna Information System. Retrieved June 19, 2025.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Experience-Based Mapping of the Samsun City-Center

Hande ASAR [1]*

ORCID 1: 0000-0003-3201-3204
[1]Assoc. Prof. Dr., Ondokuz Mayıs University, Faculty of Architecture, Department of Architecture, Samsun-Türkiye
hande.asar@omu.edu.tr (Responsible Author)

Abstract

During and after the experience of a space, individuals encounter a multiplicity of elements that shape memory, stimulate the senses, and enrich or differentiate perception. Each encounter contributes to the accumulation of new layers of knowledge, thereby expanding one's understanding of the spatial environment. Within the architectural design process, such experiences can be framed through themes such as space–user relations, the interplay of place and space, and the influence of culture, all of which contribute to design development. This study emphasizes space as a foundational dimension of design and introduces experience-based mapping as a methodological tool. The notion of space-specificity in architectural design requires a comprehensive consideration of the multiple layers of knowledge embedded within a given site. While conventional modes of representation—such as photography, sketching, and analysis—offer valuable insights, relational representational methods are particularly effective in visualizing the continuity and stratification of experience. By synthesizing diverse perspectives and techniques, these methods parallel the multifaceted process of understanding space. Accordingly, comprehending space necessitates engagement with varied perspectives. Building on this premise, the present research examines the experience-based mapping technique as a tool for relational production and critical reflection. To this end, a case study was conducted in the city center of Samsun, offering a conceptual evaluation of its outcomes. The study concludes by highlighting experience-based mapping's potential contributions to architectural design, particularly in the context of architectural education.

Keywords: Architectural design process, architectural design education, experience-based mapping, relational representations, Samsun

1. Introduction

The architectural design process is established and carried out through multidimensional modes of thinking and making. At nearly every stage of this process, the notion of spatial experience plays a crucial role. The explicit and tacit knowledge gained during the experience of a space converges to enrich and transform the perspective of the designer/architect. Thus, each new architectural design process has the potential to become an innovative and creative domain that embraces diverse viewpoints and generates new relationships by drawing upon them. Particularly in the phases of spatial construction (such as analyses, syntheses, preliminary sketches, and interrelations among units), experiential knowledge is a significant catalyst that stimulates and sustains creative thinking. Accordingly, this study focuses on experiential knowledge and discusses how this knowledge contributes to the architectural design process through various techniques. To this end, emphasis is placed on the relational dimension of architectural representation techniques, and an evaluation of how technical knowledge can be rendered relational. Within the scope of the study, the mapping technique has been employed as a relational method. Since the technique is constructed and debated through experiential knowledge, it has been referred to throughout the study as an experience-based mapping technique.

Although the architectural design process employs broadly similar techniques and is carried out through comparable approaches, it remains a highly personal and creative field. Within professional practice, each architect forges a unique trajectory throughout their career. This trajectory, which is open to continuous development, can be reproduced in diverse ways

depending on the architect's individual approach. In architectural education, however- particularly in the early years- this is not the case. Students are introduced to various techniques and methods that shape their design trajectory during the learning process. Accordingly, the greater the number and diversity of these factual and methodological encounters, the greater the student's opportunity to develop an individual and distinctive design path.

In the context of architectural education, "in a world where uncertainty is increasing and education is becoming more personal and open-ended, abstract concepts such as intuition, common sense, emotional intelligence, a sense of responsibility, a sense of justice, flexibility, and creativity come to the forefront" (Yürekli & Yürekli, 2004). Accordingly, within the scope of this study, experience-based mapping is discussed as one of the techniques that draws upon notions such as flexibility and creativity and may assist students in constructing their own design trajectories. To further elaborate on this technique—conceived as a relational tool for both production and thinking—selected works carried out in the city center of Samsun within the course "Relational Practices in Architectural Design", taught by the author in the Department of Architecture at the Faculty of Architecture, Ondokuz Mayıs University (OMÜ), have been used as examples.

As is well known, cities offer users a multi-layered field of experience. The multiple relationships between the fixed and mobile elements of the city render the time spent in the same place at different moments unique each time. Thus, even when the fixed components of the city remain unchanged, the presence of dynamic variables mediates the formation of new experiential layers associated with that place. This condition provides designers with potential opportunities to conceive action–space relations specific to a given site within the architectural design process. To reveal such potentials, however, it is necessary to make their existing relational conditions similarly visible. At this point, the notion of relational thinking—and its translation into practice—gains significance. Relational thinking, at its core, refers to "the discovery rather than the transmission of knowledge" (Aydınlı & Avcı, 2010) and constitutes a phenomenon and practice that privileges relationships over outcomes (Kızıltoprak & Yavuzsoy Köse, 2017). Relationality is established through interaction, and interaction fields serve as catalysts for stimulating creativity. Because "(...) interactive systems do not impose a particular pattern of action; rather, they provide a space of negotiation in which individuals can exercise their 'multiple' capacities of action in creative ways" (Kocaballi et al., 2011).

Various approaches to relational thinking and relationality emerge across different fields and are drawn upon within the domain of architectural knowledge. As Kararmaz and Polatoğlu Serter (2025) state, relational thinking- developed as a response to dual paradigms in Western thought- finds its architectural foundations in Alfred North Whitehead's process philosophy, Enzo Paci's phenomenological relationality, and the deconstructive ideas of Gilles Deleuze and Félix Guattari. Today, however, the discourse on relationality has expanded further through diverse media, tools, and approaches. Actor-Network Theory (ANT), for example, addresses heterogeneous structures and the relationality of the actors that constitute them (Latour, 2005). In the context of architectural design, it is particularly valuable for reassessing the relationships between human and non-human actors from a new perspective. Furthermore, this approach is influential in transforming representational methods to capture the dynamic relations inherent in architectural design.

Relational thinking and production pave the way for transforming the architect's role, positioning them as an actor who designs relationships. To this end, the architect/designer must

also reconsider the relationship established with the tools they employ. “Relational thinking opens up a multi-possibility field for the designer-subject to benefit from, or to reveal, the potential of narrative in the architectural design process” (Asar, 2023). Among such fields, diverse representational methods can be mentioned. Within the scope of this study, the experience-based mapping technique has been addressed as one such method. The study aims to discuss experience- based mapping as a relational tool for production and thinking in architecture.

Mapping- and, as articulated in this study, experience-based mapping- constitutes one of the significant tools of the architectural design process. Because “Mappings, as one of the performative and innovative methods of the design process, are nourished by the existing condition of what is to be narrated and mediate the revelation of alternative scenarios and potentials concerning that condition” (Asar et al., 2025).

The potential of mapping lies in the mapping practitioner’s freedom to combine different design techniques and tools while incorporating personal interpretations. This acting involves engaging with multiple dimensions, such as movement and flux, as well as experiential and sensory aspects. Thus, “Beyond the physical structures and factors of a place, it is also possible to map social structures and networks of relationships in daily life” (Sarı, 2013). This situation enables mapping to function as a tool for relational thinking. Mapping, which focuses on research and discovery, relates, integrates, and structures all collected data (Kozar, 2009), facilitating an understanding of the complex dynamics of social and natural processes (Corner, 1999). In this context, “mapping can be seen as an act of rethinking architecture’s relationship with place and establishing alternative relationships with it” (Şenel, 2019).

As a tool and technique for relational thinking and the establishment of new relationships, mapping plays a significant role in both the architectural design process and architectural education, particularly because it stimulates creative processes. Various terms in the literature refer to these types of mappings. For instance, Güleç (2021) notes that “(...) creative maps are defined as mental, theoretical, formal, narrative, perceptual, imaginative, functional, indexical, relational, and interactional maps” (Güleç, 2021). In this study, since the concept of experience serves as the focal point, the maps considered are employed as experience-based mappings. Experience-based mappings are discussed as tools for relational thinking and production, drawing upon technical and experiential knowledge. Finally, the study evaluates the potential of experience-based mappings for the architectural design process within the context of architectural education.

2. Materials and Methods

The visual materials used in this study are some of the outputs from the elective course “Relational Practices in Architectural Design” (designed and conducted by the author) within the curriculum of the Department of Architecture at the OMU Faculty of Architecture, during the Spring semester of 2024–2025. The design of the final project implemented in this course is related to the approach discussed in this paper (experience-based mapping). Therefore, the outputs of this project have been utilized in this study.

In the study focusing on the experience-based mapping technique, the city center of Samsun (Figure 1) was selected as the sample area due to its multi-layered urban structure. The selected area is bounded by Saathane Square, located at one end of the historic clock tower and surrounded by Taşhan, Şifa Hamam, Süleymanpaşa Mosque and Madrasa, as well as various

commercial units, and the two streets extending from the other end of the tower **(**Kasaplar Street and Kazımpaşa Street**).** All students studied the square section collectively, while the street section was divided into two groups. This study includes works covering both streets; however, during the analysis phase, no distinction was made between them as their street characteristics were almost identical. A preliminary study was conducted in the area over two weeks (using class days and hours), and the students generated the final outputs presented in this paper by building upon the drawings produced during this preliminary work.

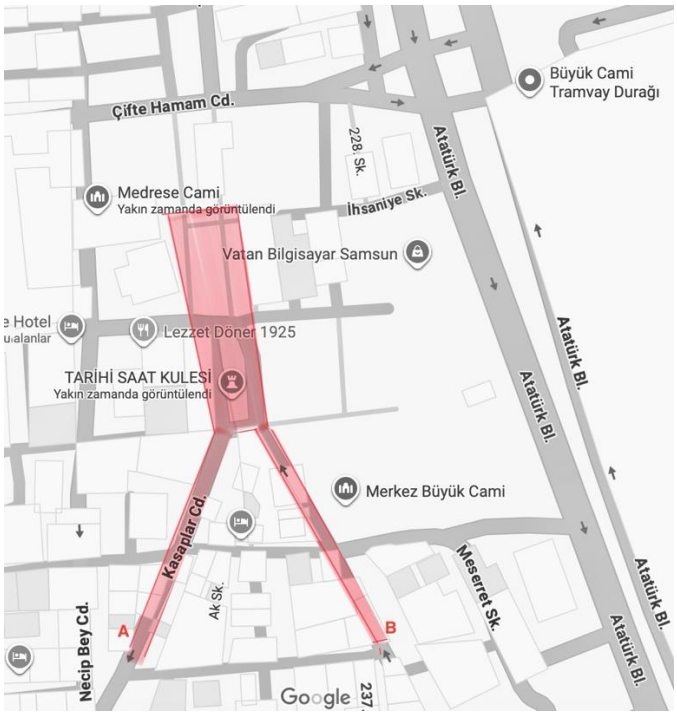


Figure 1. Boundaries of the study area (created from Google Maps)

The field study aimed for students to convey their own emotions and experiences by engaging with both fixed elements**,** such as architectural structures, urban amenities, and landscape features, and mobile elements**,** including people, activities, animals, and vehicles, within the defined urban area. The relationship between these two primary element types and their visualization was left to the students' discretion in their designs. Among the submitted works for the course (32 submissions), eight studies (Figure 2) employing different mapping techniques and visualization methods were selected. A conceptual interpretation related to the experience-based mapping technique was conducted based on these selected studies.



Figure 2. Selected mappings as samples.

Findings and Discussion

The selected studies were evaluated in terms of their implementation methods to discuss the knowledge of the technique and the information and textual expressions they conveyed to examine the understanding of experience.

An interpretation of the methods employed in the studies yields varying results. Elements such as color, perspective, textual expressions, and icons are common to all examples, and they serve as tools for creating experience-based mappings. Differences in the manner and frequency of use of these tools resulted in variations in the final outputs. A detailed examination of their application in each example highlights how the data on experiences and perceptions, which constitute personal information, diversifies. Furthermore, the students' textual expressions can be interpreted as narratives reflecting what captured their attention in the field or as means of conveying their perceptions of the place.



Figure 3. Examples of experience-based mapping I (Left: Student A; Right: Student B)

For example, in Student A's work (Figure 3 – left), a prominent route indicating the starting and ending points is depicted in yellow. Around this route, the student made each building visible by employing perspective drawings with different vanishing points. The student rendered and colored in detail the structures that represent the historical fabric and those they found noteworthy. People and sounds were represented using various icons. Textual expressions were included in the square (a couple's dinner conversation), on the street (sounds from the greengrocer), and beside the mosque (dialogues arising from traffic). The focus of this experiential mapping was the route the student established and how the surrounding fixed and mobile elements were represented.

In Student B's work (Figure 3 – right), the use of color is distributed almost evenly across the drawing. The route followed is depicted not linearly, but along the perimeters of the designated area. The square narrative is positioned on the right side of the drawing, and specific facade details of historical buildings are also included. In the drawing's double-sided representation of the street, the street is portrayed as two separate planes rather than facing each other. The use of icons, together with depictions of people's actions (such as sitting, walking, and cycling), reinforces the kinetic quality of the narrative. Similarly, the textual expressions included in the mapping (e.g., "fresh fish," "has the call to prayer been recited," and "why are you drawing here") are presented as speech bubbles, thereby conveying the experiential knowledge of the area.



Figure 4. Examples of experience-based mapping II (Left: Student C; Right: Student D)

In Student C's work (Figure 4 – left), the areas forming the focal points are represented in color. The route followed by the student is indicated with red dashed lines. Although Student C placed relatively little emphasis on mobile elements and textual expressions, the way these elements were represented distinguishes the work from others. The student draws blue lines around the icons of people and vehicles, using them to emphasize the presence of movement.

In Student D's work (Figure 4 – right), the use of color is again employed extensively. Representing all the buildings in the drawing with textures and colors highlights the structural character differences within the area. Moreover, the dense depiction of mobile elements (such as people, vehicles, and birds) conveys the intensive use of the square. The use of perspective in representing the street and its division into two planes enhances the legibility of the buildings opposite each other. The attempt to depict the mapping in two directions is further reinforced by the placement of clouds on both sides of the drawing. The limited presence of textual expressions (e.g., "*simitçi*") indicates the scarcity of site-specific experiential data.



Figure 5. Examples of experience-based mapping III (Left: Student E; Right: Student F)

Student E's work (Figure 5 – left) employs an elevation drawing technique. Another difference from previous studies is that the student uses color only in the abstractions of people and in certain textual expressions. In this representation, which is dominated by technical drawing knowledge, the dynamic nature of the city can only be inferred by including mobile elements in the drawing. While this limits the incorporation of the student's personal perspective into the mapping, it also constrains the expressive differentiation of the work.

In Student F's work (Figure 5 – right), as in Student E's, the use of color is limited; however, data related to spatial–activity relationships within the area are represented as enlarged sketches extending beyond the site's boundaries. This approach may reflect the student's intention to make certain events or dialogues (e.g., "*simitçi,*" "Aslı's drawing flew," "what are they drawing," "everyone arrived early") more visible.

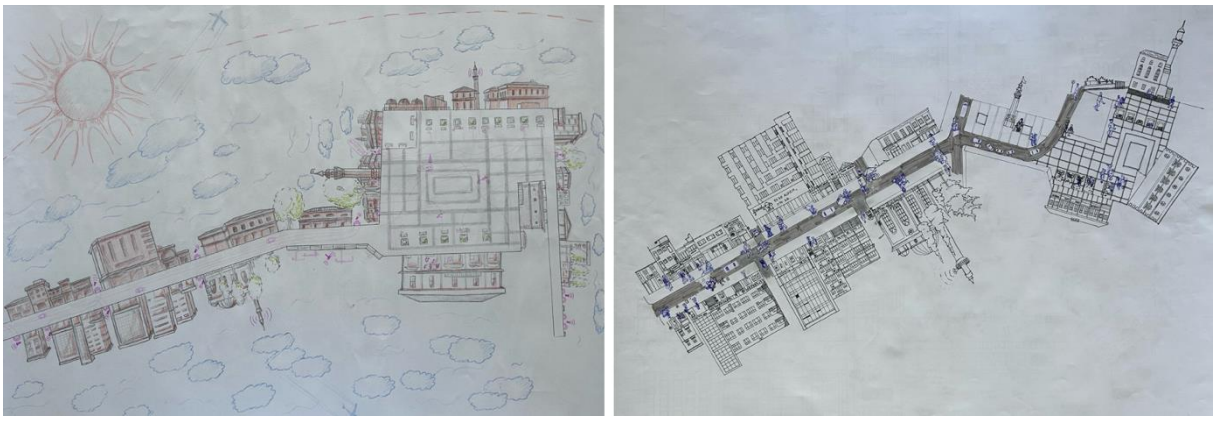


Figure 6. Examples of experience-based mapping IV (Left: Student G; Right: Student H)

In this work (Figure 6 - left), Student G attempted to have the drawing read bidirectionally, as in Student D. To this end, Student G drew clouds in both directions. In this work, Student G used a perspective drawing technique. Thus, structures perceived as one-dimensional in Student E gained dimension in this drawing. However, the absence of distorted perspectives- as in most other works- mediated the reorganization of experiential knowledge. Thus, the drawing evolved into a technique closer to existing map knowledge. In this work, we observe the use of a single color at a consistent scale, while mobile elements are represented with small icons but appear in frequently, and no textual expressions are included.

Finally, in Student H's work (Figure 6 – right), we encounter technical drawings of building elevations, as in Student E's work. However, the greater structural detail and the increased line thickness make the drawing more visually dominant. The student chose to use color only for moving elements, such as people and vehicles, while clarifying the route with pencil shading. No textual expressions are included in this mapping. Nevertheless, because the depictions of moving elements were created with attention to space–action relationships, the work provides some insight into the student's experiential knowledge.

When all the experience-based mappings used in the study are analyzed regarding their execution methods and textual expressions, similarities and divergences emerge. In some cases, where data related to experiential knowledge were incomplete, the student's chosen drawing technique resulted in a less discernible final product. On the other hand, in works where both the technical knowledge and all elements conveying experiential information are visible, multiple insights about the mapped area could be obtained.

Conclusion and Recommendations

As a relational tool for production and thinking, experience-based mapping was evaluated through the sample group addressed within the scope of this study. In this context, experience-based mapping was discussed as a process in which the designer's focus, the fixed and dynamic data of the area, and the designer's personal modes of perception, senses, and experiences converge and are represented through an individual language. In each selected case study,

students produced mappings based on their own experiences and modes of expression. However, the aspects they focused on, the elements they chose to include in their drawings, and the ways they represented fixed components such as architectural structures varied. In some instances, similar techniques and tools were observed.

Nevertheless, the similarity of representational techniques or tools did not undermine the personal language of the works. This situation highlights that even the partial inclusion of experiential data in experience-based mappings leads to differentiated outcomes. Moreover, the increased incorporation of experiential data enriches experience-based mapping in terms of its ability to convey information about both the language and the place itself.

Finally, the fact that this study was conducted specifically with architecture students positions experience-based mapping as a significant relational tool of expression and thinking within the context of architectural education. In this regard, experience-based mapping can be particularly effective in architectural education and during the early stages of the design process, as a method that facilitates the establishment of analysis-synthesis relationships and serves as a guiding approach in the design process.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. As the images used as examples were produced within the scope of a course conducted by the author, no separate ethics committee permission was obtained. Nevertheless, permission was obtained from the students to use the images in an academic study.

I would like to thank all the students who contributed to the course and formed the sample data for this study during the 2024–2025 Spring semester.

References

Asar, H. (2023). Mimari tasarım sürecinde çizerek düşünme ve anlatı ilişkisinin potansiyeli üzerine. İçinde *Mimarlık, Planlama ve Tasarım Alanında Gelişmeler* (Ed.: F. Aslan). Platanus Publishing.

Asar, H., Gür, Z. & Demirtaş, Ş. (2025). Mekansal deneyimlerin belgelenişi: Bir kent okuması. İçinde *Mimarlık Alanında Akademik Araştırmalar* (Ed.: H. S. Aşıkkutlu & O. Soydan). Platanus Publishing.

Aydınlı S. & Avcı O. (2010). Relational thinking that enhances critical thinking: A design studio case based on the discovery of knowledge. In C. Spiridonidis & M. Voyatzaki (Eds.). *Educating architects towards innovative architecture,* EAAE Transactions on Architectural Education no 50.

Corner, J. (1999). *The agency of mapping: speculation, critique and invention, mappings.* London: Reaktion Books.

Güleç, G. (2021). Mimarlıkta temsil ve tasarım araçları olarak haritalar. *GRID- Architecture Planning and Design Journal, 4*(1), 53-73. https://doi.org/10.37246/grid.796513

Kararmaz, Ö. & Polatoğlu Serter, Ç. (2025). From dots and lines to connections: Re-evaluation of relational thinking in architecture. *Buildings* (15), 2548. https://doi.org/10.3390/buildings15142548

Kızıltoprak A. & Yavuzsoy Köse, N. (2017). Relational thinking: The bridge between arithmetic and algebra. *International Electronic Journal of Elementary Education,* 10(1), 131-145.

Kocaballi, A. B., Gemeinboeck, P., Saunder, R. & Dong, A. (2011). Towards a relational approach to design process. 45th Annual Conference of the Architectural Science Association, ANZAScA 2011, The University of Sydney.

Kozar, C. (2009). *Mimarlığın ötesinde bir başlangıç noktası olarak kent okuması* (Yüksek lisans tezi). İstanbul Teknik Üniversitesi, İstanbul.

Latour, B., (2005) Reassembling the social: an introduction to Actor-network theory, Oxford: University Press.

Sarı, J. (2013). *Kenti deneyimleme aracı olarak psikocoğrafya* (Yüksek lisans tezi). İstanbul Teknik Üniversitesi, İstanbul.

Şenel, A. (2019). Mimarlık eğitiminde haritalama: geleneksel eril mimarlık üretimine yaratıcı bir eleştiri. *TMMOB Mimarlar Odası Ankara Şubesi: Dosya 42*, 5-18.

Yürekli, İpek, Yürekli, Hülya, (2004). Mimari tasarım eğitiminde enformellik, *İTÜ Dergisi, Mimarlık Planlama Tasarım Dergisi,* Cilt 3, Sayı 1, 53-62.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Discussion on the Spatial Atmosphere: The Example of Samsun Süleyman Pasha Madrasah

Hande ASAR [1]*

ORCID 1: 0000-0003-3201-3204
[1]Assoc. Prof. Dr., Ondokuz Mayıs University, Faculty of Architecture, Department of Architecture, Samsun-Türkiye
hande.asar@omu.edu.tr

Abstract

The atmosphere of a space emerges from a range of factors, including architectural elements such as light, materiality, texture, color, and scale, as well as their interrelations and the role of the space in everyday life. In public settings, this atmosphere is also influenced by the space's relationship to the city and its integration within the historical fabric. Spatial atmosphere is thus contingent on both architectural design and the perceptions of users, requiring an understanding of its layered and complex nature. Given the openness of public spaces to diverse users, perceptions within them inevitably vary. The Samsun Süleyman Pasha Madrasah, which continues to function as a public space, was selected as the case study due to its significance within Samsun's historical fabric and daily life. The study aims to advance the discussion of spatial atmosphere by examining its formation through a conceptual framework. The distinctiveness of this study lies in addressing atmosphere at the intersection of historical fabric and everyday life. Ultimately, the study evaluates the interrelated layers that contribute to the production of spatial atmosphere.

Keywords: Samsun Süleyman Pasha Madrasah, spatial atmosphere, spatial perception.

1. Introduction

When engaging in a discussion on spatial atmosphere, it is essential to acknowledge that our modes of perceiving and experiencing space are also integral to the discourse. In this context, the act of being physically present in a space and transforming everything that occurs during that experience- including all physical realities and variables- into a perceptual act is made possible through the activation and interrelation of all our senses. This interplay gives rise to the processes of perception, sensation, and experience. With the affective responses shaped by these processes- which vary from person to person- we can begin to address the phenomenon referred to as spatial atmosphere. Although the experiential aspect of atmosphere may differ for everyone, it is also necessary to consider the physical elements that constitute spatial atmosphere, as these often exhibit shared characteristics across individuals. Accordingly, this study approaches spatial atmosphere through architectural design elements such as light, material/texture, color, and scale, as well as the relationships among these elements, in addition to factors such as the location of the space within the urban fabric, its relationship with the city in public contexts, and its position within the historical texture. For this purpose, a case study has been selected, and the concept of spatial atmosphere is examined through the structural and public characteristics of the chosen example.

Nevertheless, before addressing the concept of spatial atmosphere, it would be beneficial to explore the theoretical underpinnings of the notion of atmosphere. "Professor Gernot Böhme is one of the pioneering thinkers in the philosophy of atmospheres, along with Herman Schmitz" (Pallasmaa, 2014: 233). Due to its variability, the concept of atmosphere often appears as an ambiguous *thing*. Although Böhme adopts a similar approach, he argues that the meaning of the concept is not, in fact, unclear, and continues his argument as follows: "It is difficult, owing to the peculiar intermediary position of the phenomenon between subject and object, to define the status of atmospheres and thereby render discussion of atmospheres a legitimate concept.

However, in advancing the term atmosphere as a basic concept of a new aesthetic, it is not necessary to provide original evidence for its legitimacy because Hermann Schmitz' philosophy of the body already provides an elaboration of the term atmosphere" (Böhme, 2017: 19). The body philosophy approach mentioned here is related to everyday experiences in Schmitz's approach, that is, "(…) the experience of a tense atmosphere in a room, the oppressive mood before a thunderstorm, or the serene atmosphere of a garden" (Böhme, 2017: 20). What becomes prominent in these statements are the emotions. The affective responses that emerge through one's interaction with a spatial environment can provide a basis for discussing the atmosphere of that space. Nevertheless, making definitive claims in this regard remains challenging. The atmosphere of a given space may vary significantly depending on the temporal context, situational conditions, and narrative frameworks in which it is experienced. Thus, the same architectural setting may elicit different sensory and emotional responses, leading to a multiplicity of atmospheric readings. "Atmospheres are always spatially 'unbounded, poured out and placeless, that is, not locatable', they are moving emotional powers, spatial carriers of moods" (Böhme, 2017: 20). Because of that "Atmosphere can only become a concept, however, if we succeed in accounting for the peculiar intermediary Status of atmospheres between subject and object" (Böhme, 2013).

The concept of atmosphere can be discussed through the relationship established between the surrounding environment/place/space and bodily experience. In this regard, atmosphere is inherently related to space and, by extension, to architectural thought. The atmosphere of space holds a significant place within architectural theory and literature. Various scholars and practitioners can be mentioned who engage with this concept and shape their architectural practices with attention to the notion of spatial atmosphere. In this context, for instance, Zumthor addresses his work *Atmospheres* (2006), written around the question 'What really creates an architectural atmosphere?', in nine plus three sections, articulating the design process through a form of self-observation and by engaging with various concepts such as material, proportion, light, and poetics. Another prominent figure in this field, Pallasmaa, approaches the concept of atmosphere as follows: "Atmosphere is similarly an exchange between material or existent properties of the place and the immaterial realm of human perception and imagination. Yet, they are not physical 'things' or facts, as they are human experiential 'creations'" (Pallasmaa, 2014: 232). Böhme (2017: 20) expresses the close relationship between the concept of atmosphere and experience as follows: "For atmospheres are obviously what is experienced in the bodily presence of humans and things, or in spaces." Accordingly, the concept of atmosphere is intrinsically linked—either explicitly or implicitly—to spatial knowledge. In architectural discourse, the notion of spatial atmosphere necessitates the corporeal presence of the subject within the environment, rendering embodied experience a fundamental aspect of spatial perception. Because "Atmosphere or ambience is an epic experiential dimension or prediction, as we automatically read behavioral and social aspects- either existent, potential or imaginary- into the atmospheric image" (Pallasmaa, 2016).

Regardless of our awareness, the atmosphere of a space is an integral part of our lived experience, and discussing this phenomenon involves consideration of various factors and relational dynamics. Within this framework, the concepts of perception and sensation are crucial for critically engaging with and understanding the spatial atmosphere. Indeed, perception, defined as the transfer of the objective world to subjective consciousness through the senses (Hançerlioğlu, 1976) and described as a conscious sensory experience (Goldstein, 2010), is a cognitive and experiential process. Alongside this process, the topics of perception,

sensation, spatial perception, and spatial atmosphere can be discussed in an interrelated manner. As Pallasmaa also articulates: "… I lend my emotions and associations to the space, and the space, in turn, lends me its aura that stimulates and liberates my perceptions and thoughts' (Pallasmaa, 2016, p. 14). Within the context of this reciprocal relationship, both spatial perception and the discussion of spatial atmosphere emerge as "(...) a personal experience that varies according to the individual experiencing the space" (Asar, 2023).

Due to its multidimensional nature, the concept of spatial atmosphere can be discussed in various ways; within the scope of this study, it is primarily examined through the concepts of light, material/texture, color, and scale- elements that both constitute an architectural space and act as triggers for perception and sensation in the context of spatial atmosphere. Furthermore, since the selected case study building functions as a public space, the concept of publicness is employed to discuss the building's spatial atmosphere, drawing upon factors such as its position within the urban fabric, its historical development, and the everyday life- public space relationships contained within the building.

The case study selected for this research is the Süleyman Pasha Madrasah in Samsun, chosen due to its accommodation of diverse user profiles and its integration into everyday urban life. "Located near Saathane Square in the Kale Neighborhood, the Süleyman Pasha Madrasah is a significant building within the historical fabric of the city. Constructed in 1813, it is a two-story building made of rubble brick, shaped like a horseshoe, enclosed on three sides with a courtyard in the center. The entrance to the courtyard faces the Madrasah Mosque, with which the building forms a cohesive ensemble. Two sides of the courtyard are arcaded, and shops are situated within these arcades. The building, endowed by the Süleyman Pasha foundation, was once used as the Regional Directorate of Foundations building and later restored and converted into a business center" (Yılmaz & Gül, 2018). Today, the building functions as a cultural center.

The building, located in the historic center of the city, is the subject of this study due to its continued use within everyday life today and its inclusion of various layers that allow for a nuanced exploration of spatial atmosphere. Moreover, it is argued that the building is well-suited to address the central research question of this study: "How can the spatial atmosphere of a historic building, still in active use within contemporary urban life, be analyzed, and to what extent can this analysis inform our understanding of its publicness?" This study is unique in that it attempts to discuss spatial atmosphere at the intersection of historical fabric and everyday life.

2. Materials and Methods

The methodology of this study is based on qualitative research, incorporating phenomenological reading and spatial analysis. For this purpose, the Süleyman Pasha Madrasah in Samsun (Figure 1), considered one of the significant examples within the urban fabric of Samsun in terms of its structural language and public characteristics, was selected as the case study. The building was chosen not only because it is a part of the historical texture, but also due to its location in a key area of contemporary urban life. Therefore, it is considered to have the potential to reveal aspects of the spatial atmosphere on both structural and public scales. In this context, keywords derived from the literature on spatial atmosphere were transformed into a diagram (Figure 2), which was then used to conduct a spatial analysis of the selected building. The keywords are categorized into two main groups: in terms of structural features, they include light, material/texture- color, and scale; while in terms of public characteristics, they involve

the building's position within the urban fabric, its historical development process, and the relationship between everyday life and public space embedded in the building.

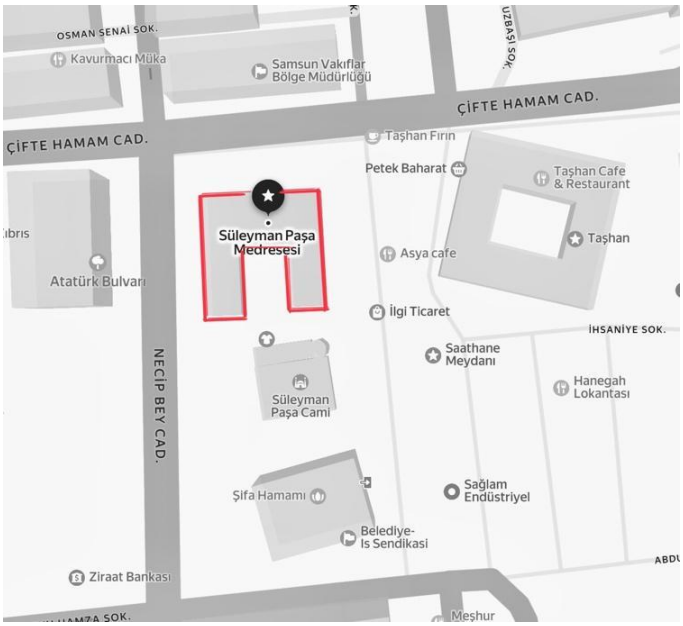


Figure 1. The location of Samsun Süleyman Pasha Madrasah in the city (Image produced from Yandex Maps)

The Samsun Süleyman Pasha Madrasah, which constitutes the material and case study of this research, belongs to the Hazinedarzade Süleyman Pasha Foundation. Located in Samsun's Saathane Square, at the corner of Şifa Bath and Taşhan, the courtyard of the building faces the entrance of the Süleyman Pasha Mosque. "The foundation date of the building is 1813. It is a two-storey structure with a horseshoe-shaped plan, constructed from load-bearing brick masonry" (URL- 1).

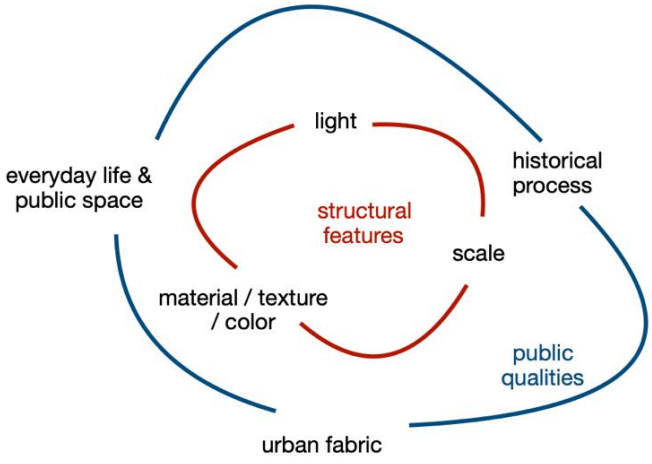


Figure 2. Spatial analysis diagram

The general information obtained about the Samsun Süleyman Pasha Madrasah is as follows: "It is known that, following the Great Samsun Fire of 1869, the original architectural configuration of the madrasah underwent significant changes and was reconstructed. (…) The building was used as a madrasah until 1914, and between 1914 and 1928, it was repurposed in

ways that did not align with its original function- first as a hotel, then as a coffeehouse *(kahvehane)*. After 1974, the building was used for a period by the Regional Directorate of Foundations and later functioned as a commercial office building. To this day, it has survived with functions that are inconsistent with its original design" (URL- 2).

"Situated within the scope of the Saathane Square Urban Renewal Project, the Süleyman Pasha Madrasah and Mosque underwent a comprehensive three-year restoration process initiated in 2016 by the Samsun Regional Directorate of Foundations. Upon completion of the restoration, the property was transferred to the administration of the Samsun Metropolitan Municipality. (…) As a result of this adaptive reuse initiative, the historic Hazinedarzâde Süleyman Pasha Madrasah- currently under the jurisdiction of the municipality- was repurposed to function as a 'Cultural House'" (URL-3) (Figure 3).



Figure 3. Samsun Süleyman Pasha Madrasah (right) and Mosque (left)

Currently functioning as a Cultural House, the building's courtyard plays a particularly significant role in discussions surrounding public space. Accordingly, the Süleyman Pasha Madrasah was chosen as the focus of this study and critically examined through the lens of spatial atmosphere.

3. Findings and Discussion

A spatial reading based on the current state of the Samsun Süleyman Pasha Madrasah has enabled a range of inferences regarding its spatial atmosphere, considered through both its structural and public attributes.

In terms of the structural element of light, the windows and their forms can be said to evoke a sense of being within a historical building, while also enhancing the visual relationship established with the surrounding historical context. The interplay of natural and artificial lighting elements further reinforces a sense of nostalgia.

When considering material/texture and color- integral and interrelated elements of any building- it can be observed that the tactile qualities of the building have become somewhat

limited, partly because of various restoration interventions. The use of white paint on both the interior and exterior façades has introduced a sterile aesthetic, slightly diminishing the historical character that the building's formal qualities would otherwise convey. On the other hand, the use of wooden materials on parts of the interior flooring, ceiling finishes, and window frames adds warmth to the space, contributing to the development of a distinctive spatial atmosphere. Similarly, movable interior elements such as wooden cabinets and patterned carpets further enhance this atmosphere (Figure 4).

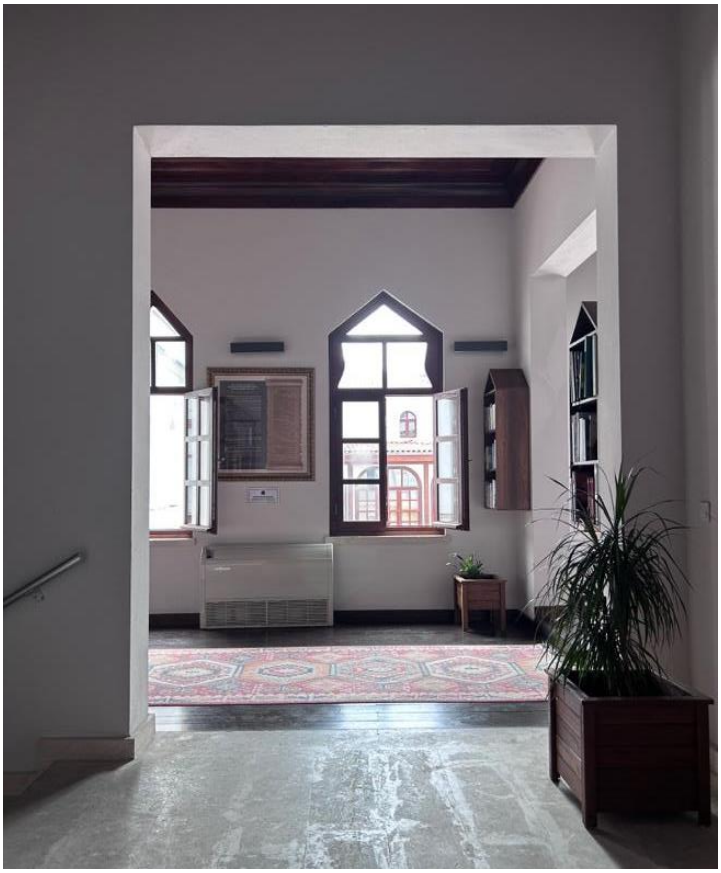


Figure 4. An example from the interior

When considering the concept of scale- the final structural element addressed in this study- the building can be regarded as a strong example of human-scaled architecture, in terms of its overall size, spatial subdivisions, and urban positioning. In particular, the courtyard element, which reinforces the spatial organization of the two-winged structure, along with the ornamental pool located at its center, contributes to a sense of human scale both formally and functionally (Figure 5).



Figure 5. Examples of the building's courtyard layout

The discussion on the public characteristics of the building- addressed as another dimension of spatial atmosphere- can also be interpreted because of the interaction between the structural features and the user. In fact, the possibility of initiating a discourse on publicness is closely related to how the building continues to be inhabited and experienced under present-day conditions. The most actively *lived* part of the building, which caters to a diverse range of users, is its courtyard. In the madrasah, which follows a U-shaped plan typology, a courtyard has been created at the center, capitalizing on the spatial potential of the layout, and an octagonal ornamental pool has been placed at its center.

The overhangs on the right and left wings of the building currently serve units functioning as tea houses, while the edges of the ornamental pool are also used for the same purpose. Due to the high intensity of use and the lack of greenery, the space faces issues of thermal discomfort, which have been partially mitigated through the installation of additional tent structures. However, these elements- being neither site-specific nor architecturally integrated- detract from the holistic spatial impact and weaken the atmosphere of the space. On the other hand, in the semi-open area near the entrance, formed by projecting elements and supported with columns, such discomforts are not observed (Figure 5).

From the perspective of its public characteristics, the building's position within the urban fabric can be considered highly significant. Although located in the historical core of Samsun, the design lacks an inviting entrance that would draw users inward, rendering the building simultaneously visible and concealed. Moreover, its spatial orientation directly across from the Süleyman Pasha Mosque contributes to the perception- particularly by those unfamiliar with the madrasah- that it is a part of the mosque complex.

The madrasah building has undergone numerous functional changes and structural interventions/restoration processes from past to present. Since its foundation date in the early 19th century, it has been affected by various disasters such as earthquakes and fires, and its function has shifted over time in response to changing social and demographic dynamics- serving at different points as a hotel and later a coffeehouse. Today, although officially functioning as a Cultural House under the authority of the Samsun Metropolitan Municipality, the courtyard continues to operate informally as a tea house.

This courtyard, primarily catering to middle-aged and older male users, becomes particularly active during prayer times. As a result, the public use of the space tends to be gender-exclusive, creating a male-dominated environment. Consequently, in terms of both usage patterns and user

profile, the building presents several limitations regarding the relationship between everyday life and public space. This condition, by reinforcing a patriarchal dynamic in the use of public space, also influences the spatial perception in a gendered manner.

Conclusion and Recommendations

When attempting to engage in a discussion about spatial atmosphere through an architectural building, it is essential to evaluate both the qualitative and quantitative characteristics that constitute that space. Elements such as light, material, texture, color, and scale- components that both shape the design process and influence spatial perception- can serve as tools for conducting an architectural space analysis through the lens of atmosphere. However, analyzing a building in isolation requires detaching it from its context. Yet, architectural works derive meaning from the contexts in which they are situated. This contextual relationship also contributes to the nature of the atmosphere that a space possesses or is perceived to possess. Therefore, factors such as the fabric in which a building is embedded, its historical trajectory, its role within everyday life, and the kinds of publicness it generates become significant. In this regard, the present study evaluates the Süleyman Pasha Madrasah in Samsun as a case study within the framework of these concepts.

Various inferences can be drawn from the spatial analysis of the building. While the formal language of the windows- as sources of natural light- creates a positive effect, the sterilized appearance resulting from successive restorations has diminished the impact of material and texture. Nevertheless, it can be observed that this effect still manifests in certain parts of the interior space. On the other hand, the courtyard, formed because of the building's U-shaped plan and its spatial organization, contributes to the building's isolation from the broader urban context. Moreover, the proportions employed in the spatial design render the building human scaled.

The forms of publicness that the building both benefits from and generates are also significant in the context of spatial atmosphere. Located in the city center of Samsun (Saathane Square) and surrounded by historical buildings, the Süleyman Pasha Madrasah and Süleyman Pasha Mosque face each other with their entrances, establishing a relationship with the square while maintaining a degree of enclosure. This spatial configuration has influenced the general user profile, transforming the courtyard- particularly after prayer times- into a male-dominated public space where men gather and use the area as a teahouse. Furthermore, the lack of greenery, which is a crucial environmental factor, has had a negative impact on both the use and atmosphere of the space.

At the conclusion of the study, it can be stated that the Süleyman Pasha Madrasah reveals both positive and negative aspects of the spatial atmosphere in the context of structural and public factors. When discussing spatial atmosphere, the discourse typically focuses on the positive elements that create the atmosphere. However, identifying and critically addressing the negative aspects of a building- especially if it is a historic building, as in the case of this study- is important for ensuring its continued use and transmission to future generations, as well as for allowing it to find a place within evolving social dynamics.

Thanks, and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All photographs used in this study were taken by the author (August 2025).

References

Asar, H. (2023). Beden-Mekân İlişkisi aracılığıyla sıradışı bir deneyim alanına açılan mekânsal algı. *Tykhe Sanat ve Tasarım Dergisi, 8*(14), 164-174., Doi: 10.55004/tykhe.1247172

Böhme, G. (2013). *Atmosphere as the fundamental concept of a new aesthetics.* In: Atmosphäre. Essays zur Neuen Ästhetik, Frankfurt/M, Suhrkamp, (Extended edition).

Böhme, G. (2017). *Atmospheric architectures, the aesthetics of felt spaces.* (Ed. & Trans., A.-Chr. Engels-Schwarzpaul). Bloomsbury Academic.

Goldstein, E. B. (2010). Sensation and perception (8th edition). Wadsworth, Cengage Learning.

Hançerlioğlu, O. (1976). Felsefe ansiklopedisi: Kavramlar ve akımlar- Cilt 1 (A-D). Remzi Kitabevi.

Pallasmaa, J. (2014). Space, place and atmosphere. Emotion and peripheral perception in architectural experience. *Lebenswelt: Aesthetics and Philosophy of Experience, 4(*1). 10.13130/2240-9599/4202

Pallasmaa, J. (2016). Tenin gözleri: Mimarlık ve duyular. (A.U. Kılıç Çev.) (3. Baskı). Yem Yayın.

URL 1: https://samsun.ktb.gov.tr/TR-59813/kultur---el-sanatlari-2.html (Accessed on 12.9.2025)

URL 2: https://www.erhanuludag.com/samsun-hazinedarzade-suleyman-pasa-medresesi-ve-camii/ (Accessed on 12.9.2025)

URL 3: https://www.iha.com.tr/samsun-haberleri/medrese-binasi-kultur-evi-olarak-hizmet-verecek-41186439 (Accessed on 12.9.2025)

Yılmaz, Ali & Gül, Seyfullah (2018). samsun şehrinde tarihî yapı mirası ve şehirsel koruma. *Journal of Ottoman Legacy Studies (JOLS),* Volume 5, Issue 13, November 2018, pp. 49-67. DOI: 10.17822/omad.2018.110

Zumthor, P. (2006). *Atmospheres: Architectural environments- surrounding objects.* Birkhäuser.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Thematic Review of Machine learning techniquess in Landscape Planning Processes

Aslı İlayda TURGUT [1*]

ORCID 1: 0000-0001-5829-2403
[1]PhD. Candidate., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
d2240126001@ogr.sdu.edu.tr (Responsible Author)

Murat AKTEN [2]

ORCID 2: 0000-0003-4255-926X
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
muratakten@sdu.edu.tr

Abstract

Landscape planning is a multidisciplinary field that addresses natural resource conservation, climate change mitigation, disaster risk management, and the improvement of urban life quality. The growing volume of spatial data and increasing complexity of planning processes require advanced analytical approaches beyond conventional methods. In this context, machine learning has gained significant relevance due to its strong capabilities in prediction, classification, and pattern recognition.

This study provides a comprehensive literature review on the applications of machine learning in landscape planning, structured within a thematic framework. Key themes include green space suitability assessment, urban heat island modeling, land use and land cover classification, ecological network and species distribution modeling, integration with decision support systems, visual perception analysis, disaster and climate risk-based planning, and time-series projections of landscape change. Across these themes, major data sources—including remote sensing, geographic information systems, environmental, and socio-demographic datasets—are examined. Commonly applied machine learning algorithms such as random forest, support vector machines, and artificial neural networks are reviewed with an emphasis on their contributions to planning workflows.

The study identifies emerging methodological trends, current limitations, and potential opportunities for future research, highlighting the transformative role of machine learning in enhancing evidence-based decision-making in landscape planning.

Keywords: Landscape planning, machine learning, geographic information systems (GIS), remote sensing, land use and land cover (LULC)

1. Introduction

Landscape planning is an interdisciplinary field that encompasses multifaceted objectives such as the conservation of natural resources, mitigation of climate change impacts, management of disaster risks, and enhancement of urban quality of life. This discipline aims not only to organize the physical environment spatially but also to develop strategic decisions that safeguard the sustainability of ecosystem services, promote societal well-being, and strengthen long-term environmental resilience (Lumeng & Jianguo, 2022).

The rapid transformation of urban and rural areas, increased pressure on natural resources, the ecological threshold stress caused by unplanned land use, and growing uncertainties driven by climate change have rendered landscape planning a far more complex and data-intensive process compared to the past. Consequently, contemporary landscape planning practices require dynamic approaches built on multi-criteria decision frameworks that evaluate spatial,

ecological, climatic, socio-economic, and cultural components simultaneously, while also adapting to evolving environmental conditions (Dong et al., 2022).

Within this process, planners are expected not only to make design or land-use decisions but also to develop decision-making frameworks capable of anticipating environmental risks, preserving ecological connectivity, addressing community needs, and assessing future change scenarios.

The widespread adoption of remote sensing technologies, advances in geographic information systems, the diversification of sensor networks and environmental monitoring systems, along with advances in machine learning techniques have accelerated the production of large volumes of spatial data. Satellite imagery, LiDAR data, climate models, topographic surface analyses, land-cover classifications, population and socio-economic indicators, and even geotagged social media posts—once considered unconventional—are now integrated into planning processes (Liu et al., 2021; Yao, 2024). However, as the volume of this data ecosystem expands, its structure becomes increasingly heterogeneous; data layers vary in scale and temporal resolution and may contain noise, missing values, or inconsistencies, making integrated analysis imperative.

Traditional statistical methods, rule-based analyses, and manual weighting approaches are inadequate for modeling these multivariate, nonlinear, and dynamic structures and often perform poorly in detecting complex spatial patterns, change tendencies, and latent relationships among variables. These limitations not only result in reduced analytical capacity but also diminish the generalizability of planning decisions, hinder scalable analyses, and weaken the accuracy of spatial predictions (Neuendorf et al., 2018).

This complexity in data and analysis has significantly increased the need for more advanced, adaptive, and data-driven analytical tools within the planning discipline. As illustrated in Figure 1, machine learning stands out due to its ability to extract meaningful patterns from large and high-dimensional datasets, model nonlinear relationships between variables, learn spatial and temporal trends, and generate predictive insights from historical data (Lyons et al., 2018; Yang et al., 2025). Unlike traditional analytical approaches, machine learning models uncover the internal structure of the data without relying on predefined assumptions and can represent the dynamics of complex ecological, environmental, and urban systems within a more flexible framework (Liu et al., 2021; Shao et al., 2025).

Supervised learning, unsupervised learning, and deep learning techniques, in particular, provide high accuracy in tasks such as classification, regression, clustering, and pattern recognition, rendering decision-making processes more measurable, repeatable, and scalable. In this context, machine learning is regarded not merely as a technical analytical tool but also as a new planning paradigm that transforms intuitive decision-making processes into data-driven planning mechanisms.

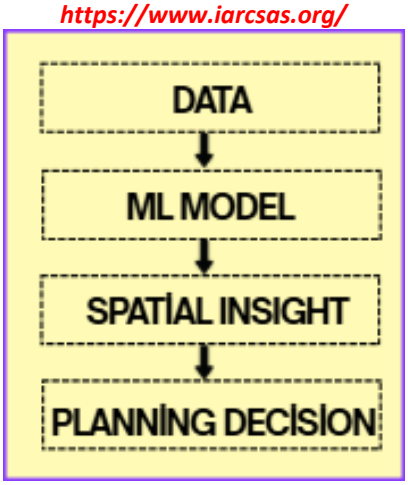


Figure 1. The Functioning of Machine learning techniquess in the Landscape Planning Decision-Making Process

In the context of landscape planning, machine learning stands out particularly through three core analytical capabilities: (1) classification, (2) prediction, and (3) pattern recognition. Classification models are used in tasks such as the automated production of land-use and land-cover maps, the differentiation of habitat categories, and the identification of landscape elements (Ouma et al., 2023; Shao et al., 2025). Prediction models, on the other hand, play a critical role in advanced analyses such as determining the spatial distribution of the urban heat island effect, generating temperature projections, calculating green space suitability potential, and modeling temporal trends of environmental variables (Tanoori et al., 2024). Pattern recognition and connectivity analysis capabilities generate strategic outputs for planning, including the evaluation of ecological network continuity, identification of biodiversity corridors, monitoring of landscape fragmentation dynamics, and detection of spatial change tendencies (Da Cruz et al., 2021). These competencies enable not only the analysis of current conditions but also the modeling of future scenarios and the pre-assessment of environmental impacts of planning decisions (Gharaibeh et al., 2023). Although the potential of machine learning in landscape planning is increasingly acknowledged, a review of the existing literature reveals that most studies focus on specific application domains, vary in methodological choices and evaluation metrics, and are not systematically integrated into a holistic planning framework. A significant portion of research concentrates on technical performance indicators (accuracy, acceptable error rates, model efficiency, etc.), while critical dimensions such as practicality within planning contexts, interpretability, integration into decision-making processes, and alignment with stakeholder needs are addressed more limitedly (Chaturvedi & Vries, 2021).

Particularly underexplored issues include how model outputs are translated into planning decisions, how social or ecological inequalities are represented within models, the sensitivity of analytical data to local contexts, and how model results can be utilized in planning practice through transparent and accountable mechanisms. Moreover, the limited number of comparative studies examining methodological overlaps or differences across themes makes it difficult to evaluate machine learning's contributions to landscape planning from a systematic perspective.

This study aims to systematically examine the use of machine learning techniquess in landscape planning processes within a thematic framework and to evaluate methodological trends, strengths, and research gaps in the literature from a planning perspective. Accordingly, the

review is structured around eight key themes that have become prominent in landscape planning: (1) green space suitability analyses, (2) urban heat island modeling, (3) land use and land cover classifications, (4) ecological network and species distribution modeling, (5) integration with decision support systems, (6) user perception and visual landscape analyses, (7) disaster- and climate risk–oriented planning, and (8) temporal landscape change and future projections. Within the scope of these themes, the study evaluates the data sources employed, the machine learning algorithms preferred, and the contributions these algorithms provide to planning processes; it also discusses critical shortcomings such as model interpretability, representation of social variables, scale compatibility, and the transferability of model outcomes to planning decisions. Thus, the research aims to offer a conceptual framework at the intersection of landscape planning and machine learning, while also providing a guiding evaluation for future studies and practical applications.

2. Materials and Methods

This study is a systematic and thematic literature review examining the use of machine learning techniquess within landscape planning processes. The aim of the research is to explain how machine learning techniques are integrated into the landscape planning discipline, to analyze the types of data and algorithms used, and to reveal trends in the literature through comparative evaluation. In this context, the study does not approach machine learning merely as a technical analytical tool; rather, it evaluates its practical value within planning, its influence on decision-making processes, and the ways in which the spatial outputs produced are translated into planning decisions. Accordingly, the literature has been examined within a framework based on analytical processing steps and the transferability of model outputs to planning decisions.

The literature search was conducted to identify studies exploring the relationship between machine learning and landscape planning. Internationally indexed databases such as Web of Science, Scopus, ScienceDirect, Google Scholar, and SpringerLink were used. During the search, keywords representing both machine learning and landscape planning processes were combined: “machine learning”, “landscape planning”, “remote sensing”, “urban heat island”, “land use/land cover classification”, “green space suitability”, “ecological connectivity”, “species distribution modeling”, and “spatial decision support”. These keywords were combined using Boolean operators (AND–OR), and studies published between 2015 and 2025 were included in the scope of analysis. However, it was observed that studies on the topic increased significantly after 2018; therefore, the review focused primarily on publications from 2018 onward. Statistical studies not involving machine learning, studies that used imagery solely for image processing without producing planning-relevant outputs, and publications without full-text access were excluded. As a result of this screening process, 112 studies suitable for thematic evaluation were identified and compiled into a dataset for analysis.

The studies obtained from the search were evaluated based on specific criteria, and inclusion and exclusion rules were established for determining which publications to analyze. The inclusion criteria were as follows: (i) application of machine learning techniquess, (ii) production of a spatial output directly relevant to landscape planning, (iii) utilization of remote sensing, GIS, environmental variables, or socio-demographic data, and (iv) publication in a peer-reviewed scientific outlet. Studies lacking contributions to landscape planning practice or focusing solely on algorithm optimization without incorporating a spatial/planning context were excluded. Additionally, studies in which model training was conducted but the transfer of outputs to planning decisions was not explained, as well as deep learning studies exclusively

devoted to image processing, were removed from the scope. This approach ensured that the review was limited to studies with practical application value for landscape planning. Following the evaluation, 76 studies that met all criteria were included in the thematic classification and analysis process. The studies included in the review were evaluated using content analysis and categorized into eight themes based on the purpose of machine learning applications within landscape planning processes. These themes are: (1) green space suitability analyses, (2) urban heat island modeling, (3) land use and land cover classifications, (4) ecological network and species distribution modeling, (5) integration with decision support systems, (6) user perception and visual landscape analyses, (7) disaster- and climate risk–oriented planning models, and (8) temporal landscape change projections.

During the thematic classification, each study was evaluated according to: (i) the types of data used (remote sensing, topography, socio-demographic data, etc.), (ii) the machine learning algorithms applied (RF, SVM, ANN, CNN, MaxEnt, etc.), and (iii) the role of the model output within the planning context (prediction, classification, pattern analysis, decision support). In this way, the planning function addressed by each study was identified and positioned under the appropriate theme. This approach makes the diversity of machine learning applications in landscape planning visible and provides a comparable structure for understanding how these methods are integrated into decision-making processes.

In this study, the literature was interpreted through a four-stage analytical framework that represents the functional workflow of machine learning in landscape planning. The first stage is data acquisition, which includes the use of multi-source data such as remote sensing, GIS layers, topographic information, climatic variables, and socio-demographic inputs. The second stage is machine learning modeling**,** in which algorithms performing classification, regression, or pattern recognition (e.g., Random Forest, SVM, ANN, CNN, MaxEnt, or LSTM) are selected based on the study's objectives. The third stage is transformation of model outputs into spatial insights, where planning-relevant layers such as suitability maps, temperature distribution surfaces, land-cover classes, risk zones, or habitat connectivity patterns are generated. The final stage involves translating these spatial insights into planning decisions**,** including prioritization of areas, scenario evaluation, identification of intervention zones, corridor planning, or policy development. This four-stage structure provided a consistent methodological basis for evaluating all studies and enabled a comparable analysis of each study's contribution to the planning process.

In the evaluation of the studies, not only the performance of the applied algorithms was considered, but also the transferability of the model to planning processes, the spatial representational power of the data sources used, the applicability of model outputs in decision-making contexts, and the reproducibility of the methods. Thus, the analysis was conducted from a perspective that prioritizes the practical relevance of the methods in landscape planning and their capacity to guide planning decisions, rather than simply focusing on technical accuracy.

However, it is acknowledged that limiting the review to accessible and peer-reviewed sources may have excluded certain local applications or reports, constituting a potential limitation. Additionally, the lack of standardization across studies in terms of data scales, sample area sizes, accuracy assessment metrics, and performance reporting formats restricted the possibility of direct quantitative comparison. For this reason, the study focuses not on one-to-one model performance comparisons but rather on identifying methodological trends, usage patterns, and planning-oriented contributions.

2 Findings and Discussion

The literature reviewed in this study demonstrates that machine learning techniquess are increasingly providing a more holistic, data-driven, and predictive analytical framework within the discipline of landscape planning. With the diversification of spatial data produced at varying scales, analyzing the complex environmental dynamics encountered in planning has become increasingly difficult to address using traditional methods alone. As a result, machine-learning-based approaches are becoming essential tools for identifying multivariate relationships, revealing spatial patterns, and generating reliable future scenarios.

The findings indicate that these methods consistently deliver higher accuracy, stronger pattern recognition capacity, and more interpretable outputs across various sub-themes of landscape planning—from ecological assessments and land-use analyses to climate-related risks and user perception studies. In this regard, the contribution of machine learning to planning processes extends far beyond technical enhancement; it establishes a new methodological plane that enables environmental decision-making to proceed in a more evidence-based, comparable, and scenario-oriented manner.

3.1. Green Space Suitability Analyses

Studies evaluated under this theme show that machine learning techniquess are becoming increasingly common and strategically important tools in the planning of urban green infrastructure. Most of the reviewed publications combine remote sensing data (NDVI, NDBI, albedo), topographic variables (slope, aspect, elevation), and socio-demographic indicators (population density, accessibility, indicators of social inequality) to determine green space potential (Gharaibeh et al., 2023). This multi-layered data approach enables machine learning models to offer greater discriminatory power compared with traditional multi-criteria evaluation methods.

Random Forest (RF) was identified as the most widely used algorithm within this theme; it is particularly preferred due to its high error tolerance, its ability to clearly reveal variable importance, and its capacity to model complex relationships. RF-generated suitability surfaces were reported to produce more stable results compared with methods such as SVM and ANN. Some studies employed hybrid models such as RF–AHP or ANN–fuzzy logic, noting that integrating multi-criteria decision-making structures with machine learning improves the sensitivity of planning outputs (Feng, 2024).

Findings indicate that machine learning–based suitability analyses perform strongly in the following areas (Gharaibeh et al., 2023; Feng, 2024):

• Prioritizing green space needs in areas heavily affected by the urban heat island effect

• Clearly identifying gaps in green infrastructure

• Making inequalities visible in social-justice-oriented green space accessibility analyses

• Enabling the comparison of spatial outcomes associated with different green infrastructure scenarios

A common limitation observed in the studies is that suitability maps are often treated primarily as model outputs, while the translation of these outputs into urban governance, policy development, or spatial planning decisions is discussed only to a limited extent. Nevertheless,

machine learning emerges as one of the most functional themes in strengthening evidence-based decision-making in green space planning.

3.2. Urban Heat Island Modeling

Most urban heat island (UHI) studies focus on estimating land surface temperature (LST), producing temperature distribution maps, and modeling the influence of urban morphology on thermal behavior. Landsat and MODIS datasets are the primary data sources, while variables such as building density, building height, impervious surface ratio, shading effects, and vegetation density are frequently used (Modjrian, 2022).

Within this theme, ensemble models (RF, XGBoost, Gradient Boosting) stand out prominently. Random Forest (RF) demonstrates high performance particularly in LST prediction, while several studies show that CNN-based deep learning models capture morphological structural features more effectively. Deep learning approaches have been especially successful in large metropolitan areas with heterogeneous urban fabrics (Zhou et al., 2025).

Findings reveal that machine-learning-based UHI models provide the following contributions (Modjrian, 2022; Ullah et al., 2025):

• High-accuracy LST predictions, with RF and CNN-based models performing particularly well

• Quantitative assessment of ecological cooling effects, highlighting NDVI as the strongest explanatory variable

• Modeling the impact of urban form components (H/W ratio, building density) on temperature

• Generating forward-looking temperature scenarios using machine learning, providing strong support for risk-oriented planning

Studies also indicate that UHI models can be directly applied in policy-making—for example, machine-learning-based scenarios estimating the cooling effects of green roofs, or LST thresholds used to identify heat-risk zones that can inform regulatory frameworks. However, many studies remain limited to the “temperature map production” stage, with relatively little emphasis on translating these outputs into adaptation strategies within planning processes.

3.3. Land Use and Land Cover Classifications

Land Use and Land Cover (LULC) classification emerges as the most common and most mature application area of machine learning within the reviewed literature. Studies in this theme frequently utilize Sentinel-2, Landsat, and WorldView imagery, while spectral bands, texture indices (GLCM), topographic variables, and NDVI constitute the most frequently used inputs (Modjrian, 2022).

Random Forest (RF) and Support Vector Machines (SVM) remain the strongest models in terms of classification accuracy. However, especially in studies published after 2020, the use of deep-learning-based models such as CNN, U-Net, and SegNet has significantly increased. These models have been shown to achieve high accuracy, particularly in urban areas where class boundaries are not clearly defined (Yashon Ouma et al., 2023).

The findings can be summarized as follows (Siddique et al., 2021):

• Machine-learning-based classification accuracies typically range between 85% and 95%, which generally meets the accuracy thresholds required by formal planning authorities.

• RF demonstrates strong performance across urban, agricultural, and natural land categories.

• The multi-purpose use of classification outputs in planning has increased—such as identifying ecologically sensitive areas, detecting land-use change, or supporting risk zoning.

• In temporal LULC series and landscape transformation studies, machine learning either complements or replaces classical models such as CA–Markov.

Limitations include a lack of standardization in classification accuracy reporting and the superficial treatment of data imbalance issues in many studies.

3.4. Ecological Network and Species Distribution Modeling

Studies under this theme focus on core components of ecological planning, such as corridor planning, habitat suitability analysis, and species distribution projections. MaxEnt is the most commonly used algorithm for species distribution modeling, while RF, BRT, and SVM are prominent in habitat suitability and landscape connectivity analyses (Modjrian, 2022). The findings highlight the following points (Mostafa et al., 2021):

• MaxEnt demonstrates stable performance even with small sample sizes, which is a major advantage for rare species.

• Using machine-learning-based suitability surfaces for identifying ecological corridors clarifies priority intervention zones against landscape fragmentation.

• Bioclimatic variables are the most influential factors in determining habitat suitability.

• The number of studies predicting habitat loss under future climate scenarios is increasing.

This theme represents one of the areas in which machine learning offers the most directly applicable outputs for conservation planning. However, only a small number of studies report that the generated corridor or suitability maps are validated through integration with on-site management practices.

3.5. Integration with Decision Support Systems

This theme represents one of the areas in which machine learning comes into closest contact with the planning process. The reviewed studies show that the integration of machine learning models with GIS-based spatial decision support systems (SDSS) is becoming increasingly widespread. The findings indicate the following (Koutra & Ioakimidis, 2023; Feng, 2024):

• The integration of machine learning and SDSS provides strong decision-making capacity, particularly in risk zoning, green infrastructure scenario development, and controlling urban growth.
• The combined use of machine learning with multi-criteria decision-making methods (AHP, ANP, TOPSIS) contributes to reducing dependence on subjective weighting in decision models.
• Studies report a significant increase in scenario generation speed when machine learning is incorporated.
• The integration offers automation opportunities that help compensate for human-resource limitations, especially in small municipalities.

A notable limitation is that many of these systems still remain at the prototype stage, and the number of real-world planning cases where they are fully integrated remains limited.

3.6. User Perception and Visual Landscape Analyses

This theme represents one of the few areas in which machine learning is integrated with social dimensions. The reviewed studies utilize street-level imagery, social media photographs, user surveys, and semantic segmentation data. CNN models stand out distinctly in visual analyses (Tian et al., 2021). The findings indicate the following (Wei et al., 2022):

• CNN-based models can automatically extract spatial aesthetic elements such as tree canopy, openness ratio, and building dominance.

• In user perception studies, RF and ANN successfully model multidimensional preference patterns derived from survey data.

• This theme provides direct feedback for policy areas such as walkability, visual quality, and satisfaction with urban open spaces.

These studies demonstrate the potential of machine learning to incorporate not only physical environmental factors but also user experience into planning processes. However, issues related to data privacy, representativeness, and sensitivity to social context remain insufficiently discussed in many studies.

3.7. Disaster- and Climate Risk–Oriented Planning Models

In studies modeling flood, landslide, wildfire, and drought risks, machine learning is used as a high-accuracy risk prediction tool. Topography, precipitation, soil type, LST, vegetation moisture, and anthropogenic pressure variables are commonly employed in this theme (Ullah et al., 2024; Toprak, 2025). The findings can be summarized as follows (He et al., 2021; Ullah et al., 2024):

• RF and XGBoost emerge as the strongest models for flood and landslide susceptibility mapping.

• In wildfire risk studies, NDVI, LST, and wind variables are the most influential predictors.

• Machine-learning-based risk maps provide more detailed zoning than traditional methods and help clarify intervention priorities.

• In some studies, combining climate projections with machine learning has enabled the generation of forward-looking vulnerability maps.

However, these outputs are often not directly incorporated into planning documents; integration of non-structural risk reduction strategies remains weak in the current literature.

3.8. Temporal Landscape Change and Future Projections

This theme focuses on modeling how landscapes change over time and how they are likely to transform in the future. LSTM, RF, Markov–machine learning hybrid models, and change detection algorithms are the most prominent approaches. The findings indicate the following (Biljecki & Ito, 2021; Ullah et al., 2024):

• LSTM-based models learn temporal patterns in time-series data more effectively than other algorithms.
• In urban growth projections, machine learning provides a more dynamic structure compared with CA–Markov models.

• Machine-learning-based models offer strong early-warning capabilities for processes such as agricultural land loss, forest conversion, and shoreline change.
• Future scenarios play a decisive role in planning land-use constraints and protected area designations.

A common limitation is that many studies lack comprehensive uncertainty analyses for their projection outputs.

4.Conclusion and Recommendations

This study demonstrates that machine learning provides a holistic framework that enhances both analytical accuracy and decision-making capacity across various thematic domains of landscape planning (Feng, 2024). The broad spectrum of applications—from green space suitability analyses and urban heat island modeling to ecological network assessments and disaster and climate risk analyses—shows that machine learning models can represent complex environmental relationships with high accuracy. In particular, ensemble-based machine learning techniquess and hybrid approaches offer predictive capabilities that exceed those of traditional analyses, owing to their capacity to capture nonlinear patterns and integrate multidimensional datasets (Biljecki & Ito, 2021).

These findings indicate that machine learning has evolved from a tool that merely evaluates existing conditions into an indispensable methodological foundation for future-oriented scenario generation, spatial prioritization, and the development of sustainable planning strategies. Future research that focuses on explainable artificial intelligence approaches—enabling more direct integration of model outputs into planning decisions—hybrid models that combine diverse data sources, and scenario-based studies centered on climate adaptation and ecological resilience will further strengthen the applicability of machine learning within landscape planning practice.

Thanks and Information Note

Ethics Committee approval was not required for the study. All authors contributed equally to the article

References

Amir Siddique, M.; Wang, Y.; Xu, N.; Ullah, N.; Zeng, P. (2021). The Spatiotemporal Implications of Urbanization for Urban Heat Islands in Beijing: A Predictive Approach Based on CA–Markov Modeling (2004–2050). *Remote Sens*, 13, 4697. https://doi.org/10.3390/ rs13224697

Biljecki, F., & Ito, K. (2021). Street view imagery in urban analytics and GIS: A review. *Landscape and Urban Planning*, *215*, 104217.

Chaturvedi, V., & de Vries, W. T. (2021). Machine learning algorithms for urban land use planning: A review. *Urban Science*, *5*(3), 68.

Da Cruz, R. B. C., de Castro Marins, K. R., & Kurokawa, F. A. (2021). Multicriteria methodological-rational model to evaluated urban areas: A case study of the São Paulo City/Brazil. *Sustainable Cities and Society*, *67*, 102718.

Dong, J., Jiang, H., Gu, T., Liu, Y. ve Peng, J. (2022). Sürdürülebilir peyzaj deseni: Mekânsal planlamaya hizmet eden bir peyzaj yaklaşımı. *Peyzaj Ekolojisi*, *37* (1), 31-42.

Feng, S. (2024). Implementation of Decision Support System for Ecological Environment Planning of Urban Green Space. *Ecological Chemistry and Engineering*, 31(2), 177-192.

Gharaibeh, A. A., Jaradat, M. A., & Kanaan, L. M. (2023). A machine learning framework for assessing urban growth of cities and suitability analysis. *Land*, *12*(1), 214.

He, Q., Jiang, Z., Wang, M., Liu, K. (2021). Landslide and Wildfire Susceptibility Assessment in Southeast Asia Using Ensemble Machine learning techniquess. *Remote Sens*. 2021, 13, 1572. https:// doi.org/10.3390/rs13081572

Koutra, S., Ioakimidis, C.S. (2023). Unveiling the Potential of Machine Learning Applications in Urban Planning Challenges. *Land,* 12, 83. https://doi.org/10.3390/ land12010083

Liu, X., Tvinnereim, E., Grimsrud, KM, Lindhjem, H., Velle, LG, Saure, HI ve Lee, H. (2021). Makine öğrenmesi yöntemine dayalı anket analizini kullanarak peyzaj tercihi heterojenliğinin açıklanması. *Landscape Research*, 46 (3), 417–434. https://doi.org/10.1080/01426397.2020.1867713

Lumeng, L. I. U., & Jianguo, W. U. (2022). Scenario analysis in urban ecosystem services research: Progress, prospects, and implications for urban planning and management. *Landscape and Urban Planning*, *224*, 104433.

Lyons, M. B., Keith, D. A., Phinn, S. R., Mason, T. J., & Elith, J. (2018). A comparison of resampling methods for remote sensing classification and accuracy assessment. *Remote Sensing of Environment*, *208*, 145-153.

Modjrian, N. S. (2022). Prediction of outdoor thermal comfort changes and uncovering mitigation strategies based on machine learning algorithm: a decision support tool for climate-sensitive design: a case study of Glasgow, UK.

Mostafa, E., Li, X., Sadek, M., Dossou, J.F. (2021). Monitoring and Forecasting of Urban Expansion Using Machine Learning-Based Techniques and Remotely Sensed Data: A Case Study of Gharbia Governorate, Egypt. *Remote Sens.* 13, 4498. https://doi.org/ 10.3390/rs13224498

Neuendorf, F., Von Haaren, C., & Albert, C. (2018). Assessing and coping with uncertainties in landscape planning: an overview. *Landscape Ecology*, *33*(6), 861-878.

Shao, Y., Ma, N., Chen, M., Zhang, C., & Cui, Y. (2025). Machine Learning in Landscape Architecture: A Comprehensive Review of Advancements, Applications, and Future Directions. *Buildings*, *15*(21), 3827.

Tanoori, G., Soltani, A., & Modiri, A. (2024). Machine learning for urban heat island (UHI) analysis: Predicting land surface temperature (LST) in urban environments. *Urban Climate*, *55*, 101962.

Tian, H., Han, Z., Xu, W., Liu, X., Qiu, W., & Li, W. (2021). Evolution of historical urban landscape with computer vision and machine learning: A case study of Berlin. J. *Digit. Landsc. Archit*, 6, 436-451.

Toprak, A. (2025). Integrating energy valley optimization with machine learning for flood susceptibility mapping in Kayseri, Türkiye. *Acta Geophysica*, 1-24.

Ullah, S., Khan, M., & Qiao, X. (2025). Evaluating the impact of urbanization patterns on LST and UHI effect in Afghanistan's Cities: a machine learning approach for sustainable urban planning: S. Ullah et al. *Environment, Development and Sustainability*, 1-42.

Wei, J., Yue, W., Li, M., & Gao, J. (2022). Mapping human perception of urban landscape from street-view images: A deep-learning approach. *International Journal of Applied Earth Observation and Geoinformation,* 112, 102886.

Yang, M., Zhuang, J. A., & Wang, M. (2025). Leveraging Recurrent Neural Networks for Lithology Identification and Chinese Rural Landscape Planning in Sustainable Design. *Sustainability*, *17*(7), 3078.

Yao, H., & Zhang, Y. (2024). Design of intelligent agricultural landscape planning and ecological balance control system based on remote sensing images. *International Food and Agribusiness Management Review*, *1*(aop), 1-20.

Yashon O. Ouma, Amantle Keitsile, Boipuso Nkwae, Phillimon Odirile, Ditiro Moalafhi & Jiaguo Qi (2023) Urban land-use classification using machine learning classifiers: comparative evaluation and post-classification multi-feature fusion approach, *European Journal of Remote Sensing*, 56:1, 2173659, DOI: 10.1080/22797254.2023.217365

Zhou, H., Wang, R., Hou, H., Xie, B., Hu, T. (2025). OptimizingUrban ThermalEnvironmentsThrough 2D/3DLandscapePatternAnalysis: A MachineLearning-DrivenApproach for the YangtzeRiverDeltaUrban Agglomeration. *Buildings*. 15, 2261. https://doi.org/10.3390/ buildings15132261

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Enhancing Urban Microclimate through a Digital Twin–Based Approach: The Case Study of Kaymakkapı Square, Isparta

Aslı İlayda TURGUT [1*]

ORCID 1: 0000-0001-5829-2403
[1]PhD. Candidate., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
d2240126001@ogr.sdu.edu.tr (Responsible Author)

Murat AKTEN [2]

ORCID 2: 0000-0003-4255-926X
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
muratakten@sdu.edu.tr

Abstract

This study aims to develop a digital twin–based approach for improving microclimatic conditions in small-scale urban areas. Kaymakkapı Square, located in Isparta, was selected as the case study area, and the effects of the existing green infrastructure on urban thermal comfort were examined. Using high-resolution orthophotos, tree crown areas were digitized, thereby quantitatively determining the current canopy cover ratio. Within the scope of scenario analyses, new afforestation interventions were proposed for the square, and the resulting changes in canopy cover ratio were identified. Subsequently, the potential effects of these changes on surface temperature were estimated using the "shading increase → temperature difference" coefficient defined in the literature.

The data obtained enabled a comparison between the current situation and the scenario outcomes through statistical analyses, maps, and tables, allowing both visual and numerical results to be jointly evaluated. The findings reveal that even small-scale design interventions can make significant contributions to microclimatic improvement. Moreover, digital twin–based approaches were shown to provide decision-makers with rapid, low-cost, and easily interpretable outputs. A key strength of this study lies in its ability to generate practical results through remote sensing and quantitative analyses without the need for field measurements. In this respect, the research offers an applicable, accessible, and replicable methodological framework for urban design processes and climate adaptation strategies.

In conclusion, this approach proposes a method that can be extended not only to Kaymakkapı Square but also to other urban areas of similar scale.

Keywords: Digital twin, microclimate, urban design, shading ratio, urban heat ısland, climate adaptation strategies

1. Introduction

As urbanization accelerates, the expansion of impervious surfaces and the reduction of natural areas produce a pronounced Urban Heat Island (UHI) effect on the urban climate. The Urban Heat Island phenomenon refers to metropolitan areas that are significantly warmer than their rural surroundings as a result of human activities. Studies conducted in Istanbul indicate that summer land surface temperatures range between 21–45 °C, with UHI intensity increasing particularly in densely built-up zones (Khorrami & Gündüz, 2017). The same study identified the NDVI value as the most influential determinant in the formation of heat islands.

International research has examined the microclimatic effects of green spaces across different spatial scales. A study conducted in the Fukuoka–Kitakyushu metropolitan region in Japan found that urbanization weakened sea-breeze circulation and caused an average increase of 0.23 °C in overall air temperature (Kawamoto, 2016). In Turkey, a study carried out in central Erzurum revealed that the relationship between Sky View Factor (SVF) and temperature is especially strong during winter months, and that shading and vegetation enhance pedestrian

thermal comfort (Yılmaz, Yılmaz, Yavaş, Mutlu, & Koç, 2016). These findings demonstrate that surface cover characteristics—such as vegetation density, ground albedo, and building ratio—are among the primary determinants of microclimate conditions even across different climate zones.

In urban microclimate management, anthropogenic heat loads play a role as critical as energy emissions and surface materials. Wagner and Viswanathan (2016) examined the impact of traffic behavior on surface temperatures using a cellular automata–based model and showed that acceleration patterns significantly increase ambient temperatures. This result indicates that micro-scale thermal mitigation strategies must account not only for vegetative cover but also for human-induced heat emissions.

In recent years, digital twin–based analyses have gained prominence as a means of evaluating these multidimensional factors simultaneously. Digital twin technology creates a virtual replica of physical systems or environments, enabling scenario-based analysis and decision-support processes. In Turkey, this technology has been integrated into urban planning applications—particularly in Bursa Metropolitan Municipality's 3D building modeling and structural inspection workflows (Aslan, 2024). According to Aslan (2024), digital twins enhance the efficiency of public resource allocation, reduce the risk of misinvestment, and have become an important tool for sustainable city management. This approach allows for the visualization and quantification of parameters such as changes in green-space ratios, shading potential, and surface temperatures in urban open spaces.

In this context, the present study conducts a digital twin–based microclimate assessment using the example of Kaymakkapı Square in Isparta. The objective is to spatially analyze the potential impact of incremental increases in green-space ratio on surface temperatures and to demonstrate the benefits that the digital twin approach can provide in micro-scale planning processes. In this respect, the study offers an original contribution to the literature in terms of both microclimatic heat management and data-driven urban design..

1.1. Microclimate and the Urban Heat Island Phenomenon

Urban microclimate is shaped by the altered energy balance and atmospheric processes that occur when artificial surfaces replace natural ground cover. This transformation gives rise to the Urban Heat Island (UHI) phenomenon, in which urban centers exhibit higher temperatures compared to their surrounding environments. According to Oke's (1982) classical definition, the UHI effect is associated with the disruption of the surface energy balance of cities and results from the interactions among surface heat fluxes, longwave radiation, air circulation, and anthropogenic heat sources, particularly within the urban canopy layer (UCL). This condition is directly linked to the high heat capacity of impervious surfaces, their low albedo values, and the reduction in evapotranspiration rates.

Subsequent studies have emphasized that the UHI effect should be evaluated not only in terms of land surface temperatures (LST) but also through atmospheric heat accumulation (Voogt & Oke, 2003). Urbanization intensity, building height ratio, surface albedo, wind flow, and the proportion of urban greenery are the key morphological parameters that determine the magnitude of the UHI effect (Santamouris, 2015). Similar patterns have been observed in research conducted in Turkey. For instance, Okumuş (2022) found that surface temperature in Istanbul is positively correlated with building density and negatively correlated with NDVI values. Saka and Atmaca (2023) reported that the mean land surface temperature in Yozgat

increased by 1.18 °C between 2012 and 2022. The LCZ (Local Climate Zone) classification developed by Sinancıoğlu (2024) further illustrated the spatial variations in UHI intensity associated with local climate zones.

These findings confirm that the energy balance principles described in Oke's (1982) theoretical framework are also valid for urban fabrics in Turkey. The interaction between the thermal properties of urban surfaces—such as albedo, thermal conductivity, and heat-storage capacity—and land-cover characteristics accelerates microclimatic heat accumulation, particularly during the summer months. Therefore, the Urban Heat Island phenomenon constitutes one of the primary parameters that must be considered in micro-scale urban planning and landscape design.

1.2. Green Infrastructure and Its Effects on Microclimate

One of the most effective strategies for mitigating the Urban Heat Island (UHI) effect is the enhancement of green and blue infrastructure components. Vegetated surfaces reduce both surface and air temperatures through mechanisms such as evapotranspiration, shading, and increased albedo, while water bodies moderate thermal fluctuations by absorbing heat during the day and releasing it at night due to their high specific heat capacity (Budzik, Sylla, & Kowalczyk, 2025).

According to a comprehensive meta-analysis conducted by Kumar et al. (2024), which evaluated more than 27,000 studies, botanical gardens (5.0 ± 3.5 °C), wetlands (4.9 ± 3.2 °C), green walls (4.1 ± 4.2 °C), and street trees (3.8 ± 3.1 °C) exhibit the strongest cooling effects among green–blue infrastructure elements. A systematic review by Budzik et al. (2025) further reported that the average cooling intensity varies by methodological approach, with remote sensing studies indicating a mean reduction of 4 °C, field measurements showing 3 °C, and numerical models demonstrating 2 °C.

The influence of green infrastructure is not limited to physical cooling; it also reduces radiative heat absorption through shading and alters wind flows to create cooling air movements known as "park breezes" (Toparlar et al., 2017). Field measurements have shown that the temperature difference around urban parks ranges between 1–3 °C, with park corridors aligned parallel to prevailing wind directions significantly enhancing cool-air advection.

In Turkey, Ortaçeşme and Zeğerek Altunbey (2022) identified green infrastructure as a "key" component of climate adaptation, while Göksoy Sevinçli and Bayrakcı (2024) emphasized its importance in strengthening urban resilience. In this context, the microclimatic benefits of green infrastructure should be evaluated not only in terms of reducing surface temperatures but also through its contributions to ecosystem services, improved air quality, and enhanced thermal comfort.

1.3. Remote Sensing and GIS-Based Microclimate Analyses

Remote sensing and Geographic Information Systems (GIS) technologies are fundamental tools in urban microclimate research, particularly for detecting thermal anomalies. Land Surface Temperature (LST) values are commonly analyzed through their correlations with indicators such as NDVI, NDBI, and albedo (Weng, 2009). The observation that areas with higher NDVI values exhibit lower LST provides quantitative evidence of the cooling function of vegetation.

Macarof and Statescu (2017), using Landsat 8 imagery, demonstrated that the NDBI–LST relationship is strongly positive, whereas the NDVI–LST relationship is negative and subject

to seasonal variation. Similar patterns have been documented in studies conducted in Turkey, where increases in NDVI correspond to reductions of approximately 0.7–1.2 °C in surface temperatures (Okumuş, 2022; Saka & Atmaca, 2023).

Remote sensing data not only supports the identification of temperature distribution but also provides the foundational database for constructing digital twins. Budzik et al. (2025) emphasized that this integration lies at the core of GIS-based spatial modeling within the "geoinformatics approach," and further argued that artificial intelligence (AI) and digital twin technologies should be prioritized in future research for the management of Blue–Green Infrastructure (BGI).

1.4. Digital Twin Technology and the Urban Planning Context

Digital twin technology is an approach that creates a virtual representation of physical systems, enabling scenario generation, monitoring, and decision-support processes. Batty (2018) describes digital twins as "dynamic digital reflections of cities," emphasizing their capacity to simulate various urban processes—such as energy, transportation, and environmental management—simultaneously.

In Turkey, Aslan (2024) examined the integration of digital twin technology into urban planning processes through the case of Bursa Metropolitan Municipality and demonstrated that this technology functions as a strategic tool for the efficient allocation of public resources. When combined with GIS-based datasets, the digital twin approach can generate highly accurate spatial scenarios for microclimate analysis, green infrastructure planning, and thermal comfort modeling.

Furthermore, Budzik et al. (2025) and Kumar et al. (2024) highlight digital twins as one of the emerging research frontiers for the optimization of green–blue infrastructure management. In this context, the digital twin is not only a visualization tool but also a critical component of data-driven climate adaptation planning.

1.5. Micro-Scale Applications and Scenario Approaches

Recent efforts to improve urban microclimates have increasingly focused on micro-scale applications such as squares, parks, and streets. Analyses conducted at this scale demonstrate that even small-scale green interventions can produce perceptible thermal effects. Measurements by Toparlar et al. (2017) identified an average air temperature reduction of 1–3 °C in urban parks, while Okumuş (2022) reported that a 10% increase in NDVI corresponds to a 2% decrease in LST values.

Kumar et al. (2024) further calculated that the combined implementation of local interventions—such as parks, green walls, and green roofs—can produce cooling effects of up to 2.7 °C at the city scale. These findings highlight the importance of GIS-based tools such as buffer analyses, vectorization, and green-ratio scenarios in micro-scale planning processes.

The digital twin approach integrates these micro-scale analyses both visually and analytically, enabling the comparison of alternative green-ratio scenarios. In doing so, it supports data-driven microclimate design in urban open spaces and provides a scientifically grounded basis for planning processes.

2. Materials and Methods

The study area comprises Kaymakkapı Square and its surroundings, located in the city center of Isparta (Figure 1). This area is a public open space characterized by intensive commercial functions, a high proportion of impervious surfaces (>60%), and limited vegetation cover. Due to increased pedestrian activity during the summer months, the square functions as a critical thermal hotspot in terms of urban microclimate. The total area is 34,350.75 m², with the existing green-space ratio estimated at approximately 39.4%. For these reasons, the square was selected as a suitable test site for urban microclimate optimization.

The methodological framework is based on a digital twin–supported GIS analysis. The workflow includes vegetation detection from satellite imagery, spatial thresholding to delineate green areas, vectorization, area calculations, and scenario-based buffer analyses (Figure 1). The resulting numerical data were subsequently used for the empirical modeling of cooling potential.



Figure 1. Study Area: Kaymakkapı Square, Isparta

2.1. Data Sources

Open-access remote sensing data and secondary datasets generated within the GIS environment were used in this study. The primary datasets include:

• Satellite imagery: High-resolution RGB satellite imagery obtained from Google Earth Pro (summer season, 2023).

• Coordinate system: WGS 84 / UTM Zone 36N.

• Climate data: According to the Turkish State Meteorological Service (MGM, 2023), the mean summer air temperature is approximately 31 °C, with maximum values reaching around 36 °C.

The secondary datasets consist of:

• Green-space vector layers, buffer analyses, and polygon area calculations, all produced in QGIS 3.34.

• All computations were performed using metric units, and the analysis scale was defined as 1:1,000.

2.2. Vegetation Digitization (ExG Method)

The Excess Green Index (ExG) method was applied to identify vegetated surfaces. This method calculates the green intensity of vegetation based on the difference between the RGB bands. The formulation is expressed as:

$$ExG=2G-R-B$$

where R, G, and B represent the red, green, and blue spectral band values, respectively (Macarof & Statescu, 2017). In the resulting raster dataset, pixels with ExG > 10 were classified as green areas. To reduce noise, small polygons smaller than 5 m² were removed from the dataset. Owing to its computational efficiency and robust accuracy, this method is consistent with comparable studies in the literature (Weng, 2009; Okumuş, 2022).

The raster data were converted to vector format in QGIS using the Polygonize (Raster to Vector) tool, and the area (m²) of each polygon was calculated. In the initial state, the total green-space area was determined to be 13,533.5 m² (≈ 39.4%).

2.3. Scenario Development and Buffer Analysis

Two scenarios were developed to model the incremental increase in vegetation coverage:

• Scenario 1 (S1): A 0.3 m buffer applied to the existing green-area polygons.

• Scenario 2 (S2): A 0.6 m buffer applied to the same polygons.

For both scenarios, the resulting total green-space area was intersected with the study area boundary, and proportional changes were calculated. Accordingly, the green-space ratio increased to 44.8% in S1 and to 49.3% in S2. These increases illustrate how small-scale surface modifications can significantly influence total green-space composition.

The buffer analyses were conducted within the spatial scenario-generation framework of the digital twin approach (Aslan, 2024; Budzik et al., 2025). This enabled different green-space configurations to be compared in a manner akin to real-time simulation.

2.4. Cooling Effect Model

In estimating the cooling effect, the empirical relationship commonly used in the literature between the Percentage of Shaded Area (PSA) and the surface temperature difference (ΔT) was adopted. According to the meta-analysis conducted by Kumar et al. (2024), each 10% increase in vegetated area results in an approximate reduction of 0.25–0.30 °C in land surface temperature.

Based on this relationship, the estimated temperature decrease for the scenarios developed in the present study—corresponding to increases in green-space ratios (5.4% → 9.9%)—was calculated using the following formulation:

$\Delta T = 0.03 \times \Delta$Green Ratio (%)

Accordingly, the cooling potential was estimated at approximately 0.17 °C for Scenario 1 (S1) and 0.32 °C for Scenario 2 (S2). These results are consistent with the field measurement ranges reported by Budzik et al. (2025) and demonstrate the direct thermal influence of vegetation cover in micro-scale urban environments.

2.5. Digital Twin–Based Spatial Modeling

The digital twin model was constructed upon a set of layer combinations developed in the QGIS environment, including ground-surface data, green-space vectors, buffer scenarios, and the raster-based heat map. This system functions as a data-driven digital replica of the physical environment. The model aims to analyze the effects of changes in green-space ratio on surface temperature distribution both numerically and visually.

In line with the recommendations of Budzik et al. (2025) and Kumar et al. (2024), the digital twin approach was evaluated as a spatial decision-support tool. The results reveal microclimatic variations across different functional zones within the square—such as pedestrian corridors, seating areas, and vegetated islands—and provide a foundation for future design interventions.

2.6. Limitations of the Method

In this study, ExG-based vegetation detection was supported through visual verification and manual boundary refinements. However, due to the unavailability of NDVI or thermal band data, direct Land Surface Temperature (LST) calculations could not be performed. Consequently, the cooling effect was estimated using an empirical model. Moreover, micro-scale wind-flow and shading analyses (e.g., ENVI-met simulations) were excluded from the scope of this research.

Nevertheless, the scenario-generation speed and visualization capabilities offered by the digital twin–based approach represent a major strength of the method, providing a simple yet effective analytical framework for decision makers (Aslan, 2024).

3. Findings and Discussion

3.1. Current Situation Analysis

The digital twin–based analysis conducted for Kaymakkapı Square in Isparta revealed that the study area covers a total of 34,350.75 m², of which 13,533.5 m² consists of green space. This corresponds to approximately 39.4% vegetated surface coverage. The majority of green areas are concentrated along the northern and western edges of the square, whereas pedestrian corridors, ground-level seating zones, and commercial frontages are predominantly composed of impervious surfaces. This configuration contributes to the formation of microclimatic hotspots, where midday surface temperatures commonly range between 35–40 °C (Okumuş, 2022).

In the raster-based ExG analysis, the areas with the highest vegetation density were identified as lawn zones and shaded areas beneath tree canopies. The shading effect was found to be particularly weak along the northeast–southwest pedestrian axis, while it was more pronounced

along the vegetated strip on the western edge. These results indicate that the microclimatic cooling potential is unevenly distributed across the site.

3.2. Scenario Analyses

The green-space enhancement scenarios (S1 and S2) were applied within the digital twin model, with each scenario evaluated as a separate spatial layer. The findings are summarized in Table 1.

Table 1. Green-Space Scenarios and Area Ratios

Scenario	Description	Green Area (m²)	Green Ratio (%)	Δ Ratio (%)
S0	Current State	13.533,5	39,4	–
S1	+0,3 m Buffer	15.392,7	44,8	+5,4
S2	+0,6 m Buffer	16.934,1	49,3	+9,9

As a result of the buffer scenarios, the green-space ratio increased by 5.4% in S1 and 9.9% in S2. Visually, the expansion of green areas was most pronounced along the edges of the vegetated islands surrounding the square and along the boundaries of the commercial axis. This increase also reduced the proportion of impervious surfaces from 60% to 51%, resulting in a more sustainable distribution in terms of surface energy balance.

3.3. Estimated Cooling Effect

According to the empirical model, the reduction in surface temperature associated with the increase in green-space ratio was calculated to be within the range of 0.17–0.32 °C (Kumar et al., 2024). Accordingly:

S1 (44.8%): $\Delta T \approx -0.17$ °C

S2 (49.3%): $\Delta T \approx -0.32$ °C

Although these values may appear small in absolute terms, they are highly significant for micro-scale open spaces. The literature indicates that even temperature differences of 0.2–0.4 °C can substantially influence pedestrian thermal comfort in small urban areas (Toparlar et al., 2017; Budzik et al., 2025).

The simulations show that the cooling effect is more pronounced in areas with high tree density, while it remains relatively limited in lawn-dominated zones. This finding aligns with the global meta-analysis by Kumar et al. (2024), which emphasizes the influence of vegetation type and canopy density on cooling performance. Additionally, the buffer scenarios contribute most effectively by connecting fragmented vegetated patches, thereby creating a more continuous green corridor. Such connectivity enhances cool-air advection along the prevailing wind direction, reinforcing the park-breeze effect (Oke, 1982; Voogt & Oke, 2003).

3.4. Spatial Distribution and Visual Assessment

In the color-scaled analysis conducted within the digital twin model (Figure 2), impervious surfaces with low green-space ratios are represented in orange–red tones, whereas shaded areas appear in light green hues. This map enabled a clear visualization of microclimatic differences across various functional zones. Notably, temperature disparities in the west-oriented seating areas and in front of ground-level cafés decreased by 7–10% under the S2 scenario. This finding

confirms the observation reported by Budzik et al. (2025), namely that "increases in vegetation density and spatial continuity expand the effective cooling range." Furthermore, the microclimatic variation of 1–3 °C observed by Toparlar et al. (2017) in urban parks appears to follow a linear pattern at the scale of this study.

One of the key advantages of the digital twin system is its ability to visually compare scenario-based differences in real time. This capability makes it possible to clearly identify which locations would yield the greatest microclimatic benefit from new green interventions.

3.5. Comparison of Findings with the Literature

The results obtained in this study are consistent with findings reported in global-scale research. Budzik et al. (2025) indicate that cooling intensity averages 4 °C in remote-sensing-based studies, 3 °C in field measurements, and 2 °C in numerical models. The 0.3 °C cooling difference observed in this study is therefore within the expected range for a micro-scale urban square.

Similarly, Toparlar et al. (2017) observed temperature differences of 1–3 °C in parks in Antwerp, and Oke (1982) emphasized that microclimatic variations of this magnitude play a significant role in surface energy balance. In the Turkish context, the model developed by Okumuş (2022) also demonstrated a linear negative correlation between green-space ratio and surface temperature ($r = -0.71$), which aligns with the findings for Kaymakkapı Square.

Furthermore, the digital twin–based analysis employed here is consistent with Aslan's (2024) concept of "data-driven decision making in smart city management and planning." In this regard, the method extends beyond traditional GIS analyses by offering dynamic scenario generation and visual impact assessment capabilities.

4. Conclusion and Recommendations

This study evaluated the microclimatic effects of increasing green-space coverage in Kaymakkapı Square, Isparta, using a digital twin–based analytical approach. The findings demonstrate that raising the green-space ratio from 39.4% to 49.3% generates a potential surface temperature reduction of approximately 0.32 °C. This outcome is largely consistent with the global meta-analysis by Kumar et al. (2024), which reports that each 10% increase in green-space ratio yields an average cooling of 0.25–0.30 °C.

Although the cooling magnitude obtained in this research is situated at the lower bound of the 3–4 °C macro-scale cooling range documented by Budzik et al. (2025), it remains fully aligned with expectations for a micro-scale urban square. Similarly, the 1–3 °C temperature differences observed by Toparlar et al. (2017) around parks support the notion that the microclimatic trends observed in this study follow a scaled but parallel pattern. Studies conducted within the Turkish context (Okumuş, 2022; Saka & Atmaca, 2023; Sinancıoğlu, 2024) further corroborate this trend, highlighting a negative correlation between NDVI and LST and confirming that increased vegetation density results in lower surface temperatures. Accordingly, the findings for Kaymakkapı Square exhibit both quantitative and qualitative consistency with national and international literature. The digital twin framework employed in this study goes beyond traditional GIS-based analysis by enabling scenario-based simulation on a virtual replica of the physical environment. This approach facilitates both numerical and visual assessment of green infrastructure interventions, particularly in micro-scale urban areas such as squares, parks, and streets (Aslan, 2024).

One of the central contributions of the digital twin model is its ability to allow real-time visual comparison between different green-space scenarios. This capability made it possible to explicitly identify the locations where additional vegetation would yield the greatest microclimatic benefits. This aligns directly with the perspective of Budzik et al. (2025), who emphasize digital twin technology as a priority research direction for future BGI (blue–green infrastructure) management.

Furthermore, the application of digital twins—previously highlighted by Aslan (2024) in the context of Turkish cities—is recognized as an instrument that enhances resource efficiency in urban planning and public administration. In this study, the use of a digital twin introduced a new analytical dimension to microclimate assessment, providing an innovative decision-support mechanism.

The research findings indicate that even small-scale green infrastructure interventions can produce meaningful microclimate improvements in urban centers. Increased vegetation connectivity contributed to the dispersal of thermal hotspots and strengthened the park-breeze effect (Oke, 1982; Voogt & Oke, 2003). This demonstrates that spatial configuration, continuity, and orientation are just as important as the total amount of vegetation in green infrastructure design. As also noted by Budzik et al. (2025), the shape complexity and spatial structure of BGI significantly influence the effective cooling footprint.

In the context of Turkish urban areas—particularly medium-sized cities like Isparta—public open spaces are predominantly composed of impervious surfaces. Therefore, micro-scale greening strategies carry a level of importance comparable to large-scale park developments. This study shows that such strategies can be quantified and monitored effectively through the integration of GIS and digital twin technologies. Overall, the digital twin–based GIS analysis demonstrated that this methodology offers a measurable, visualizable, and scenario-compatible tool for urban microclimate planning. The results clearly indicate that increasing green-space ratios reduces surface temperatures, enhances thermal comfort, and mitigates microclimatic imbalance. These findings align with global trends reported in the literature (Oke, 1982; Kumar et al., 2024; Budzik et al., 2025), confirming the applicability of digital twin technology for localized urban interventions. In conclusion, the case of Kaymakkapı Square illustrates that even modest interventions can improve urban climate quality. It also highlights that data-driven, participatory, and digitally supported planning approaches will be among the key tools for building sustainable cities of the future.

Thanks and Information Note

Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Aslan, M. M. (2024). Bir akıllı kent uygulaması olarak dijital ikiz teknolojisinin kent planlaması ve yönetimi sürecindeki rolü. *Gaziantep University Journal of Social Sciences*, 23(4), 1613–1624. https://doi.org/10.21547/jss.1514231

Budzik, G., Sylla, M., & Kowalczyk, T. (2025). Understanding urban cooling of blue–green infrastructure: A review of spatial data and sustainable planning optimization methods for mitigating urban heat islands. *Sustainability,* 17(1), 142. https://doi.org/10.3390/su17010142

Göksoy Sevinçli, A., & Bayrakcı, E. (2024). Kentsel altyapının iklim değişikliğine karşı dirençli hale getirilmesinde yeşil altyapı çözümleri. *Uluslararası Yönetim Akademisi Dergisi,* 7(4), 1001–1014.

Kumar, P., Debele, S. E., Khalili, S., et al. (2024). Urban heat mitigation by green and blue infrastructure: Drivers, effectiveness, and future needs. *The Innovation*, 5(2), 100588. https://doi.org/10.1016/j.xinn.2024.100588

Macarof, P., & Statescu, F. (2017). Comparison of NDBI and NDVI as indicators of surface urban heat island effect in Landsat 8 imagery: A case study of Iasi. *Present Environment and Sustainable Development*, 11(2), 141–150. https://doi.org/10.1515/pesd-2017-0032

Oke, T. R. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society,* 108(455), 1–24. https://doi.org/10.1002/qj.49710845502

Okumuş, D. E. (2022). Kentsel mikro iklimin iyileştirilmesine yönelik kent dokularında ısı adası etki değerlendirme ve azaltım stratejileri geliştirme modeli: İstanbul örneği [Doktora tezi, İstanbul Teknik Üniversitesi].

Ortaçeşme, V., & Zeğerek Altunbey, P. (2022). İklim adaptasyonunun anahtarı olarak yeşil altyapı: Kentsel doğa ve iklim değişikliği. *Peyzaj – Eğitim, Bilim, Kültür ve Sanat Dergisi,* 4(2), 123–132. https://doi.org/10.53784/peyzaj.1220747

Saka, C., & Atmaca, H. (2023). Uzaktan algılama yöntemleri ile kentsel yüzey sıcaklıklarının haritalanması: Yozgat kenti örneği. *Bozok Journal of Engineering and Architecture,* 2(2), 38–43.

Sinancıoğlu, M. N. (2024). Uzaktan algılama ve derin öğrenme yöntemleri ile İstanbul'un yerel iklim alanları ve yer yüzeyi sıcaklığı değişimleri arasındaki ilişkinin incelenmesi [Yüksek lisans tezi, İstanbul Teknik Üniversitesi].

Toparlar, Y., Blocken, B., Maiheu, B., & van Heijst, G. J. F. (2017). The effect of an urban park on the microclimate in its vicinity: A case study for Antwerp, Belgium. *International Journal of Climatology,* 37(Suppl. 1), 3607–3624. https://doi.org/10.1002/joc.4940

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment,* 86(3), 370–384. https://doi.org/10.1016/S0034-4257(03)00079-8

Weng, Q. (2009). Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. *ISPRS Journal of Photogrammetry and Remote Sensing,* 64(4), 335–344. https://doi.org/10.1016/j.isprsjprs.2009.03.007

Yılmaz, H., Yılmaz, S., Yavaş, M., Mutlu, E., & Koç, A. (2016). Climate-sensitive pavement modelling for pedestrian ways. *Procedia Engineering*, 169, 408–415. https://doi.org/10.1016/j.proeng.2016.10.050

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Mobility as Cultural Heritage: Rethinking Yörük Settlements through Spatial Practices

Uğur Efe UÇAR[1]*

ORCID 1: 0000-0002-1080-3080
[1]Research Assistant, Istanbul Technical University, Faculty of Architecture, Department of Interior Architecture, Istanbul-Türkiye
ucar15@itu.edu.tr (Responsible Author)

Ethem GÜRER [2]

ORCID 2: 0000-0002-3482-2526
[2]Assoc. Prof. Dr, Istanbul Technical University, Faculty of Architecture, Department of Interior Architecture, Istanbul-Türkiye
egurer@itu.edu.tr

Abstract

This paper explores the spatial logic and ecological intelligence embedded in the temporary settlement practices of Yörük nomadic communities, reframing them as mobile heritage ecosystems. Drawing on an in-motion visual grammar approach, the study analyzes six transitional settlements through schematic diagrams and ethnographic documentation. The analysis focuses on three interrelated parameters—positional patterns, componential layouts, and transition paths—revealing the ways in which mobility functions as a form of resilience rather than a lack of permanence.

Findings highlight a consistent spatial intelligence across varied contexts: solar-oriented positioning, clear separation of human and animal domains, and flexible circulation paths. These recurring arrangements demonstrate inherited design strategies that embody environmental responsiveness, modular organization, and multispecies cohabitation. By interpreting these spatial logics through the lens of ecosystemic heritage thinking, the paper positions nomadic settlements as dynamic, living systems that transmit ecological and cultural knowledge across generations.

This perspective expands heritage discourse beyond sedentary and monumental frameworks, acknowledging mobility as a sophisticated cultural practice with enduring value. Ultimately, the study contributes to debates on cultural sustainability by conceptualizing ephemeral settlement systems as heritage ecosystems, where temporality, adaptability, and ecological intelligence converge. Through the integration of visual pattern analysis and ethnographic insight, it argues that the Yörük case exemplifies how nomadic heritage can be mobilized as a critical lens for rethinking spatial resilience, mobility, and cultural continuity in contemporary heritage studies.

Keywords: Nomadic heritage, yörük settlements, mobility, ecological intelligence, heritage ecosystem, cultural sustainability

1. Introduction

The ongoing discourse on cultural heritage increasingly underscores its integration within ecological systems and everyday cultural practices. Rather than being viewed as static remnants of the past, heritage is now conceived as a living, relational, and context-dependent phenomenon, continually shaped through the interactions of people, materials, landscapes, and non-human entities (DeSilvey, 2017; Harrison, 2015; Holtorf & Fairclough, 2013). This conceptual turn signals a broader paradigm shift from object-based preservation toward process-oriented heritage management, in which heritage itself becomes an active participant in sustaining identity, resilience, and ecological balance (DeSilvey, 2012).

Such an ecological orientation creates new possibilities for understanding and engaging with nomadic and pastoralist groups whose lifeways remain finely synchronized with environmental rhythms, animal welfare, and cyclical mobility (Krätli, 2015; Nori, 2019). For these

communities, spatial organization is governed less by permanence than by seasonal adaptation and the health of herds, reflecting a pragmatic environmental intelligence. Their practices also unsettle the sedentary assumptions that dominate conventional heritage discourse, revealing mobility as both an epistemic and ecological mode of existence (Rose, 2011; Viveiros de Castro, 2004).

Gilbert (2014) distinguishes multiple forms of nomadism in mobile cultures, emphasizing pastoral nomadism as a distinct form defined by movement organized around the care and management of livestock. It represents a way of life structured by ecological cycles and animal needs rather than by commerce or extraction (Barfield, 2013; Barnard & Wendrich, 2008; Zvelebil, 1980). Among groups embodying these principles, the Yörüks of Anatolia provide a particularly instructive case. Their settlements demonstrate an intricate entanglement with seasonal variation, environmental uncertainty, and multispecies coexistence (Doğan & Doğan, 2004; Ersavaş & Özkanlı, 2018; Lindner, 1983; Yeni, 2013). The Yörüks were selected for this study as one of the few remaining pastoral nomadic groups in Anatolia that continue to sustain mobility-based traditions.

To explore these dynamics, the research concentrates on transitional phases, specifically the acts of settling and departing that punctuate the seasonal cycle. These liminal moments encapsulate complex judgments about terrain, weather, and available resources, translating them into spatial and material gestures. They serve as critical thresholds where ecological awareness and collective coordination become most visible (Figure 1). While relatively stable intervals (e.g., t2–t3; t4–t5; t6–t7; t10–t11) structure daily life, this study foregrounds the transitional junctions (t1–t2 and t11–t12) where built configurations are dismantled and re-assembled. These phases offer insight into how nomadic communities evaluate sites, channel livestock movements, and coordinate communal and material arrangements.

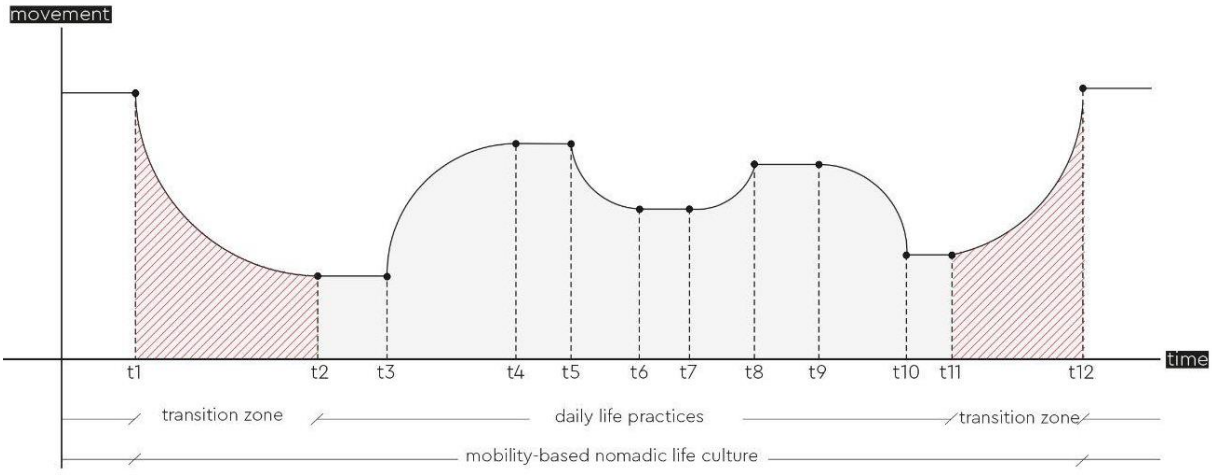


Figure 1. Thresholds of settlement and departure in Yörük mobility (Source: Authors).

Guided by this perspective, the study seeks to understand how the key moments of temporary settlement and departure within the Yörük mobility cycle reveal embedded environmental reasoning and relational heritage practices, and to explore in what ways mobility-centered

traditions can expand current understandings of heritage ecosystems while informing sustainability-oriented management frameworks.

2. Materials and Methods

The term Yörük, derived from the Turkish verb "yörü-" (to walk or move), encapsulates a lifestyle grounded in habitual movement, environmental awareness, and spatial adaptability (İnalcık, 2014). Historically, Yörük communities developed a settlement logic based on ephemeral, modular, and reparable structures that supported cyclical mobility while remaining responsive to shifting climatic and ecological conditions (Bates, 1973; Beşirli & Erdal, 2008; Ersavaş & Özkanlı, 2018). Their encampments are organized around the *karaçadır*, a portable black tent woven from goat hair, strategically positioned in response to climatic, topographic, and ecological factors (Pfeifer, 2015) (Figure 2).



Figure 2. Exterior (left) and interior (right) views of the Karaçadır, the central spatial unit of the Yörüks' mobile settlement system (Source: Authors).

Within the scope of this research, selected instances of Yörük encampments were documented through schematic visualizations focusing specifically on transitional phases, namely the acts of temporary settlement and departure. Six distinct examples were identified through ethnographic documentation, archival photographs, and field observations. Each case was subsequently analyzed to produce schematic drawings mapping the core spatial components: karaçadır tents, livestock enclosures, communal zones, and circulation paths. These drawings were standardized and compiled into a comparative visual matrix structured around variations in spatial configuration, environmental orientation, and functional zoning.

The visual dataset was developed by synthesizing ethnographic literature, archival imagery, and prior field surveys with newly constructed schematic documentation. Selection emphasized cases where both setup and dismantling phases were visible and reconstructable. Each chosen example was redrawn as a schematic plan intended to represent the spatial reasoning and morphological logic inherent in the original observation. To maintain consistency, a uniform drawing scale and north orientation were applied to all diagrams. Functional domains were classified to distinguish between areas for human habitation, animal care, and storage or resource management (Figure 3).

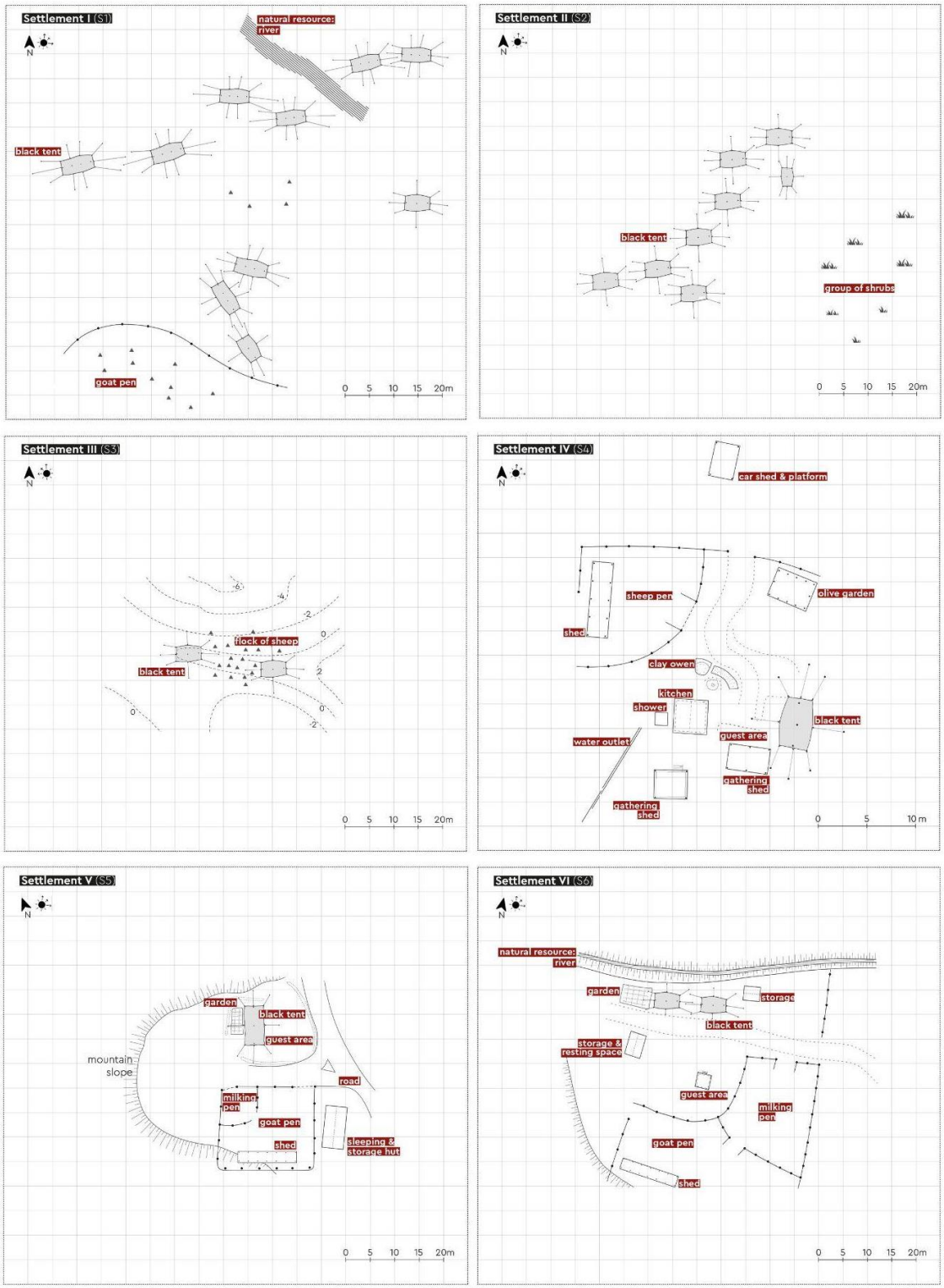


Figure 3. Matrix-based representation of six Yörük settlements (Source: Authors).

The study adopts a visual-computational framework based on shape grammars (Knight, 2000; Knight & Stiny, 2015; Stiny, 2006). Extending this method beyond morphological analysis, the framework incorporates ethnographic dimensions such as communal roles, group mobility, and

seasonal behavior. Building on previous adaptations, including the "lived-in grammar" (Rezoug & Özkar, 2023) and user-oriented models (Eloy et al., 2018; Ferreira et al., 2011; Vardouli, 2015), this study proposes an *in-motion visual grammar* that identifies recurring, mobility-driven spatial patterns revealing the embedded design intelligence of nomadic lifeways.

The in-motion visual grammar was applied to analyze the organizational principles embedded in Yörük settlements. The standardized schematic corpus provided the analytical foundation for a comparative study structured around environmental, functional, and social parameters. Through this framework, the study aimed to visually systematize the underlying logic governing how tent clusters are spatially composed and organized. Translating observed settlement configurations into schematic visual patterns made it possible to identify recurring organizational logics, adaptive strategies, and forms of environmental reasoning that characterize Yörük spatial practices.

Figure 4 conceptually illustrates how nomadic camp layouts are determined not only by social and protective factors but also by livestock movement patterns (Figure 4). It contrasts two grazing models: in the continuous grazing tract model, herds move within a single central area with tents densely clustering along its periphery, whereas in the dispersed grazing tract model, grazing zones extend over a broader terrain, producing a looser and more flexible tent configuration. This diagram underpins an integrated analysis across three spatial parameters: (a) positional patterning among tents, (b) componential relationships between human and animal domains, and (c) the flow paths required for effective herd circulation.

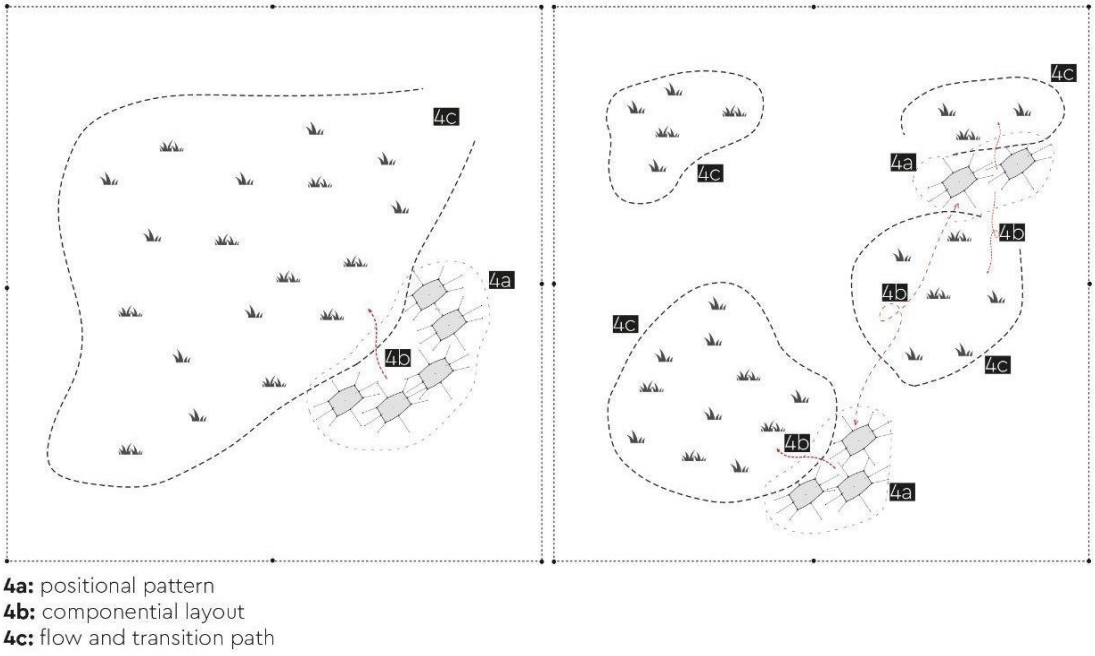


Figure 4. Spatial logic of nomadic camps: Positional patterning (4a), componential layout (4b), and transition paths (4c) (Source: Authors).

To operationalize this framework, three interrelated parameters were defined and examined across all settlement samples.

The first parameter, *positional patterning*, analyzed how tents were oriented and grouped within each camp. This included examining entrance directions relative to sunlight and prevailing

winds, as well as identifying clustering tendencies such as linear, radial, or dispersed formations. The presence of a central void and the orientation of the overall layout (inward-facing or outward-oriented) were also considered. This dimension provided insight into how climatic factors such as solar gain, wind protection, and thermal comfort informed collective settlement form.

The second parameter, *componential layout*, examined spatial relationships among principal functional elements such as karaçadır tents, livestock pens, water sources, and communal or cooking spaces. The analysis explored the grouping and separation of these components, the degree of functional segregation between human and animal areas, and their proximity to natural resources. This layer illuminated how Yörük encampments balanced ecological pragmatism with social organization through adaptable spatial configurations.

The third parameter, f*low and transition paths*, focused on patterns of movement within and across the campsite. It identified visible and implied circulation routes linking tents, livestock zones, and resource areas, and analyzed how these paths were oriented and scaled relative to daily mobility routines. Circulation was further classified as centralized, radial, or decentralized, depending on the internal organization of movement.

Collectively, these three parameters establish the analytical foundation of the proposed in-motion visual grammar. Rather than isolating single morphological traits, the analysis uncovers how orientation, zoning, and circulation interact to sustain mobile lifeways. This composite grammar articulates the interdependencies between human practice, environmental condition, and material arrangement, providing a nuanced understanding of how temporary settlements are enacted, negotiated, and maintained. Accordingly, the framework functions not only as a tool for documentation but as a generative model for interpreting the spatial intelligence embedded in nomadic heritage ecosystems.

3. Findings and Discussion

Although each Yörük settlement analyzed in this study exhibits a distinct environmental context, group composition, and degree of permanence, the spatial analysis reveals a remarkable convergence in the underlying organizational logic. Despite differences in topography and context, the camps exhibit consistent tendencies in orientation, zoning, and circulation that indicate the presence of an embedded spatial intelligence. This convergence points to a culturally transmitted yet uncodified design grammar that is pragmatically enacted through lived practice.

Across the six settlements, *positional patterns* consistently align with solar exposure, most often oriented toward the south or southeast, and reveal flexible clustering strategies shaped by terrain, herd behavior, and visibility needs. Camps alternate between open radial forms and compact linear layouts. Distributed settlements generally include a central open space, while denser ones support multidirectional access. These tendencies correspond with broader ethnographic observations. Tent clusters maintain gaps of approximately four to five meters between individual units, while wider intervals, typically 20 to 30 meters, separate clusters to facilitate grazing circulation and minimize animal mixing. Such dimensions are consistent with studies suggesting that flock maneuvering requires 10 to 20 meters of clearance. Entrances most frequently face south, optimizing sunlight and airflow while enhancing both thermal comfort and inter-tent communication.

Componential layouts reveal recurrent patterns of functional separation combined with selective integration. Human habitation areas and livestock zones are generally distinct, often divided by natural thresholds or topographical buffers. Auxiliary functions such as cooking, storage, or guest reception appear as permanence increases, yet their placement remains adaptive to terrain and group size. This modular configuration is particularly visible in the recurring spatial modules found across most Yörük camps. A central tent serves for rest, indoor cooking, and hospitality; an adjacent outdoor kitchen contains a fire area; a gathering space, open or semi-sheltered, is positioned in front of the tent; and minimal hygiene infrastructures including washing areas near water sources and toilets located toward vegetated peripheries. Some encampments also include small vegetable gardens hidden from main circulation paths and animal pens shaded by fencing. Collectively, these arrangements reveal a design intelligence rooted in ecological pragmatism, balancing hygiene, control, and efficiency through distance, slope, and modularity.

Circulation and transition logics also demonstrate recurring spatial principles. Camps with dispersed clustering feature open, non-hierarchical movement paths, whereas compact or enclosed configurations organize circulation along radial or linear axes connecting human and animal zones. Across all cases, circulation pathways emerge organically from habitual movement, shared access, and interspecies negotiation rather than from formal planning. Mobility therefore manifests as open fields of action shaped by daily routines and communal rhythms. Pathways and entry alignments influence cluster formation, directing both herd flow and social interaction through spatial porosity and permeability.

Taken together, the six settlements display a coherent set of spatial patterns operating across scales and contexts: consistent solar orientation that reflects environmental literacy and landscape attunement; functional separation between species domains that expresses multispecies agency; modular organization of auxiliary functions that reinforces resilience and cyclical continuity; and circulation systems that sustain cohabitation and shared spatial agency among human and non-human actors.

Beyond spatial efficiency, these patterns embody social flexibility. Families choose neighboring clusters according to personal preference, kinship relations, or seasonal cooperation. During collective grazing or weaving periods, especially in highland pastures, tents are reconfigured to accommodate social events such as weddings, collaborative craftsmanship, or communal herding duties. In these situations, tents act as loci of intergenerational knowledge transfer and social reproduction, demonstrating how spatial design and heritage co-evolve as dynamic, lived practices. Mobility therefore emerges not merely as a response to environmental conditions but as a cultural mechanism that sustains collective memory, reciprocity, and ecological consciousness.

These findings affirm that Yörük spatial practices are not ad hoc reactions to environmental constraints but deliberate, inherited expressions of ecological heritage intelligence. They illustrate how mobility-centered practices preserve cultural continuity not through resistance to change but by embedding adaptability into both spatial and social systems. Viewed through this lens, Yörük encampments appear as living heritage ecosystems that are dynamic, negotiated, and multispecies environments. These configurations challenge sedentary preservation models and open new pathways for sustainability-oriented heritage discourse.

4. Conclusion and Recommendations

This study has examined the spatial intelligence embedded within Yörük settlement practices by analyzing the adaptive patterns, functional distributions, and circulation logics that structure their mobile camps. Through an in-motion visual grammar, it has revealed a culturally transmitted yet uncodified design language that sustains ecological responsiveness, social cohesion, and interspecies coexistence through cyclical mobility. These findings contribute not only to the empirical understanding of nomadic spatial practices but also to a broader reframing of cultural heritage through the lens of movement, adaptability, and multispecies interaction.

Rather than defining heritage as a fixed inventory of artifacts or architectural remains, this research conceptualizes it as a dynamic ecosystem that evolves through situated interactions among humans, animals, materials, and landscapes. The Yörük example demonstrates how environmental reasoning, functional flexibility, and cyclical routines converge into sustainable forms of inhabitation, offering a model for understanding heritage as a living process. From this perspective, the Yörük encampments examined here function not as temporary dwellings but as spatial expressions of an ecological epistemology in which environmental awareness and material modesty represent sophisticated design strategies.

This discussion has particular relevance for contemporary heritage discourse that increasingly confronts climate change, forced migration, and urbanization pressures. Within this context, the heritage ecosystem can be understood not only as a descriptive model but also as a normative one, suggesting that sustainability depends less on monumental permanence and more on relational continuity, spatial resilience, and adaptive stewardship. The Yörük experience illustrates how communities can inhabit fragile environments, navigate transformation, and sustain cultural identity through flexible practices that preserve ecological balance.

Furthermore, the spatial patterns identified in this study, including solar orientation, functional separation, modular organization, and adaptive circulation, constitute a transferable grammar of heritage-making. These principles reveal how traditional knowledge systems embody spatial solutions to complex environmental and social challenges, highlighting the need for their renewed recognition within academic and institutional frameworks. Acknowledging these systems reinforces the idea that sustainability is not solely a technological goal but also a form of cultural inheritance.

Looking ahead, the findings of this study point to several directions for future research. First, heritage analysis should broaden its conceptual and methodological scope to encompass ephemeral, mobile, and relational forms of spatial knowledge. Second, interdisciplinary approaches that combine computational modeling with ethnographic inquiry can make intangible practices more visible and analyzable. Third, the inclusion of non-human actors as integral participants in heritage ecosystems should become central to conservation and evaluation frameworks.

In this light, the Yörük settlements serve not only as a subject of study but also as a conceptual resource: a living archive of ecological adaptation, heritage transmission, and communal design intelligence. Their camps are not relics of a fading tradition but examples of sustainable cohabitation that testify to a heritage ecosystem in motion. As ecological instability and sociocultural fragmentation intensify, learning from such mobile epistemologies becomes not merely an academic pursuit but an ethical responsibility.

Ultimately, this study affirms that heritage ecosystems, when understood as distributed, adaptive, and multispecies, can offer resilient alternatives to extractive and static models of preservation. Embracing mobility as both a spatial and epistemological strategy allows heritage management to move toward futures that are inclusive, sustainable, and grounded in the lived intelligence of diverse cultural practices. In this process, the insights drawn from the Yörüks are not peripheral; they are essential.

Thanks and Information Note

The article complies with national and international research and publication ethics. This study is derived from the doctoral dissertation currently being conducted by Uğur Efe Uçar under the supervision of Assoc. Prof. Ethem Gürer within the Architecture Design Computing PhD Program at Istanbul Technical University. An extended and revised version of this study has been submitted to the Journal of Cultural Heritage Management and Sustainable Development.

References

Barfield, T. J. (2012). Nomadic Pastoralism. J. H. Bentley (Ed.). *The Oxford Handbook of World History.* UK: Oxford University Press.

Barnard, H. & Wendrich, W. (2008). The Archaeology of Mobility: Definitions and Research Approaches. H. Barnard and W. Wendrich (Eds.). *The Archaeology of Mobility: Old World and New World Nomadism*. USA: University of California.

Bates, D. G. (1973). *Nomads and farmers: A study of the yörük of southeastern turkey*. Michigan: Ann Arbor.

Beşirli, H. & Erdal, İ. (2008). *Anadolu'da yörükler: tarihî ve sosyolojik incelemeler.* Ankara: Phoenix Yayınevi.

DeSilvey, C. (2012). Making sense of transience: Anticipatory history. *Cultural Geographies,* 19(1), 31–54.

DeSilvey, C. (2017). *Curated decay: Heritage beyond saving.* Minneapolis: University of Minnesota Press.

Doğan, M. S. & Doğan, C. (2004). Tarihsel gelişim sürecinde yörükler. *Istanbul Journal of Sociological Studies,* 30, 15–29.

Eloy, S., Dias, M. A. & Vermaas, P. E. (2018). User-centered shape grammars for housing transformations: Towards post-handover grammars. S. Richardson, L. Fredline, A. Patiar, & M. Ternel (Eds.). *SIGraDi 2018. Proceedings of the 22nd Conference of the Iberoamerican Society of Digital Graphics,* São Carlos, Brazil (7–9 November), 156–164. https://cumincad.scix.net/cgi-bin/works/Show?sigradi2018_1248 (accessed 1 May 2025).

Ersavaş, H. & Özkanlı, O. (2018). 20. Yüzyılda orta toroslardaki yörüklerin mutfak kültürü. *Aydın Gastronomy,* 2(1), 39–49.

Ferreira, M. P., Cabral de Mello, D. & Duarte, J. P. (2011). The grammar of movement: A step towards a corporeal architecture. *Nexus Network Journal,* 13(1), 131–149.

Gilbert, J. (2014). *Nomadic peoples and human rights.* New York: Routledge.

Harrison, R. (2015). Beyond 'natural' and 'cultural' heritage: Toward an ontological politics of heritage in the age of Anthropocene. *Heritage & Society,* 8(1), 24–42. https://doi.org/10.1179/2159032X15Z.00000000036

Holtorf, C. & Fairclough, G. (2013). The New Heritage and Re-shapings of the Past. A. González-Ruibal (Ed.). *Reclaiming Archaeology: Beyond the Tropes of Modernity,* pp.197–210. Abingdon and New York: Routledge.

İnalcık, H. (2014). The Yörüks: Their origins, expansion and economic role. *The Journal of MCRI,* 467–495.

Knight, T. (2000). Shape grammars in education and practice: History and prospects. *International Journal of Design Computing,* 2.

Knight, T. & Stiny, G. (2015). Making grammars: From computing with shapes to computing with things. *Design Studies,* 41, 8–28. https://doi.org/10.1016/j.destud.2015.08.006

Krätli, S. (2015). *Valuing variability: New perspectives on climate resilient drylands development.* London: IIED.

Lindner, R. P. (1983). *Nomads and ottomans in medieval anatolia.* Indiana: Sinor Research Institute for Inner Asian Studies.

Nori, M. (2019). Herding through uncertainties – Regional perspectives. Exploring the interfaces of pastoralists and uncertainty. Results from a literature review, *Robert Schuman Centre for Advanced Studies Research,* Paper No. RSCAS 2019/68. http://dx.doi.org/10.2139/ssrn.3457235 (accessed 1 May 2025).

Pfeifer, K. (2015). *The Yörük black tent: Adaption in design in the course of changes in production (PhD thesis). Technische Universität Wien, Vienna. https://repositum.tuwien.at/bitstream/20.500.12708/9077/2/Pfeifer%20Kristina%20-%202015%20-%20The%20Yoeruek%20Black%20Tent%20adaption%20in%20design%20in%20the... pdf.*

Rezoug, A. & Özkar, M. (2023). A lived-in shape grammar: Parsing the dwelling activities in a modernist residential building in Algiers. *Design and Culture,* 16(2), 145–172. https://doi.org/10.1080/17547075.2023.2259672

Rose, D. (2011). *Wild dog dreaming: Love and extinction.* London: University of Virginia Press.

Stiny, G. (2006). *Shape: Talking about seeing and doing.* Cambridge: MIT Press.

Vardouli, T. (2015). Making use: Attitudes to human-artifact engagements. *Design Studies,* 41, 137–161. https://doi.org/10.1016/j.destud.2015.08.002

Viveiros de Castro, E. (2004). The transformation of objects into subjects in Amerindian ontologies. *Common Knowledge,* 10(3), 463–485.

Yeni, H. (2013). *The yörüks of the ottoman western thrace in the sixteenth century (PhD thesis). İhsan Doğramacı Bilkent University, Ankara.*

Zvelebil, M. (1980). *The rise of the nomads in central asia.* Cambridge: Cambridge University Press.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

From Cognitive Tool to Pedagogical Assistant: Rethinking AI in Interior Design Education through Student Experiences

Gözde GÖKDEMİR [1]*

ORCID 1: 0000-0002-6717-6241
[1]Res. Assist., Istanbul Technical University, Faculty of Architecture, Department of Interior Architecture, Istanbul-Türkiye
gokdemirg@itu.edu.tr (Responsible Author)

Hande Zeynep KAYAN [2]

ORCID 2: 0000-0003-3233-4788
[2]Assoc. Prof., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Interior Architecture, Istanbul- Türkiye
hande.kayan@msgsu.edu.tr

Abstract

Artificial intelligence (AI) has introduced new dynamics into interior design education, where linguistic articulation intersects with spatial reasoning and theoretical knowledge. As a discipline that integrates user experience, spatial configuration, and material understanding, interior design offers a fertile ground for positioning AI not only as a cognitive tool but also as a pedagogical assistant. This transformation reshapes how design knowledge is produced and transmitted, influencing students' creativity and critical engagement with design. However, how students perceive and negotiate these transformations within educational settings remains underexplored.

This study addresses this gap through a mixed-methods survey of fifteen interior design students conducted after a workshop introducing AI-based design tools. The survey focused on students' reflective evaluations rather than workshop outcomes. Findings reveal that students perceive AI as a supportive partner that assists in idea generation, enriches visualization, and facilitates narrative-driven design thinking, while also raising concerns about originality, ethics, and overreliance.

The study concludes that integrating AI into interior design curriculum requires reinforcement through critical literacy and structured pedagogical guidance, ensuring that computational assistance enriches learning in spatial representation, atmosphere, and user experience.

Keywords: Artificial intelligence, interior design pedagogy, design cognition, design thinking, reflective practice

1. Introduction

The rapid integration of artificial intelligence (AI) into design pedagogy has sparked new debates on how computational tools influence creativity, authorship, and critical thinking. In the context of interior design education, these debates carry particular weight, as linguistic articulation and spatial reasoning are deeply intertwined with designers' intrinsic values and theoretical knowledge (Brooker & Stone, 2010; Ching, 2012; Pile, 2007; Piotrowski, 2014). While existing studies have conceptualized AI as a transformative force in design cognition (Adeleye, 2023; Patel, 2024; Pfeiffer, 2018), empirical insights into how students perceive and navigate these transformations within pedagogical settings remain scarce.

This study aims to address this gap by examining students' reflections on AI-based design processes in interior design education, revealing how they conceptualize AI as a pedagogical partner following their workshop experience. Recent studies have positioned AI as a linguistic interface capable of reshaping the communicative dimension of design thinking (Agarwal, 2024; Almaz et al., 2024; Li et al., 2024). These perspectives point to a shift from tool-based to dialogue-based design processes, where AI acts as a collaborative agent in the articulation of

design intent. Complementing this view, interior design pedagogy provides a distinctive context in which user experience, spatial configuration, and material knowledge intersect with conceptual reasoning (Abercrombie, 2018; Gibbs, 2005; Uçar et al., 2025). Within this framework, AI extends beyond output generation, mediating reflective engagement that prompts students to question assumptions about creativity, originality, and responsibility.

Building upon the earlier study by Gökdemir and Kayan (2025), which examined the integration of AI as a linguistic interface in interior design education, this research shifts from process-based analysis to a student-centered reflective investigation. While the earlier study focused on how AI shaped linguistic and spatial articulation during the design process, the present research extends this inquiry toward understanding how students retrospectively interpret and evaluate those experiences. In that constructive linguistic study, a two-month workshop was conducted with fifteen undergraduate students at Istanbul Technical University, where AI tools such as ChatGPT-4o and DALL-E were used to explore text-to-text (txt2txt) and text-to-image (txt2img) generative processes for scenario-based spatial representations. The workshop demonstrated how linguistic articulation shaped spatial reasoning and how structured AI dialogues enhanced conceptual coherence, visual consistency, and critical awareness throughout the design process.

The present study builds directly on this pedagogical experiment, examining the reflections of students who participated in or were later introduced to the same AI-supported framework. To capture and assess this reflective dimension, a follow-up survey was conducted as a complementary phase rather than an independent assessment, aiming to reveal interpretive insights that were not observable during the workshop itself. Through this connection, the research explores how the same AI-driven learning environment is re-experienced by students as a pedagogical assistant that structures design communication while fostering critical thinking, creativity, and authorship awareness within interior design education. As illustrated in Figure 1, the conceptual framework of the study positions artificial intelligence as a design tool that operates at the intersection of language, communication, and interior design (Figure 1). In this context, the term ‘pedagogical assistant’ refers to AI’s active role in mediating learning processes rather than merely automating design tasks.

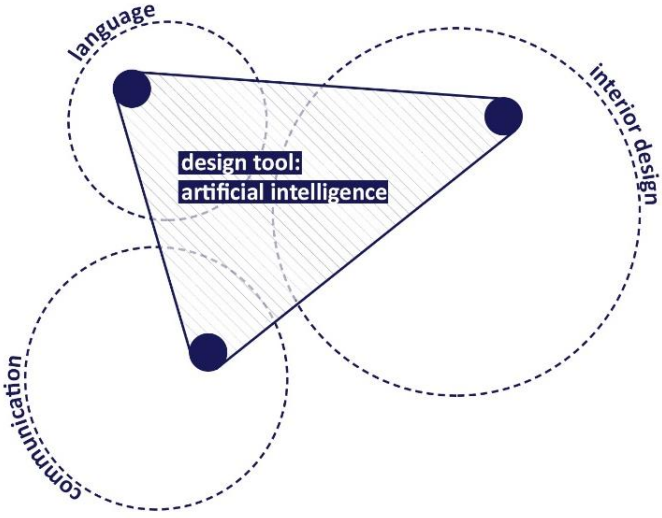


Figure 1. Conceptual background of the study.

2. Materials and Methods

The study was conducted within the pedagogical framework of a two-month AI-assisted design workshop that formed the basis of the earlier constructive research by Gökdemir & Kayan (2025). Implemented with fifteen undergraduate interior design students at Istanbul Technical University, the workshop was designed as a progressive process composed of four interrelated phases:

(a) Conceptual framing, in which students developed text-based spatial scenarios focused on historical healing environments,

(b) Initial AI integration, where tools such as ChatGPT-4o and DALL-E were introduced to visualize scenario narratives through text-to-text and text-to-image generative processes,

(c) Iterative dialogue, during which students refined their prompts through a guided model (SV + HS) designed to enhance consistency between linguistic input and spatial output,

(d) Final evaluation, where students analyzed the coherence between their narratives and AI-generated visual representations (Figure 2).

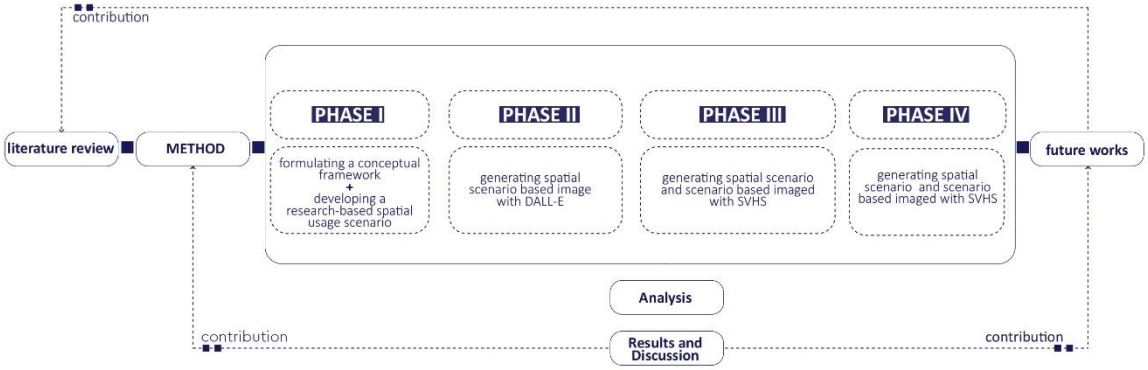


Figure 2. Workshop process.

The workshop produced a diverse set of outputs, including scenario texts, AI-generated images, and structured dialogue records that demonstrated how linguistic articulation shaped spatial reasoning. These results showed that AI could function as a linguistic co-agent in the design process, enriching conceptual clarity and visual communication. However, beyond these tangible outcomes, understanding how students perceived and interpreted these hybrid processes—how they internalized, critiqued, and reflected on AI-assisted design—became equally significant. This need led to the development of a student-centered follow-up survey as an extension of the pedagogical inquiry.

A mixed-methods survey was conducted with the same group of fifteen interior design students. Developed with reference to the Learning Object Evaluation Scale, the survey aimed to assess students' reflective evaluations of AI-assisted design processes rather than the workshop activities themselves. The Learning Object Evaluation Scale was selected because it provides a structured framework for assessing both the pedagogical and technical dimensions of digital learning environments, aligning closely with the hybrid nature of AI-assisted design education. The instrument was structured to capture both quantitative and qualitative dimensions of learning, focusing on students' perceptions of creativity, authorship, and cognitive engagement with AI-based tools. Quantitative items measured the perceived impact of AI on design learning, while qualitative questions explored students' individual concerns, expectations, and

interpretive insights. Data analysis combined descriptive statistics with thematic coding of open-ended responses to provide a comprehensive understanding of students' reflections and learning experiences.

The survey consisted of twelve questions and was completed anonymously. The first question identified participants' year of study in the interior design program, while the second examined whether they had prior experience with AI-based design tools. Questions three through nine were designed as five-point Likert scale items evaluating students' perceptions of the workshop process, the integration of AI tools, and the relationship between their scenario narratives and generated visual outputs. The final three questions (10–12) were open-ended, allowing students to provide reflective assessments of the workshop and their experiences with AI-based tools. To ensure objectivity and confidentiality, all responses were collected anonymously.

The survey was structured according to the four key dimensions of the Learning Object Evaluation Scale: educational content, design and presentation, interaction level, and technical adequacy (Leacock, 2004; Nesbit et al., 2002). Learning objects are defined as reusable, modular digital units designed to facilitate structured knowledge transfer, and their evaluation provides valuable insights into how digital tools function as pedagogical mediators (Wiley, 2002; Churchill, 2007). Within this framework, the educational content dimension assesses the clarity, alignment, and adaptability of materials with intended learning outcomes, while the design and presentation dimension concerns the visual organization and aesthetic quality that enhance motivation and comprehension (Mishra & Koehler, 2006). The interaction level refers to the extent of engagement between the learner and the digital tool, emphasizing how language, terminology, and prompt formulation influence production in AI-assisted environments (Moreno & Mayer, 2007). The technical adequacy dimension focuses on system performance, accessibility, and platform stability, all of which shape user experience and learning efficiency.

In this study, these four dimensions were applied to evaluate students' communicative and productive interactions with AI-based design tools. Each survey question corresponded to at least one dimension, encompassing subthemes such as content knowledge, scenario-oriented production, linguistic structure, and technical experience. Through this correspondence, the survey provided a multidimensional assessment of students' cognitive, technical, and communicative engagement within the learning process. The results, therefore, offered a holistic understanding of the pedagogical potential of AI-based design tools as learning objects within interior design education (Figure 3).

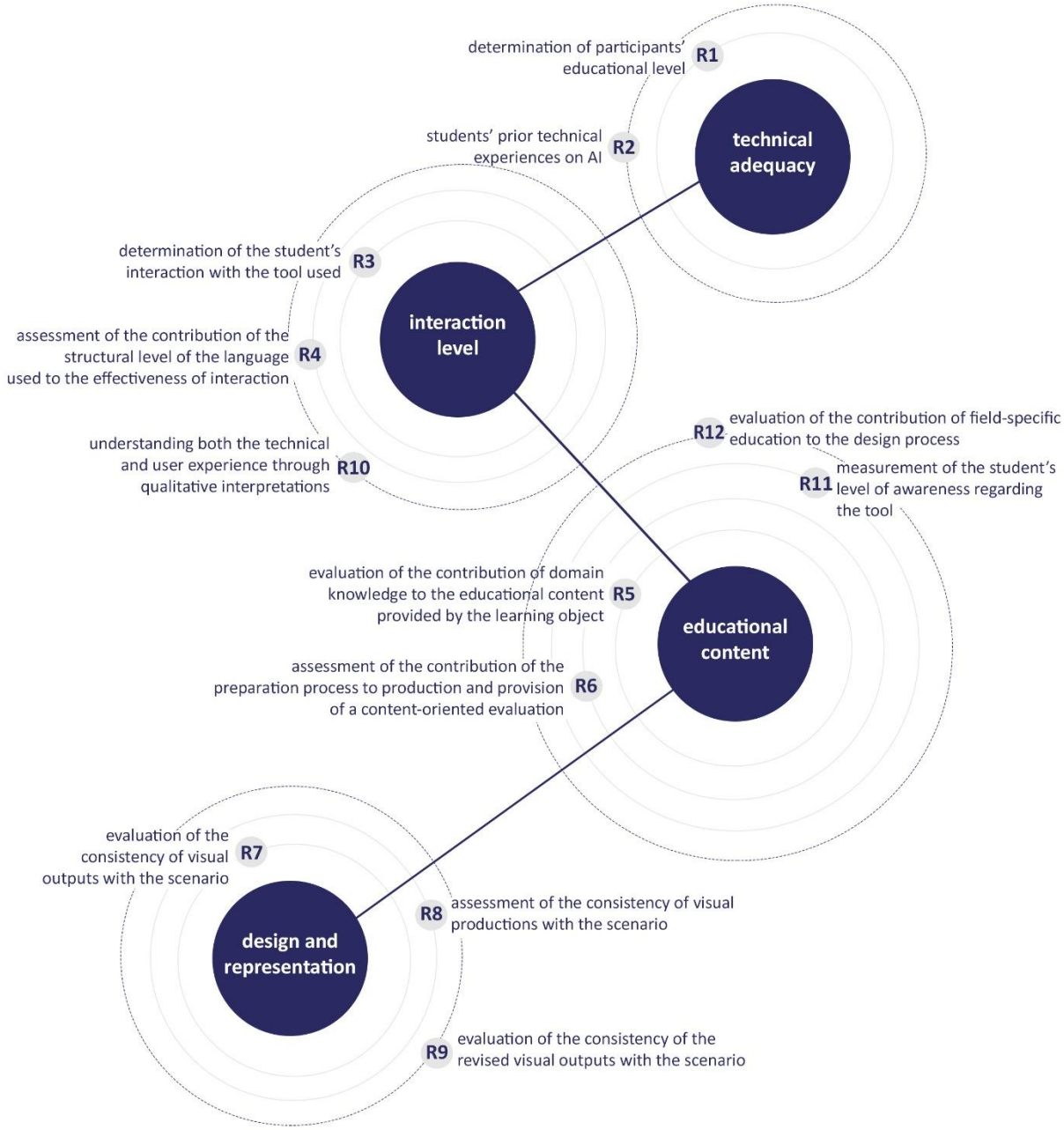


Figure 3. Evaluation of the survey content (R1-12) in parallel with the learning object evaluation scale.

3. Findings and Discussion

Building upon the reflective phase described earlier, this section operationalizes the theoretical shift from conceptualizing AI as a linguistic interface to understanding it as a pedagogical assistant. Through students' reflective evaluations, the empirical analysis translates this theoretical link into concrete educational insight. By doing so, this section presents and discusses the empirical findings derived from the mixed-methods survey conducted with 15

interior design students. Although the participant group was limited to fifteen students, the consistency of responses across both quantitative and qualitative dimensions strengthens the internal validity of the findings. The results are organized thematically to illustrate how students perceived, interpreted, and reflected upon the role of AI within the design learning process. Quantitative data provide an overview of students' general attitudes toward AI-assisted design, while qualitative reflections reveal deeper insights into their cognitive, linguistic, and ethical considerations. The discussion integrates both dimensions to outline how AI was experienced not only as a technical tool but as a pedagogical agent mediating creativity, authorship, and reflective thinking in interior design education.

The quantitative findings reveal how students perceived the communicative and procedural dynamics of AI-assisted design learning. Table 1 summarizes these results (Table 1). Overall mean scores ranged between 4.00 and 4.50 out of 5, indicating a consistently positive evaluation of linguistic, conceptual, and iterative dimensions of the process.

Table 1. Quantitative findings.

questions		**question_3** effect of the used language	**question_4** effect of sentence structures	**question_5** effect of the terminology	**question_6** effect of the individual research	**question_7** consistency between text and visual (2nd phase)	**question_8** consistency between text and visual (3rd phase)	**question_9** consistency between text and visual (4th phase)
students	student 1	3	4	4	4	4	5	5
	student 2	4	5	4	5	4	4	4
	student 3	5	5	5	5	4	4	4
	student 4	5	3	5	5	4	5	3
	student 5	4	4	4	5	4	4	3
	student 6	4	4	5	3	4	3	3
	student 7	3	4	4	2	4	3	4
	student 8	4	5	4	3	3	3	3
	student 9	4	5	5	5	4	5	4
	student 10	4	4	5	5	4	4	4
	student 11	4	5	5	5	3	4	4
	student 12	4	4	3	4	4	4	4
	student 13	3	3	4	4	4	4	5
	student 14	4	3	4	4	4	4	4
	student 15	5	5	5	4	4	4	4

The quantitative results of the survey, based on questions 3–9, reveal that students developed a strong awareness of the linguistic, cognitive, and iterative dimensions of AI-assisted design learning. Overall mean scores ranged between 4.00 and 4.50, indicating a predominantly positive perception of the AI-supported process.

When asked "Do you think the language you used was effective in communicating with the AI-based design tool?", most students agreed that the wording of their prompts was crucial in guiding the AI's responses. The mean score of 4.20 demonstrates that language functioned not merely as a medium of instruction but as a generative mechanism that shaped design decisions and spatial reasoning. This suggests that students actively recognized the relationship between linguistic precision and the quality of the design outcomes. Similarly, in response to the question "Do you think the sentence structures you used were effective in communicating with the AI tool?", the average score of 4.13 indicated that syntactic clarity and well-structured expressions contributed meaningfully to the effectiveness of AI-assisted production. Taken collectively, these linguistic parameters—clarity, syntax, and terminology, illustrate how students gradually developed communicative agency in directing AI outputs. Students observed that carefully composed and goal-oriented sentences helped translate abstract design ideas into coherent visual and narrative outputs. This result also reflects the pedagogical need to cultivate grammatical awareness and linguistic structure as integral components of design literacy.

The highest average score (4.47) emerged in response to "Do you think the terminology you used was effective in communication with the AI tool?". Students acknowledged that the correct use of disciplinary terminology not only improved AI comprehension but also added conceptual depth to their design reflections. They emphasized that terminological accuracy strengthened both communicative precision and cognitive coherence, confirming that technical vocabulary operates as a form of design knowledge in itself. Regarding preparatory research, students answered the question "To what extent did your preliminary research before using AI influence your communication with the design tool?" with a mean score of 4.13, suggesting that independent investigation prior to engaging with AI tools enriched their conceptual framing and scenario development. They highlighted that the process of research fostered a deeper understanding of the project context and improved their ability to formulate meaningful prompts aligned with design intentions.

The stage-based questions provided further evidence of progress in text–image consistency throughout the workshop. For the second stage—"How well did the AI-generated visuals correspond to your scenario?"—the mean score of 3.93 reflected initial challenges in aligning narrative intent with visual representation. In the third stage, this value rose to 4.00, and by the fourth stage "How well did the AI-generated visuals correspond to your scenario in the final phase?" the mean reached 4.47, demonstrating significant improvement. This upward trend confirms that students gradually refined their prompting strategies and achieved greater conceptual alignment between textual input and visual outcome.

Taken together, the overall improvement in mean scores highlights the development of multimodal literacy, where students combined linguistic and visual reasoning into a coherent reflective practice. Within this process, according to students' reflections AI emerged not merely as a technical instrument but as a collaborative cognitive partner which students practiced linguistic precision, conceptual articulation, and reflective authorship.

The qualitative findings, derived from students' open-ended responses, complement the quantitative results by illuminating how they interpreted and internalized their experiences with AI-based design tools. The thematic analysis identified two major domains of reflection: (1) communicative parameters influencing the quality of interaction and (2) design contributions highlighting AI's pedagogical role in the design process.

When reflecting on the communicative dimension, students consistently emphasized the importance of language clarity, accurate word choice, disciplinary terminology, and prompt structure including the length and number of commands. They noted that the clarity of expression directly determined the reliability and relevance of AI-generated results. Many respondents described effective collaboration with AI as dependent on both linguistic precision and conceptual understanding, stating that even small ambiguities in sentence formulation could significantly alter visual outcomes. These remarks strongly corroborate the quantitative results, particularly the high ratings assigned to language, sentence structure, and terminology.

On the design side, students articulated a wide range of areas where AI contributed to their creative and cognitive processes. They highlighted its role in concept generation, scenario writing, creativity enhancement, idea development, visualization, and atmosphere design. Several participants noted that AI served as a stimulus for imagination, especially in the early stages of ideation, helping them break through conceptual barriers and explore alternative solutions. At the same time, they recognized AI as a facilitator of reflection, enabling them to iteratively test and refine ideas rather than accepting initial outputs at face value.These reflections underscore that students perceived their interaction with AI not as a command-response mechanism but as a dialogic and reflective exchange. They learned to view the AI-assisted process as one that required continuous critical engagement, linguistic precision, and ethical awareness. Many also warned that uncritical dependency on AI could limit personal authorship, indicating an emerging sensitivity toward responsible design practices. These insights underscore the need to integrate ethical reflection into AI literacy within design curricula, ensuring that critical awareness accompanies creative experimentation.

The thematic mapping illustrates the relationship between communicative parameters and design contributions, showing how linguistic factors such as clarity, terminology, and conceptual mastery correlate with design outcomes like creativity and scenario coherence (Figure 4). This relationship reinforces the effectiveness of the language-driven pedagogical model applied in the workshop.

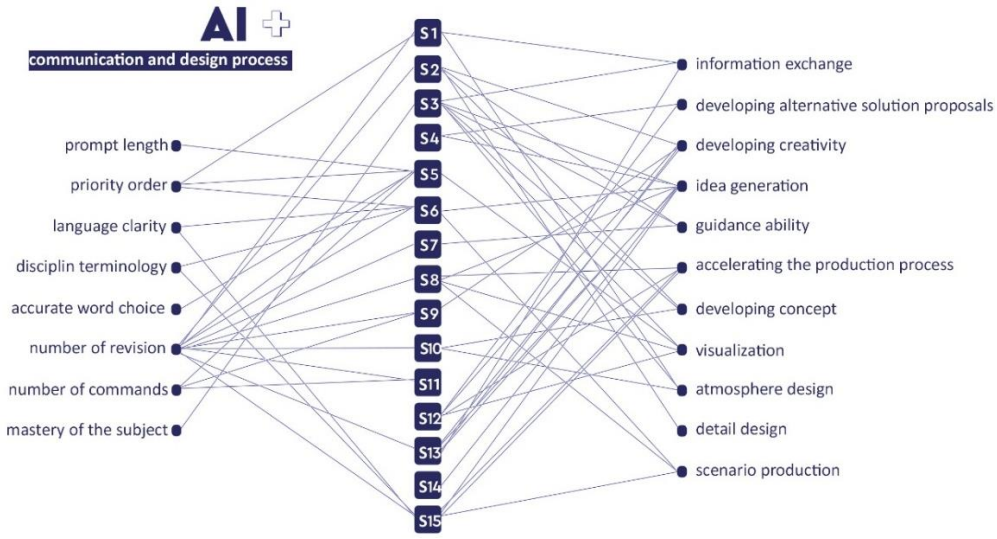


Figure 4. Thematic mapping of qualitative findings

Overall, the qualitative findings depict AI as a pedagogical assistant that supports self-reflection, conceptual awareness, and linguistic literacy rather than replacing human creativity.

When embedded within a structured and ethically guided curriculum, such tools can nurture students' reflective capacity and strengthen the dialogic nature of interior design education.

Together, the quantitative and qualitative analyses demonstrate that AI-assisted learning fosters linguistic sensitivity, iterative reasoning, and reflective authorship—key competencies for cultivating a critically engaged and communicative design pedagogy.

4. Conclusion and Recommendations

This study explored how interior design students perceive and negotiate the integration of artificial intelligence in design learning, reframing AI from a cognitive tool to a pedagogical assistant. The findings revealed a dual perception: while students recognized AI as a catalyst for idea generation, visualization, and narrative thinking, they simultaneously expressed concerns about originality, authorship, and ethical responsibility. These tensions illustrate the necessity of embedding AI within a structured pedagogical framework that fosters both creativity and critical literacy.

The originality of this research lies in its focus on interior design education—a field where linguistic articulation, spatial reasoning, and user experience intersect. By analyzing students' reflective responses through the lens of the Learning Object Evaluation Scale, the study expands the discussion of AI beyond efficiency or aesthetics, situating it within communicative and cognitive dimensions of learning. It demonstrates that AI can mediate reflective engagement, linguistic awareness, and multimodal literacy when pedagogically contextualized.

Nevertheless, the study's scope remains limited to a single institutional context and a small participant group, restricting the generalizability of its findings. Future studies could extend this framework across different educational settings, longitudinally investigate how students' perceptions evolve over time, or examine the role of AI dialogue interfaces in cultivating design authorship. Building upon the current results, further research should explore how AI tools can be integrated into interior design curricula without diminishing reflective depth, what forms of pedagogical scaffolding can balance computational assistance with creative autonomy, and how AI-mediated communication might transform design studios into more dialogic and participatory learning environments.

Ultimately, this research contributes to the emerging discourse on AI-integrated design pedagogy by offering a model for interpreting computational tools as communicative and pedagogical interfaces rather than as mere productivity enhancers. Its theoretical contribution lies in redefining the relationship between linguistic articulation and spatial reasoning within design cognition. Practically, it provides an adaptable framework for instructors aiming to integrate AI tools into interior design education in ways that maintain critical, ethical, and creative balance.

In conclusion, the study emphasizes that the future of AI in design education depends not solely on technological advancement but on cultivating reflective, linguistic, and ethical literacy—qualities that preserve the interpretive depth of design learning while enabling meaningful collaboration between human and artificial intelligence.

Thanks and Information Note

This study is derived from the doctoral dissertation currently being conducted by Gözde Gökdemir under the supervision of Assoc. Prof. Hande Zeynep Kayan within the Interior Architecture PhD Program at the Graduate School of Mimar Sinan Fine Arts University. The

authors would like to express sincere gratitude to Prof. Dr Ervin Garip at Istanbul Technical University for his invaluable support and contributions throughout the workshop process, particularly for providing the educational framework in which the study was conducted. The authors are also grateful to students who participated in the workshop for their active engagement and creative productions, which significantly enriched the outcomes of this research.

The authors declared no potential conflicts of interest with respect to the research, authorship, or publication of this article and all authors contributed equally to the article.

The article complies with national and international research and publication ethics. The study was approved by the The Ethics Committee of the Mimar Sinan Fine Arts University (Ethical Clearance Reference Number: 202583) on October 15, 2025. All participants provided written informed consent prior to participating

References

Abercrombie, S. A. (2018). *Philosophy of interior design.* London: Routledge.

Adeleye, I. O. (2023). The AI effect: rethinking design workflows for enhanced productivity and creativity. *International Journal of Science and Technology Innovation,* 2, 1–19. doi:10.70560/c9m3kd97.

Agarwal, M. K. (2024). Paradigm shift in architectural pedagogy incorporating artificial intelligence. *Ijraset Journal For Research in Applied Science and Engineering Technology,* 12, 1315–1329. doi: 10.22214/ijraset.2024.60055.

Almaz A. F., El-Agouz E. A. E., Abdelfatah M. T. & Raafat, I. (2024). The future role of artificial intelligence (AI) design's integration into architectural and interior design education is to improve efficiency, sustainability, and creativity. *Civil Engineering and Architecture*, 12(3), 1749–1772. doi:10.13189/cea.2024.120336.

Brooker, G. & Stone, S. (2010). *What is interior design?.* Sussex: Rotovision.

Ching, F. D. K. & Binggeli, C. (2012). *Interior design illustrated.* Princeton, NJ: Wiley and Sons.

Churchill, D. (2007). Towards a useful classification of learning objects. *Educational Technology Research and Development,* 55(5), 479-497. doi:10.1007/s11423-006-9000-y.

Gibbs, J. (2005). *Interior design.* London: Laurence King Publishing.

Gökdemir, G. & Kayan, H. Z. (2025). Artificial intelligence as a linguistic interface in interior design education: Reconceiving design tools as communication media. *International Journal of Architectural Computing,* doi:10.1177/14780771251352955

Leacock, T. (2004). Learning object evaluation and convergent participation: Tools for professional development in e-learning. V. Uskov (Ed.), *Proceedings of the IASTED International Conference on Computers and Advanced Technology in Education.* Hawaii, USA. Access Address (21.10.2025): https://www.actapress.com/Content_Of_Proceeding.aspx?ProceedingID=261.

Li, X., Xia L, He Z, Wu, P., Chen, D. & Fan, L. (2024). Enhancing interior design education through the integration of AIGC tools: a novel "creatorthon" approach. I*EEE Frontiers*

in education conference. Washington., USA. Access Address (21.10.2025): doi:10.1109/FIE61694.2024.10893341

Mishra, P., & Koehler, M. J. (2006). Technological pedagogicalcontent knowledge: A framework for teacher knowledge. *Teachers College Record,* 108(6), 1017–1054. doi:10.1111/j.1467-9620.2006.00684.x

Moreno, R. & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review,* 19. doi:10.1007/s10648-007-9047-2.

Nesbit, J. C., Belfer, K. & Vargo, J. (2002). A convergent participation model for evaluation of learning objects. *Canadian Journal of Learning and Technology,* 28(3), 105–120. doi: 10.21432/T25C8C.

Patel, K., Beeram, D., Ramamurthy, P., Garg, P. & Kumar, S. (2024). AI-enhanced design: revolutionizing methodologies and workflows. *International Journal of Artificial Intelligence Research and Development*, 2(1), 135–157. https://iaeme.com/Home/issue/IJAIRD?Volume=2&Issue=1

Pfeiffer, A. (2018). *Creativity and technology in the age of AI.* Malakoff: Pfeiffer Report.

Pile, J. (2007). *Interior design.* London: Pearson.

Piotrowski, C. M. (2014). *Professional practice for interior designers.* Princeton, NJ: Wiley and Sons.

Uçar, U. E., Gökdemir, G., Güzelci, O. Z., Garip, E., & Garip, B. (2025). Enhancing design pedagogy with architectural technology: integrating rule-based and generative approaches. *Open House International,* 50(3), 526-542. doi: 10.1108/OHI-03-2024-0122.

Wiley, D. (2002). Learning Objects Need Instructional Design Theory. A. Rossett (Ed.). *The ASTD e-Learning Handbook,* (pp. 115-126). New York, NY: McGraw-Hill.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Landscape Character Analysis Evaluation in Rural Settlements: Erzurum Palandöken Example

Ahmet KOÇ [1]*

ORCID 1: 0000-0001-6932-6680
[1] Assoc. Prof. Dr., Dicle University, Vocational School of Technical Sciences, Park and Garden Plants Department, Diyarbakır-Türkiye
ahmet.koc@dicle.edu.tr (Responsible Author)

Sevgi YILMAZ [2]

ORCID 2: 0000-0001-7668-5788
[2] Prof. Dr., Atatürk University, Architecture and Design Faculty, Landscape Architecture Department, Erzurum-Türkiye
sevgiy@atauni.edu.tr

Abstract

Landscape Character Analysis (LCA) is an essential methodology for comprehending and overseeing the intricate interconnections among the biological, cultural, and perceptual characteristics of landscapes. LCA seeks to advance sustainable land utilization and the preservation of biodiversity. Recently, it has emerged as a novel planning approach aimed at addressing the unintentional exploitation of environment and its associated issues. The Palandöken rural settlement area served as the basis for this model. Raster files, including geology maps, main soil group maps, contour maps, Corine land use maps, and vegetation maps, from the 575 km² research region were digitized with ArcGIS 10.2. The digitized maps were consolidated for the application of the LCA approach. Consequently, these groups revealed two distinct elevation zones, fourteen geological formation kinds, three principal soil groups, three vegetation types, and five land use categories. The use of the LCA technique via on-site observations in the study region found 78 landscape character types and 10 distinct landscape character patterns in the Palandöken rural settlement area. Recommendations were formulated for several prospective applications of the research area based on the acquired results.

Keywords: Palandöken, landscape character analysis, landscape pattern

1. Introduction

Landscape character is defined as the distinct and perceivable pattern of natural, cultural, and historical elements that distinguishes one landscape from another. It provides a framework for spatial planning, heritage conservation, and the sustainable management of human-environment interactions. The landscape character of an area or region can be defined as a distinct and recognizable pattern of elements within the landscape, focusing on managing landscapes sustainably rather than simply preserving their texture (Zhao et al., 2023; Hong et al., 2024). Landscape character analysis (LCA), on the other hand, is a systematic methodology used to assess and describe the unique physical, cultural, and visual attributes of a landscape, which are essential for informed planning and sustainable development (Öztürk et al., 2020). It uses quantitative techniques such as clustering and segmentation, as well as qualitative assessments, to identify distinct landscape character types and areas (Wang et al., 2023). Practitioners use LCA to support rural settlement management, heritage conservation, and spatial planning by mapping variables ranging from landforms to cultural heritage features. This process informs decisions that balance ecological sustainability with socioeconomic needs (Öztürk et al., 2020; He et al., 2024). In this context, LCA integrates natural and human dimensions into a coherent framework that guides development, resource management, and the protection of distinctive landscape values in various environments (Wang et al., 2023; Pihler et al., 2021). Through this integration, it offers a multifaceted package of benefits that enhance spatial planning, sustainable development, community participation, and tourism management. Another of the

key benefits of LCA is the ability to identify the unique biophysical and cultural characteristics of a landscape, thereby informing decision-making, and that it allows providing a structured framework for spatial planning (Teh et al., 2017; Oliveira and Guiomar, 2016). By identifying the distinctive spatial patterns and intrinsic qualities of a given area, LKA facilitates tailor-made management strategies that are compatible with the objectives of the European Landscape Convention and respect natural beauty and local heritage (Oliveira and Guiomar, 2016; Morrison et al., 2018). This analytical process increases the capacity of planners and policy makers to integrate ecological, cultural, and social dimensions into environmental management, optimizing resource allocation and informing politicians (Teh et al., 2020; Morrison et al., 2018)

Erzurum is a province encompassing diverse landscape compositions due to its geographical location. Palandöken, located close to the Erzurum central district, reflects the province's general characteristics. This study aims to determine the landscape character analysis and potential of Palandöken, a location with a natural and cultural landscape potential and an area of 575 km².

2. Materials and Methods

The material of the study area is located in the Palandöken border, which is located at the coordinates of 39°50′56″N 41°17′03″E in Erzurum province and has an area size of approximately 575 km² (Figure 1). The Palandöken study area has an altitude of between 3200 and 2100 m.

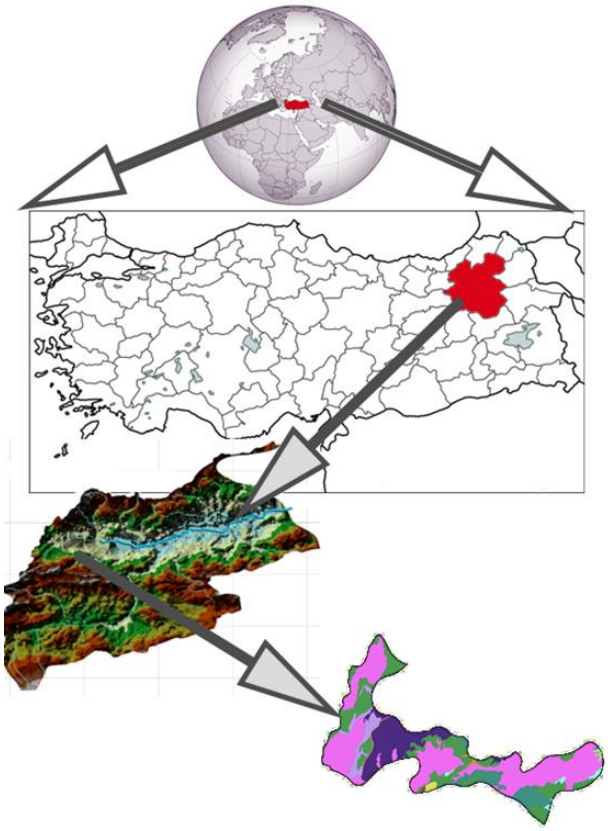


Figure 1. Map showing the location of the study area

2.1 Determination of landscape types of the study area

Typologies based on the association of essential landscape variables—topography, land use, predominant soil groups, geological formations, and land capacity classes—were modified from Wascher 2005 and Atik et al. 2015 (Figure 2). The "Landscape Character Method," utilized in the context of the European Landscape Character Initiative (ELCA), was applied to identify local landscape character types. A five-letter coding system was implemented to classify the landscape character types in the Palandöken Landscape Character Area, situated inside Erzurum Province.

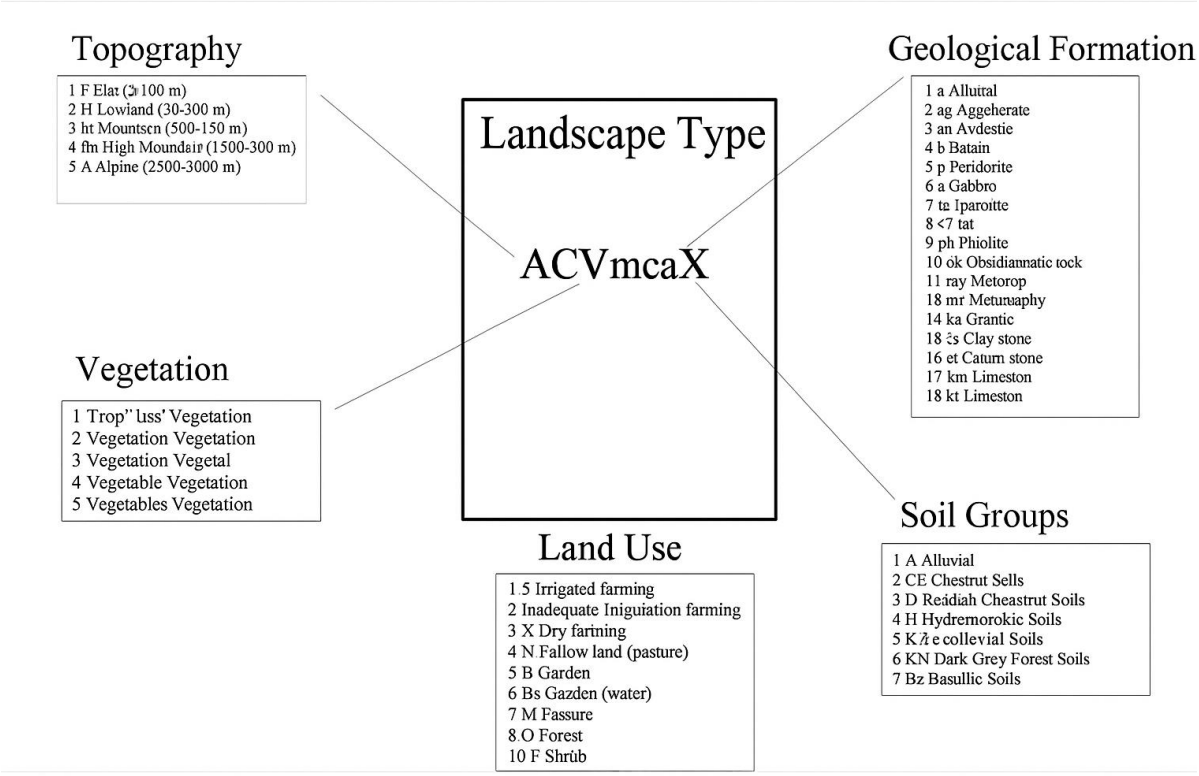


Figure 2. Landscape type classification system (Washer 2005; Atik et al. 2015)

2.2 Utilization of Geographic Information Systems (GIS) Tools in the Study Area

Subsequent to the formulation of the landscape classification type for the study region, the resultant data was digitized using Arc-GIS 10.2. The topography, soil types, soil classifications, vegetation, geological context, and land use layers were superimposed. A landscape typology map was generated using the superimposed maps.

A model was developed in the Model Builder of Arc-GIS 10.2 to intersect the typology maps for the creation of the landscape typology map. To reduce the inaccuracy in this model, the overlays were constructed from vector maps. The Intersect submodule in the Overlay layer of the Analysis Tools module was utilized to superimpose the vector maps. Subsequent to utilizing the module, classifications of landscape types were produced. Microsoft Excel was employed to categorize these classes. Subsequent to grouping, the raster landscape typology maps were imported into the attribute table in Arc-GIS and subsequently generated within the Classification module (Figure 3).

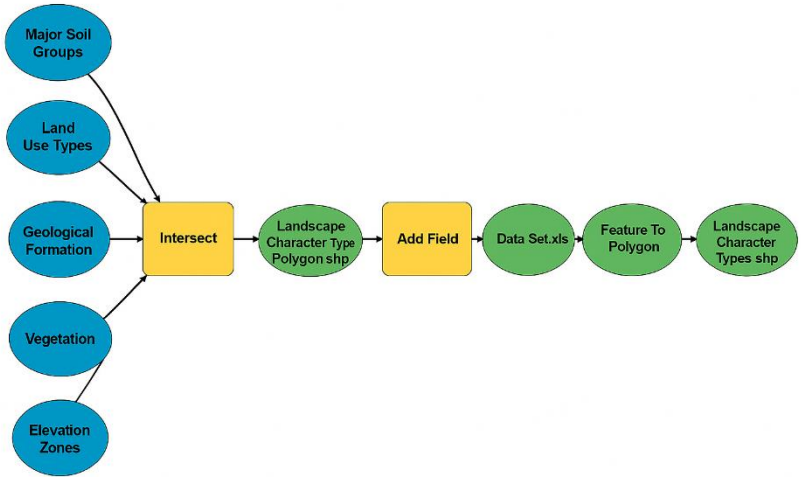


Figure 3. Model used to create landscape typology maps

3. Findings and Discussion

In the analysis of the Palandöken landscape character region, which spans 575 km², 78 landscape character types were discovered, and 10 landscape patterns were delineated (Figure 4). The predominant landscape type in the Palandöken landscape character area is classified as AMvManX, characterized by alpine topography, prevalent pasture vegetation, primary land use for pastures, and geological formations of andesite layers, with basaltic soils as the principal soil group. Simultaneously, it was shown that natural meadows and shrublands predominated the Palandöken Landscape character region within the landscape patterns identified in the CORINE type 2 land classification (Figure 6).

From 2014 to 2017, intermittent field studies were conducted in the Palandöken landscape character area throughout various time intervals. The field research revealed that the land possessed a rough structure. Consequently, the existence of herbaceous plants and a limited quantity of broadleaf woods may be noted in the area.

Table 1. Data from the Palandöken landscape character area

Number of Character Types	Number of Landscape Patterns	Area Covered (Km²)	Number of Area Uses	Altitude Zone	Geological Formation	Great Land Group	Vegetation Number
78	10	575	5	2	14	3	4

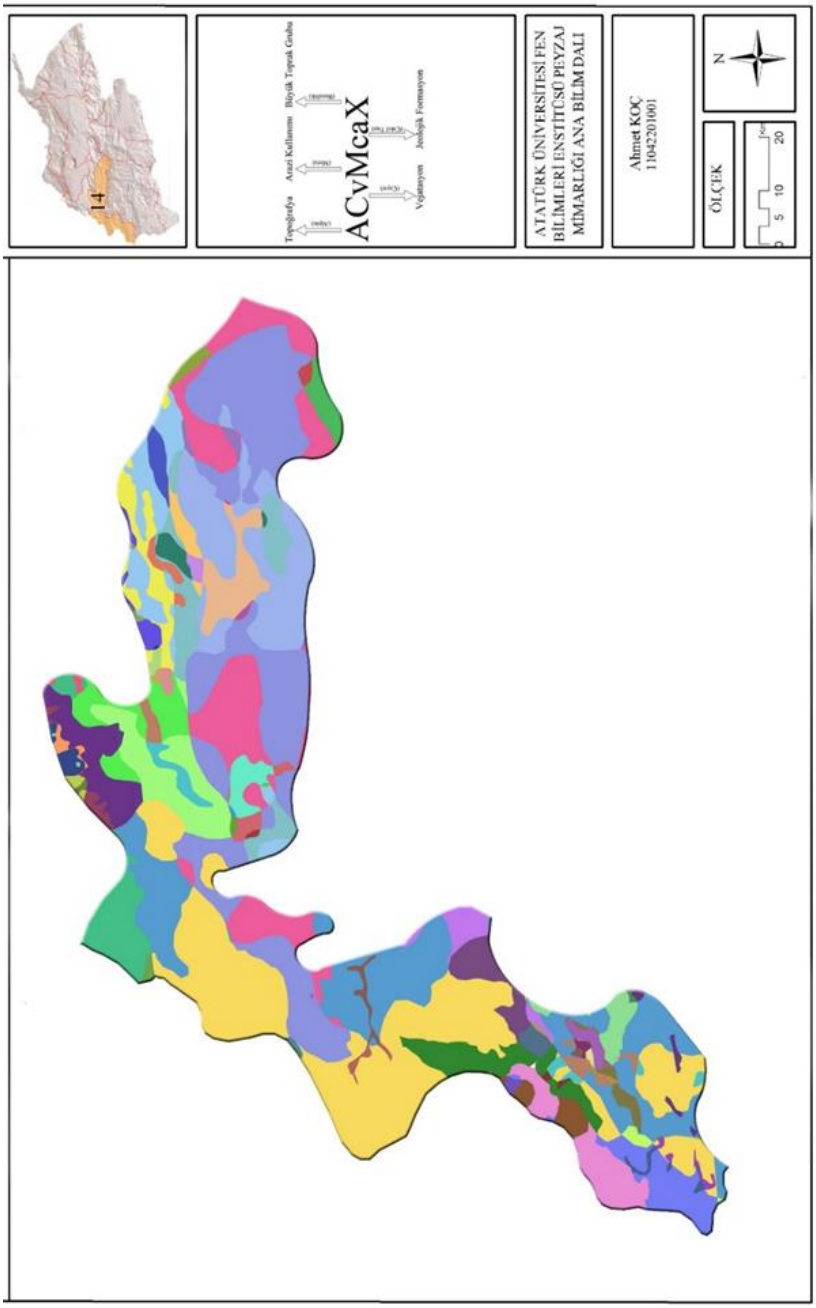


Figure 4. Palandöken landscape character types

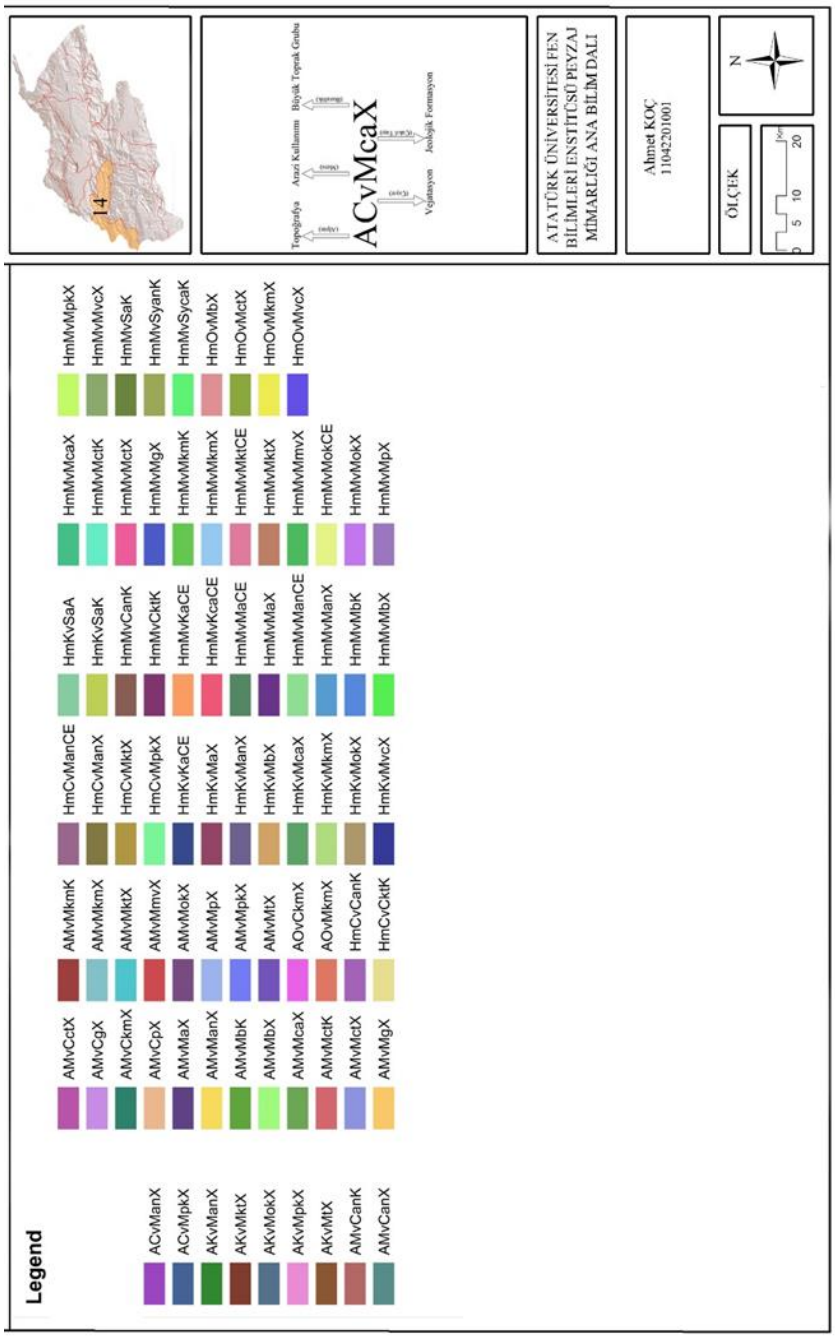


Figure 5. Palandöken landscape character types legend

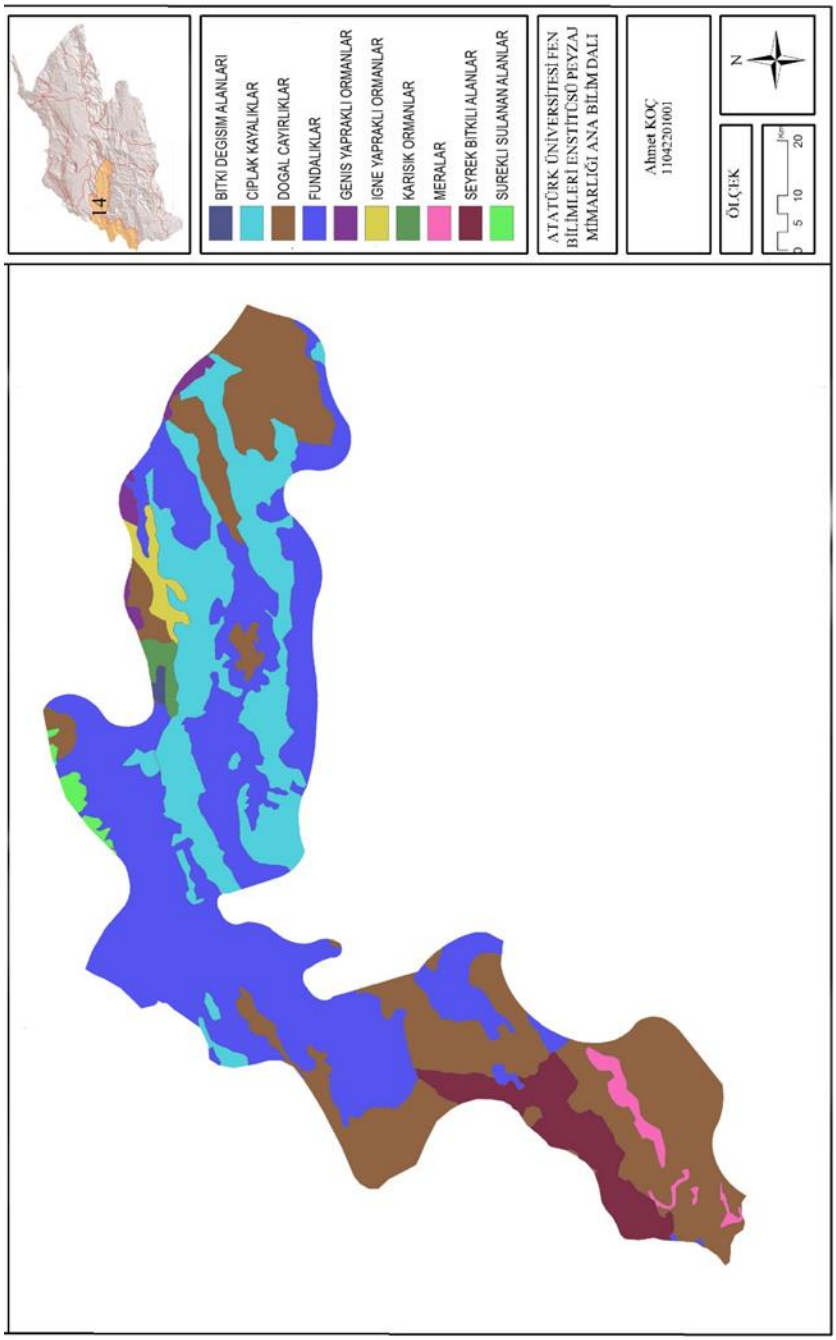


Figure 6. Landscape patterns of the Palandöken landscape character area

Conclusion and Recommendations

Types of landscape character in the research area: In the Palandöken rural settlement region, 78 landscape character categories and 10 distinct landscape character patterns were found. The spatial distribution among these landscape types ranges from 0.002 km² to 23.08 km². In the entirety of the research region, the predominant landscape character type is HmKvSaA, characterized by high mountainous topography, cultural vegetation cover, irrigated agricultural

land use, geological formations with alluvial layers, and an alluvial soil group. This predominant landscape character type encompasses an area of 23.08 km², or approximately 2.1% of the total area.

A further issue observed in the research area is the emergence of regions designated as pastures, modified by anthropogenic vegetation, indicating areas transformed by human activity. Amendments were enacted to Pasture Law No. 4342 on February 25, 1998, which ensured optimal utilization of pastures. Nevertheless, human involvement has caused the vegetation type to revert to a culturally predominant form.

Landscape character evaluations are crucial in basin planning and management. Öztürk (2011) asserts that effective basin management and planning necessitate the collaborative efforts of several professional specialties. Nevertheless, for the sustainable development of basin regions and the preservation of natural and cultural resource values, landscape character analysis studies will establish a basis for future efforts to safeguard the basin's resource values and promote the advancement of the adjacent community.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. This article was produced from a doctoral thesis. There is no conflict of interest in this article.All authors contributed equally to the article / Or 1st Author 50%, 2nd Author 50% contributed.

References

Atik, M., Işıklı, R. C., Ortaçeşme, V., & Yıldırım, E. (2015). Definition of landscape character areas and types in Side region, Antalya-Turkey with regard to land use planning. *Land use policy,* 44, 90-100.

He, D., Chen, W., & Zhang, J. (2024). Integrating heritage and environment: characterization of cultural landscape in beijing great wall heritage area. *Land*, 13(4), 536. https://doi.org/10.3390/land13040536

Hong, Z., Cao, W., Chen, Y., Zhu, S., & Zheng, W. (2024). Identifying rural landscape heritage character types and areas: a case study of the li river basin in guilin, china. *Sustainability*, 16(4), 1626. https://doi.org/10.3390/su16041626

Morrison, R., Barker, A., & Handley, J. (2018). Systems, habitats or places: evaluating the potential role of landscape character assessment in operationalising the ecosystem approach. *Landscape Research*, 43(7), 1000-1012. https://doi.org/10.1080/01426397.2017.1415314

Oliveira, R. and Guiomar, N. (2016). Landscape character assessment and regional landscape strategy in the azores, portugal., 127-138. https://doi.org/10.4324/9781315590110-22

Öztürk, S., Vural, Ö., & Meydan, K. (2020). Kırsal alanlarda peyzaj karakter analizi "Kastamonu-Gölköy ve Yakın Çevresi Örneği". *Turkish Journal of Agriculture - Food Science and Technology,* 8(8), 1720-1725. https://doi.org/10.24925/turjaf.v8i8.1720-1725.3480

Öztürk, S. (2011). Devrekani Çayı Alt Havzası Örnekleminde Havza Yönetim Planının Geliştirilmesi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, Ankara

Pihler, V., Vasiljević, N., Đorđević, D., Bajić, L., & Dunčić, D. (2021). New landscape conceptualization as a guideline for spatial development: a case study from serbian spatial planning practice. *Geographica Pannonica,* 25(3), 204-213. https://doi.org/10.5937/gp25-30177

Wang, Y., Du, J., Kuang, J., Chen, C., Li, M., & Wang, J. (2023). Two-scaled identification of landscape character types and areas: a case study of the yunnan–vietnam railway (yunnan section), china. *Sustainability,* 15(7), 6173. https://doi.org/10.3390/su15076173

Teh, M., Ghani, I., Abdullah, M., & Pugi, N. (2020). Landscape character: relationship between existing acts, policies and guidelines in malaysia. *Environment-Behaviour Proceedings Journal,* 5(14), 165-170. https://doi.org/10.21834/ebpj.v5i14.2259

Teh, M., Pugi, N., & Rahman, N. (2017). Visual landscape assessment for development landscape structure: case study at taiping, perak. *Environment-Behaviour Proceedings Journal,* 2(5), 231. https://doi.org/10.21834/e-bpj.v2i5.698

Wang, Y., Du, J., Kuang, J., Chen, C., Li, M., & Wang, J. (2023). Two-scaled identification of landscape character types and areas: a case study of the yunnan–vietnam railway (yunnan section), china. *Sustainability,* 15(7), 6173. https://doi.org/10.3390/su15076173

Wascher, D. M. (Ed.) 2005 Euro-pean Landscape Character Areas: Typologies, Cartography and İndicators for the Assessment of Sustainable Landscapes. Final project report as deliverable from the EU's Accompanying Measure Project, European Landscape Character Assessment Initiative (ELCAI), Environment and Sustai-nable Development, pp. 150

Zhao, S., Yang, D., & Chi, G. (2023). Identifying landscape character for large linear heritage: a case study of the ming great wall in ji-town, china. *Sustainability,* 15(3), 2615. https://doi.org/10.3390/su15032615

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Human-Centered Approaches to Educational Furniture Design: Ergonomic Analysis of Classroom Desks

Emre ECEVİT [1]

ORCID 1: 0009-0009-8358-2862
[1]Student, Kayseri University, Interior Design Program, Kayseri- Turkey
ecevit3899@gmail.com

Merve BİLGEN IŞIK [2 *]

ORCID 2: 0000-0001-7832-6527
[2]Lecturer, Design Department, Kayseri University, Interior Design Program, Kayseri- Turkey
mervebilgen@kayseri.edu.tr (Responsible Author)

Abstract

Ergonomics, defined as the adaptation of the physical environment to human needs, is closely related to interior design through a human-centered approach. In educational contexts, students spend a significant portion of their time at classroom desks; therefore, anthropometric compatibility and functionality constitute critical factors for comfort, attention, and learning. However, desks designed according to standard measurements do not adequately accommodate variations in students' physical characteristics, which may result in discomfort, distraction, and potential health risks. In Turkey, the most comprehensive anthropometric study in this field was conducted in 1937, and contemporary research on ergonomically optimized educational furniture remains limited. This study investigates classroom desks in the Interior Design Department at Kayseri University Technical Sciences Vocational School from an ergonomic perspective. The methodology involves the collection of 18 anthropometric measurements from 80 students, documentation of existing desk dimensions, and administration of a user experience survey. The data obtained are utilized to generate design proposals through three-dimensional modeling software. The study aims to develop adjustable and inclusive desk models that correspond to students' anthropometric characteristics. Such models are expected to minimize discomfort, enhance concentration, reduce health risks, and improve spatial comfort in educational environments. By prioritizing evidence-based and human-centered approaches, the research seeks to contribute to the advancement of ergonomic and equitable furniture design in higher education. The outcomes are intended to be disseminated at international conferences in order to support the wider implementation of adaptable classroom solutions.

Keywords: Ergonomics, interior design, anthropometry, educational furniture

1. Introduction

Ergonomics, which can be defined as the process of adapting the physical environment to the human body, originates from the Greek terms ergon (work, labor, product) and nomos (law, rule). Ergonomics applies theories, principles, data, and methods to design in order to enhance human well-being and optimize system performance (Weerdmeester, 2001). The primary aim of ergonomics is to make human life easier and more humane by improving living conditions, eliminating potential hazards, and promoting human health (Güler, 1997). As a multidisciplinary science, ergonomics examines every field in which humans are involved and seeks to ensure that individuals work more efficiently with less physical strain. The term was first introduced by Wojciech Jastrzebowski in 1857, and the foundational developments in the discipline were initiated by experts in experimental psychology (Yararel, 2019). Münsterberg's Psychology and Industrial Efficiency (1913) became one of the pioneering works in this field, followed by the establishment of the first laboratory of experimental psychology at Cambridge University in 1921. During World War II, significant losses caused by the lack of attention to human factors in rapidly developing weapons and machinery led to extensive studies on

human–machine systems. In the United States, the term human factors is widely used instead of ergonomics (Yararel, 2019).

In 1949, during a meeting at Oxford University chaired by Murrell, researchers from various disciplines—including anatomy, anthropology, physiology, psychology, engineering, and design—recommended the use of the term ergonomics (Köksüz, 2019). Anthropometry, one of the fundamental scientific bases of ergonomics, examines human body measurements and forms the basis for designing spatial and product dimensions. In interior architecture, anthropometric data are classified as static (body measurements in still positions) and dynamic (measurements of movements such as reaching and bending) (Kahya et al., 2018). Designing environments in accordance with the anthropometric characteristics of societies contributes significantly to the physical and psychological well-being of future generations. When the national literature on ergonomics in interior architecture and interior design is examined, only a limited number of graduate theses and articles are encountered. Existing studies largely focus on smart home systems, office spaces, or the effects of color, texture, and spatial organization in preschool and primary school interiors. Although related works—such as the theses titled The Effects of Environmental Graphics and Wayfinding Design in School Spaces for Children with Disabilities and Interior Space Design and Student Interaction in Primary Schools—provide broad perspectives, they do not focus specifically on school desk design (YÖK National Thesis Center, 2023). Yet, students spend most of their school time seated at desks, making this topic highly important and academically underexplored. In educational environments, ergonomics refers to organizing teaching and learning settings to maximize efficiency for both teachers and students. Education is broadly defined as a process of behavioral change, which requires suitable physical, social, and psychological conditions (Uşan, 2010; Dönmez, 2008). Considering that compulsory education occupies a major portion of children's developmental years, classrooms must be designed in accordance with the anthropometric characteristics of the society. International studies—such as The Effects of Standing Desks Within the School Classroom: A Systematic Review and The Role of School Desks on the Learning of Graphic Skills in Early Childhood Education in Brazil—demonstrate that classroom desk design significantly affects both physical development and learning performance.

Despite the availability of various desk models in the furniture industry, many designs lack scientific grounding and do not account for different user profiles or regional anthropometric data. This study therefore conducts an ergonomic evaluation of different desk types used in the design classrooms of the Technical Sciences Vocational School of Kayseri University and proposes an ergonomically optimized studio desk design suitable for design-oriented departments. The study aims to contribute to national literature, provide foundational data for the furniture industry, and raise awareness among students and practitioners, highlighting its originality and significance.

2. Materials and Methods

In this study, the methodological process involved several sequential stages. First, the necessary anthropometric measurement instruments were procured, along with a set of colored table covers to support observational analyses. A comprehensive literature review on ergonomics, anthropometry, and educational furniture design was conducted to establish the theoretical framework. Subsequently, the anthropometric measurements of the participating students were collected, and these data—together with their calculated averages—served as the basis for developing an ergonomic classroom desk design. To examine the influence of color on the

learning environment, classroom sessions were conducted using desks covered in different colors, followed by a survey administered to determine which color elicited the most positive student responses. The selected color was then integrated into the proposed desk design. Finally, all collected insights informed the creation of a 3D digital model of the desk, for which detailed renderings were produced to visually communicate the final design proposal.



Figure 1. Measuring instruments (Ecevit, 2025)

A comprehensive literature review was conducted to determine which anthropometric measurements are required for classroom desk design and how these measurements should be collected in accordance with ergonomic standards. The review focused on identifying the specific body dimensions necessary for developing an ergonomic desk suitable for students, including both static and dynamic anthropometric parameters. Based on the findings, the essential measurement set was established, and the complete list of required dimensions is presented in Figure 2.

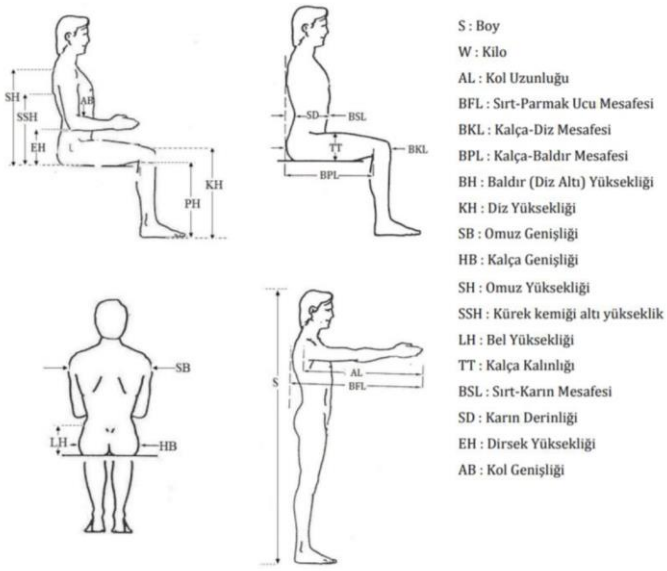


Figure 2. Series of eighteen anthropometric measurements (Kahya et al., 2018: 62)

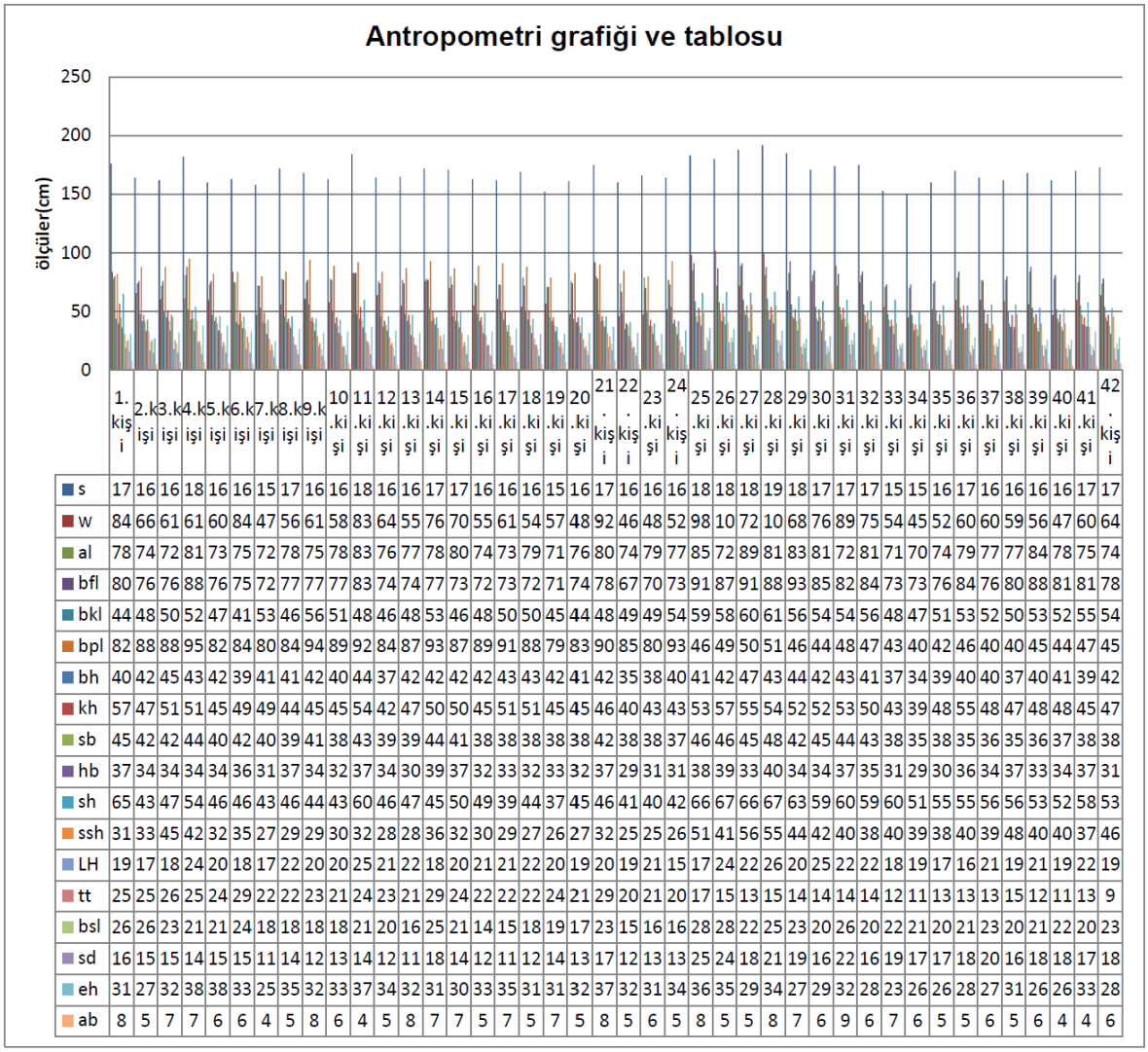
3. Findings and Discussion

The anthropometric measurements collected from students were recorded, tabulated, and visualized through graphical representations (Figure 3). The mean values of these measurements were subsequently calculated, organized into tables, and presented graphically. These measurement results and their averages were then compared with anthropometric data obtained from the literature to conduct a preliminary ergonomic evaluation of the classroom desk design. Based on this comparative analysis, initial conceptual sketches were developed to establish the fundamental formal structure of the proposed desk (Table 1-2.).



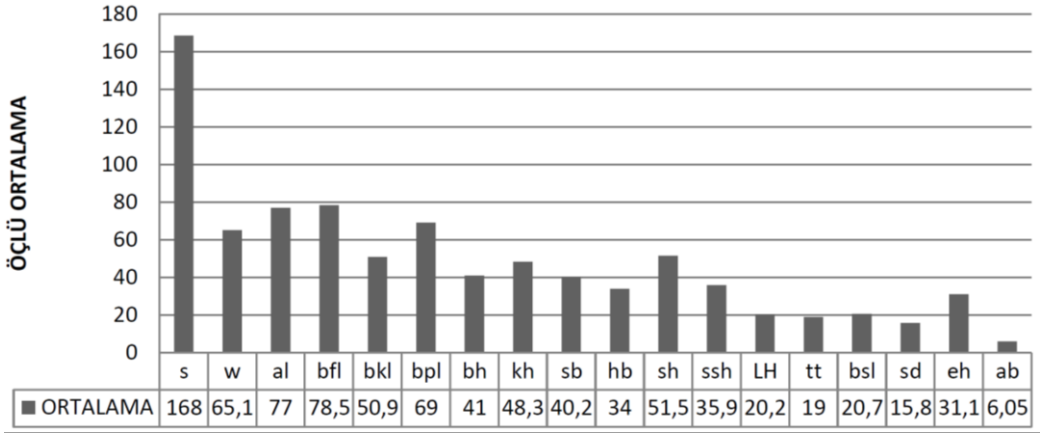
Figure 3. Class and students where anthropometric measurements were made (Ecevit, 2025)

Table 1. Graph and table of anthropometric measurements (Ecevit, 2025)



	1. kişi	2.kişi	3.kişi	4.kişi	5.kişi	6.kişi	7.kişi	8.kişi	9.kişi	10.kişi	11.kişi	12.kişi	13.kişi	14.kişi	15.kişi	16.kişi	17.kişi	18.kişi	19.kişi	20.kişi	21.kişi	22.kişi	23.kişi	24.kişi	25.kişi	26.kişi	27.kişi	28.kişi	29.kişi	30.kişi	31.kişi	32.kişi	33.kişi	34.kişi	35.kişi	36.kişi	37.kişi	38.kişi	39.kişi	40.kişi	41.kişi	42.kişi
s	17	16	16	18	16	16	15	17	16	16	16	18	16	16	17	17	16	16	16	15	16	17	16	16	16	18	18	18	19	18	17	17	17	15	15	16	17	16	16	16	16	17	17
w	84	66	61	61	60	84	47	56	61	58	83	64	55	76	70	55	61	54	57	48	92	46	48	52	98	10	72	10	68	76	89	75	54	45	52	60	60	59	56	47	60	64
al	78	74	72	81	73	75	72	78	75	78	83	76	77	78	80	74	73	79	71	76	80	74	79	77	85	72	89	81	83	81	72	81	71	70	74	79	77	77	84	78	75	74
bfl	80	76	76	88	76	75	72	77	77	77	83	74	74	77	73	72	73	72	71	74	78	67	70	73	91	87	91	88	93	85	82	84	73	73	76	84	76	80	88	81	81	78
bkl	44	48	50	52	47	41	53	46	56	51	48	46	48	53	46	48	50	50	45	44	48	49	49	54	59	58	60	61	56	54	54	56	48	47	51	53	52	50	53	52	55	54
bpl	82	88	88	95	82	84	80	84	94	89	92	84	87	93	87	89	91	88	79	83	90	85	80	93	46	49	50	51	46	44	48	47	43	40	42	46	40	40	45	44	47	45
bh	40	42	45	43	42	39	41	41	42	40	44	37	42	42	42	42	43	43	42	41	42	35	38	40	41	42	47	43	44	42	43	41	37	34	39	40	40	37	40	41	39	42
kh	57	47	51	51	45	49	49	44	45	45	54	42	47	50	50	45	51	51	45	45	46	40	43	43	53	57	55	54	52	52	53	50	43	39	48	55	48	47	48	48	45	47
sb	45	42	42	44	40	42	40	39	41	38	43	39	39	44	41	38	38	38	38	38	42	38	38	37	46	46	45	48	42	45	44	43	38	35	38	35	36	35	36	37	38	38
hb	37	34	34	34	34	36	31	37	34	32	37	34	30	39	37	32	33	32	33	32	37	29	31	31	38	39	33	40	34	34	37	35	31	29	30	36	34	37	33	34	37	31
sh	65	43	47	54	46	46	43	46	44	43	60	46	47	45	50	49	39	44	37	45	46	41	40	42	66	67	66	67	63	59	60	59	60	51	55	55	56	56	53	52	58	53
ssh	31	33	45	42	32	35	27	29	29	30	32	28	28	36	32	30	29	27	26	27	32	25	25	26	51	41	56	55	44	42	40	38	40	39	38	40	39	48	40	40	37	46
LH	19	17	18	24	20	18	17	22	20	20	25	21	22	18	20	21	21	22	20	19	20	19	21	15	17	24	22	26	20	25	22	22	18	19	17	16	21	19	21	19	22	19
tt	25	25	26	25	24	29	22	22	23	21	24	23	21	29	24	22	22	22	24	21	29	20	21	20	17	15	13	15	14	14	14	14	12	11	13	13	13	15	12	11	13	9
bsl	26	26	23	21	21	24	18	18	18	18	21	20	16	25	21	14	15	18	19	17	23	15	16	16	28	28	22	25	23	20	26	20	22	21	20	21	23	20	21	22	20	23
sd	16	15	15	14	15	15	11	14	12	13	14	12	11	18	14	12	11	12	14	13	17	12	13	13	25	24	18	21	19	16	22	16	19	17	17	18	20	16	18	18	17	18
eh	31	27	32	38	38	33	25	35	32	33	37	34	32	31	30	33	35	31	31	32	37	32	31	34	36	35	29	34	27	29	32	28	23	26	26	28	27	31	26	26	33	28
ab	8	5	7	7	6	6	4	5	8	6	4	5	8	7	7	5	7	5	7	5	8	5	6	5	8	5	5	8	7	6	9	6	7	6	5	5	6	5	6	4	4	6

Table 2. Average graph and table of anthropometric measurements (Ecevit, 2025)



	s	w	al	bfl	bkl	bpl	bh	kh	sb	hb	sh	ssh	LH	tt	bsl	sd	eh	ab
ORTALAMA	168	65,1	77	78,5	50,9	69	41	48,3	40,2	34	51,5	35,9	20,2	19	20,7	15,8	31,1	6,05

To determine the appropriate color for the final desk design, a series of observations was carried out using table covers in different colors. These covers were applied weekly to different student

groups during courses offered in the Interior Design Program at Kayseri University Vocational School of Technical Sciences. Through this process, the effects of color variations on students' attention levels and psychological perception were observed and documented (Figure 4).



Figure 4. Interior design students' color analysis (Ecevit, 2025)

4. Conclusion and Recommendations

The entire project plan was successfully implemented in this study. Surveys and anthropometric measurements collected from students revealed that existing classroom desks do not adequately meet ergonomic and anthropometric requirements. Based on these findings, a more ergonomic and comfortable prototype was developed to support healthy postures both during forward-leaning and upright sitting, and to facilitate comfortable work on both desk surfaces and computers. Although commonly used seating arrangements are generally considered suitable for computer-based activities, desks with fixed surfaces are often inadequate for tasks such as writing, drawing, cutting, or other tabletop activities. When the desk surface cannot be adjusted for inclination, users tend to lean forward to see and work comfortably, which can lead to poor posture and potential physical issues, including spinal deformities.

In this design, a seating element was developed to allow users to work comfortably both at the desk and on a computer, providing healthy posture support when leaning forward and adequate support when sitting upright. The seat is adjustable in height, width, and depth according to the average anthropometric measurements of the users. The desk features an adjustable inclined surface, enabling comfortable performance of various activities such as drawing, writing, cutting, pasting, and computer use. The designed desk incorporates adjustable height and tilt, integrated lighting, power outlets, a solar panel, an adjustable footrest, a front compartment for project bags, and a dedicated section for pens and small stationery. The seating element offers adjustable height and tilt, a contoured backrest providing spinal support, and knee rests to enhance ergonomic comfort. The resulting design is manufacturable and suitable for mass production. Furthermore, the study provides a foundational framework that can be extended to different user groups and work environments in future research, facilitating more comprehensive ergonomic data collection (Figure 5.-6.).

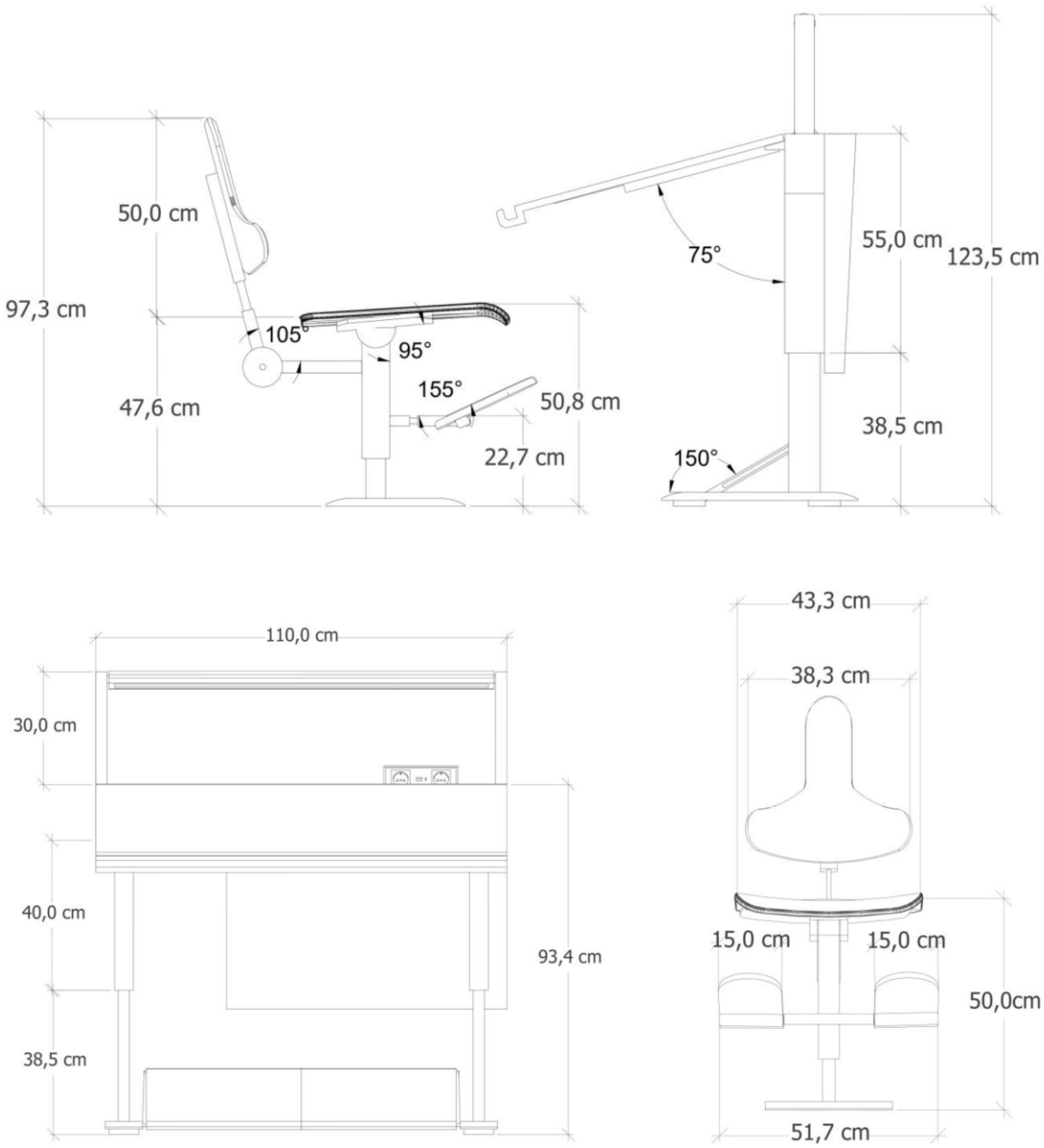
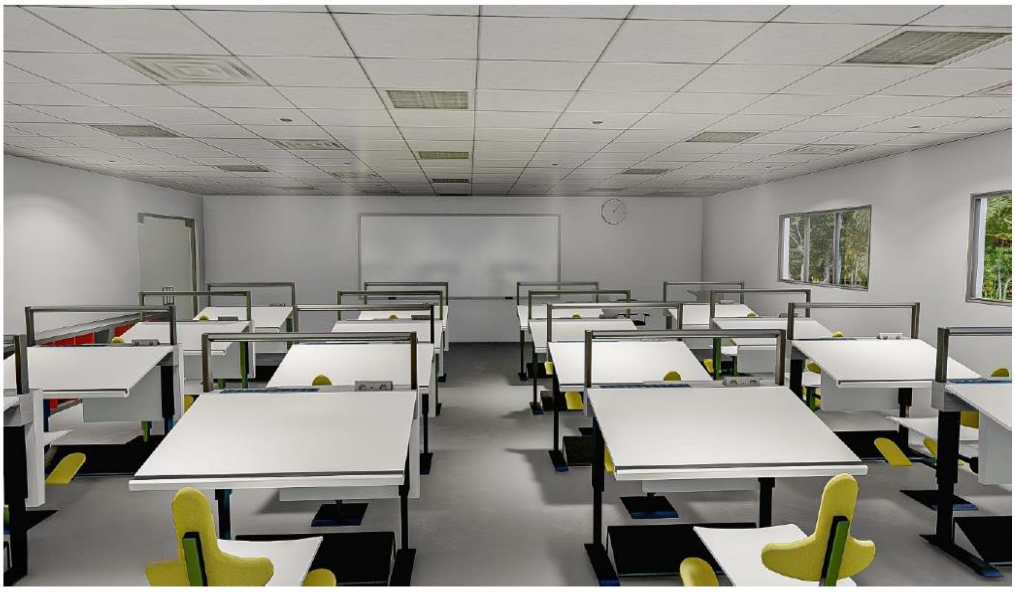


Figure 5. Technical drawings of the design (Ecevit, 2025)



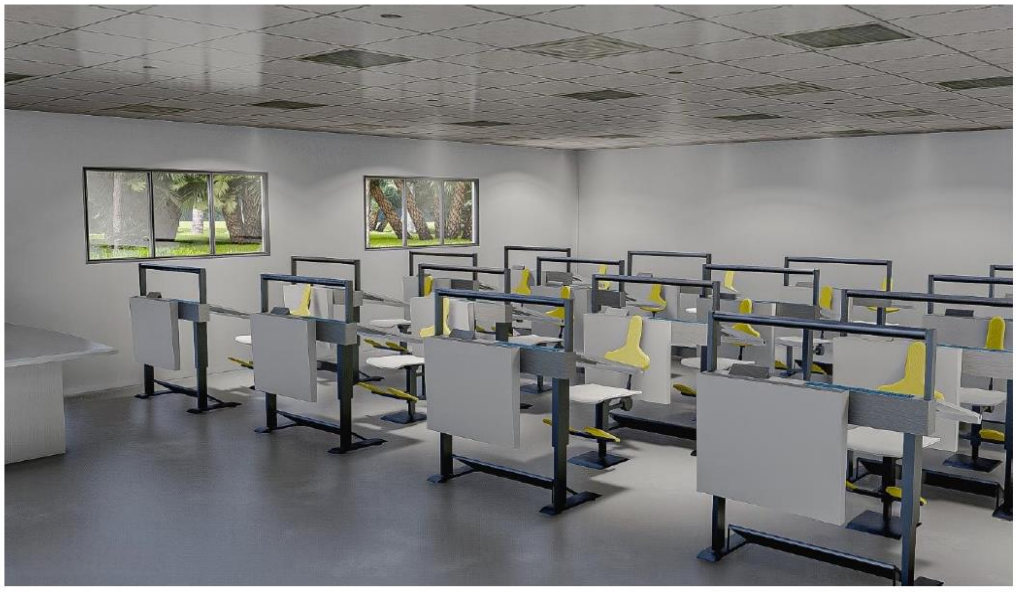


Figure 6. 3D Model of the design (Ecevit, 2025)

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval for this study was obtained from the Ethics Committee of Kayseri University on October 2, 2024, with decision number Form No: 113597. This research has been supported within the scope of TÜBİTAK 2209-A Program. All authors contributed equally to the article.

References

Gimenez, R., do Nascimento Soares, R., Ojeda, V. V., et al. (2016). The role of school desk on the learning of graphic skills in early childhood education in Brazil. *SpringerPlus, 5,* 1120. https://doi.org/10.1186/s40064-016-2554-1

Güler, Ç. (1997). *Introduction to ergonomics* (1st ed.). Ankara: Sağlık Projesi Genel Koordinatörlüğü.

Kahya, E. (2018). Evaluation of the classroom furniture for university students. *Eskişehir Osmangazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi, 26*(1), 20–29.

Kahya, E., Ünlüer, G., Güzeldal, Z., & Demirci, Z. Ö. (2018). Bir yükseköğretim kurumundaki öğrenci sıralarının uygunluğu analizi. *Ergonomi Dergisi, 1*(2).

Köksüz, A. (2019). Her alanda ergonomi. *Sürdürülebilir Mühendislik Uygulamaları ve Teknolojik Gelişmeler Dergisi, 2*(1), 3–24.

Küçükoğlu, A., & Özerbaş, M. A. (2010). Eğitim ergonomisi ve sınıf içi fiziksel değişkenlerin organizasyonu. *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 4*(2).

Sherry, A. P., Pearson, N., & Clemes, S. A. (2016). The effects of standing desks within the school classroom: A systematic review. *Preventive Medicine Reports, 3,* 338–347.

Yararel Doğan, B. (2019). Kullanıcı perspektifinde çalışma mekanlarının ergonomik tasarım kriterleri bakımından incelenmesi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 28*(3), 266–276.

Dul, J., & Weerdmeester, B. (2008). *Ergonomics for Beginners: A quick reference guide* (3rd ed.). CRC Press.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Streets and Avenues in The Formation of City Identity; Gaziantep Karagöz Street

Ebru Begün SAÇIKARA[1]*

ORCID 1: 0009-0005-8478-4264
[1]Architect, Hasan Kalyoncu University, Postgraduate Education Institute, Department Of Architecture, Gaziantep-Türkiye
ebegun.sacikara1@std.hku.edu.tr (Responsible Author)

Meltem BARIŞ ARARAT[2]

ORCID 2: 0000-0002-7329-1967
[2] Asst. Prof. Hasan Kalyoncu University, Postgraduate Education Institute, Department Of Architecture, Gaziantep-Türkiye
meltem.ararat@hku.edu.tr

Abstract

A city can be defined as a spatial whole formed by the convergence of settlement systems that have emerged over time and in different periods, shaped by geographical conditions. The memory of cities is formed by the memories, experiences, and spatial spirit they offer to their inhabitants. This memory plays an active role in shaping the city's identity by undergoing processes of acceptance, transformation, or rejection over time. Therefore, socio-economic, cultural, and social dynamics are among the factors that directly influence the formation of the city's identity. Within the urban fabric, there are concrete arteries that define the identity and facilitate the lives of city dwellers. Streets and avenues are the most prominent examples of these arteries, offering users and researchers important clues about the city's memory and identity based on periodic changes. These spaces sometimes connect the city's districts along a linear axis, while at other times they are characterized by labyrinthine streets that emerged as a result of organic development. It is not only physical structures that determine urban identity; migration movements, natural disasters, regime changes, and the social, economic, and spatial transformations they cause also play a decisive role in this process. Throughout history, streets and avenues have been regarded not only as transportation axes but also as cultural and sociological transition points. These arteries are concrete axes that reflect the spatial memory and identity of cities. Their locations, the areas they surround, and the structures built on them reveal historical stratification and contribute to the city's identity continuity. Therefore, streets and avenues are considered key elements shaping the city's identity due to their historical, cultural, and spatial qualities in terms of urban memory.

Keywords: City, identity, Gaziantep, street.

1. Introduction

Place plays a connecting role at the center of the material and spiritual relationships users establish with their surroundings, forming the most fundamental component of spatial meaning (Togay, 2002). Place emphasizes its importance as an identity carrier, as an experiential space strengthened by social and cultural contexts. In this sense, place constitutes a dimension that acquires meaning in people's memories, beyond being merely a physical entity (Relph, 1976).

Space, on the other hand, can be defined as a broader perspective than place, as an area where individuals live their lives, where social interactions take place and gain meaning. It can be stated that space is a phenomenon enriched by historical and socio-cultural contexts, beyond its material characteristics. As a carrier of social memory, space contributes to shaping the relationships between individuals and society. In this context, spaces enriched with historical meanings play an important role in connecting both individuals and societies with the past (Ahunbay, 2009).

The city, as a multidimensional organization of space, is a complex system of structures shaped by social, economic, cultural, and political processes (Lynch, 2016). It emphasizes that cities gain meaning not only through physical spaces but also through the historical and cultural accumulation these spaces contain. The city occupies an important position not only as part of individuals' daily lives but also as a stage where social memory and identity are shaped (Kuban, 2001). In this context, analyzing urban structures and processes can determine the effects on a city's identity and memory (Hasol, 2017).

Identity encompasses the ways in which individuals and communities define and express themselves. Social and cultural identity is a reflection of historical processes and spatial relationships. In this context, identity is constructed through the interaction of the individual and society with historical, socio-cultural, and spatial contexts. In social science literature, the concept of identity is central to understanding the effects of social structures and processes on individuals (Çekindir & Aktan, 2021). Urban identity is the sum of a city's historical, cultural, social, and physical characteristics. Preserving urban identity is of great importance in terms of transferring historical and cultural heritage to future generations during modernization processes. In this process, the preservation of historical structures and spaces, in particular, plays a critical role in maintaining the unique identity of cities (Ahunbay, 2009). Gaziantep can be considered a concrete example that supports this view with its rich historical heritage; in particular, its historic bazaars and inns both bear the traces of the past and strengthen the city's identity by bringing these traces together with modern life.

Urban identity gains meaning both through the preservation of the physical environment and through the perpetuation of this environment's place in social memory (Eczacıbaşı Art Encyclopedia, 2008). When urban identity is passed on to the future, it draws attention to the functionality and preservation of historical spaces. (Eryazıcıoğlu & Markoç, 2018) Urban identity reflects the unique character and spirit of the city. This character can be examined through a wide range of aspects, from street layout to architectural structures, art, and traditions. On the other hand, urban memory shows the change and evolution of this identity over time and how it has established itself in the minds of city dwellers. Concepts that form the cornerstone of the development and growth of cities are included. Among these, value emphasizes the economic, social, cultural, and aesthetic importance of the city, while sustainability refers to the balanced and conscious use necessary to preserve these values and pass them on to future generations. In Turkish cities, streets and avenues are not only transportation axes but also spaces where social relationships and neighborhood culture are shaped(Bektaş, 1981). On the other hand, trade is a fundamental factor supporting the economic and social vitality of the city. It enables the city's growth and strengthens its global connections. Along with these, urban planning is also extremely important for making city architectures more livable, accessible, and sustainable.

2. Materials and Methods

This research was conducted to examine the effects of Karagöz Street, located in the city center of Gaziantep, on the city's identity and memory. Based on Lefebvre's (1991) approach to the social production of space, the city was considered a dynamic system that shapes individuals' cultural relationships and social characters. The study evaluated monumental structures, public spaces, and street fabric directly related to urban memory as a whole; the effects of building restorations and renovation processes on the street silhouette and spatial integrity were observed. Karagöz Street and the Karagöz Mosque, Nuri Mehmet Paşa Mosque, Eski Camlı

Kahve, and Nakıp Cinema/Hotel located on it were taken as material; fieldwork, photographic documentation, archive scanning, and comparative spatial analysis methods were used. In this regard, the aim of the study is not only to examine the buildings themselves, but also to reveal the role of the system formed by these buildings together on the city's identity and to contribute to urban axis-centered assessments that are lacking in the literature.

3. Findings and Discussion

3.1. The History and Development of Gaziantep City

Gaziantep Province, one of the oldest and most deeply rooted settlements in Anatolia, has been home to many different empires and civilizations throughout its historical process. Its historical significance lies not only in being a city of users but also in being an important commercial area. Located on the Silk Road trade route, Gaziantep occupies an important position both economically and culturally (Utanır Karaduman, 2023).

The city's historical fabric has formed a unique identity by bearing the traces of various periods. In this context, the Gaziantep City Plan prepared by Herman Jansen in 1938 is an important work that combines the traditional structure of the city with a modern urban planning approach (Keleş, 1996).

In this plan, Jansen aimed to preserve the character of narrow streets and historic neighborhoods while adding new transportation axes and squares to the city. Thus, the goal was to protect Gaziantep's cultural heritage and ensure its adaptation to the modernization process. This plan envisaged preserving the city's values inherited from the past while supporting its development in line with contemporary urban planning principles.

Gaziantep's contributions from the past to the present have had a noticeable impact both regionally and nationally. Structurally, the city also has a silhouette where traditional and modern lines comfortably coexist. These formations and changes have had a significant impact on shaping its identity (Kuyucu, 2019).

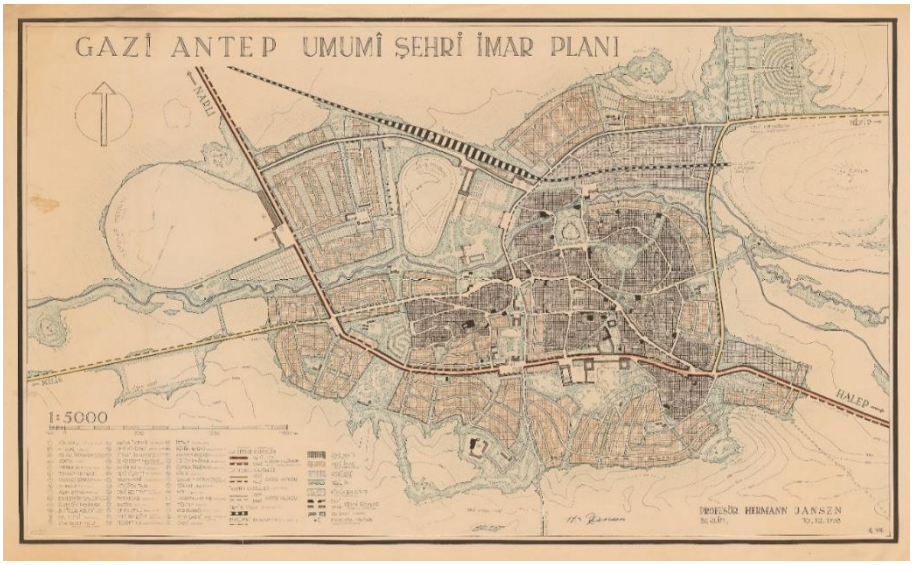


Figure 1. Hermann Jansen's Gaziantep Plan (Jansen, 2024) (1869-1945)

Gaziantep's contributions from the past to the present have had a noticeable impact both regionally and nationally. Structurally, the city also has a silhouette where traditional and modern lines comfortably coexist. These formations and changes have had a significant impact on shaping its identity (Kuyucu, 2019).

3.1.1. Historical Background

Historically, Gaziantep is known to be located in a rich geography that has been home to many different civilizations. Its origins date back to the Neolithic period around 3650 BC. The city was home to the Hittites, Persians, and the Hellenistic period. The most prominent traces of the city can be seen in the Roman and Ottoman periods. During the Roman period, due to its geographical location, it became a stopping point for trade caravans and was able to achieve economic and social development linked to trade. As a result of this development process, it became a regional administrative center and increased its fame (Sönmez, 1995).

During the Ottoman Empire, the city became a cultural center, influenced by trade and social development dating back to the Roman period. The impact of trade led to the development of handicrafts, carpet weaving, and copperware industries that continue to this day. With the development of industry, the direction of trade changed, and economic growth was observed. In addition to these, the urban architecture characteristic of Ottoman Empire culture, with its narrow streets, stone walls, and residential buildings, shaped a unique urban identity. With the proclamation of the Republic, an industrial revolution took place without disrupting the city's traditional structure, accelerating the city's development (Söylemez, 2018).

Today, it is a cradle of great civilizations that bears the historical signatures of its past. Markets specializing in copper, carpets, and handicrafts, whose foundations were laid during the Ottoman period, are located here. These markets are active both as tourist attractions and commercial centers. In addition, Gaziantep has made significant developments in the field of gastronomy and has become globalized.

During the Ottoman period, Gaziantep gained importance as a center of trade and culture. Traditional handicrafts in the city, particularly carpet weaving, copperwork, and food industries, flourished, and trade was largely shaped around these areas. The urban structure of the city during the Ottoman period is characterized by narrow streets, stone-paved avenues, and residential buildings. This structure of the city created an urban identity where the people interacted intensively and small shops and workshops were common. With the advent of the Republican era, the city began to industrialize rapidly, with the textile, food, and metal industries coming to the fore. This industrialization led to the city's growth and accelerated urbanization processes (Söylemez, 2018).

Today's Gaziantep is a modern city shaped by its rich historical heritage, possessing a structure that encompasses both its traditional architecture and its industrialization process. The city's development, parallel to growth in both trade and industry, reflects the evolution of its social fabric and way of life.

3.1.2. The Importance of Streets and Alleys in Gaziantep City

Gaziantep consists of narrow streets and alleys paved with basalt stone, particularly influenced by the Ottoman period. These streets and alleys have not only been used as means of transportation but have also been distinctive in shaping the city's identity with their historical structure. Today, narrow streets are not very practical. However, in order to preserve the

historical structures and prevent damage to the city's identity, the streets in the city center have mostly been left untouched. Streets and alleys that have worn out and deteriorated over time have been restored to their former appearance through restoration work.

The streets of Gaziantep feature a complex structure where traditional and modern architecture intertwine. This complexity allows visitors to breathe in the traditional architecture and feel the historical textures, while also providing the opportunity to experience modern world structures (Kuyucu, 2019). Throughout history, they have been trade centers where people interacted. These streets and avenues, which have been shared spaces, have greatly contributed to the city becoming a trade center. This has shaped the city's dynamics. Today, streets that have retained their traditional architecture are considered the city's social centers because they are home to the most distinctive and widely accepted structures that represent the city's identity. These factors, which form the fabric of the city, have persisted and been reshaped throughout history (Şahin, 2016).

One of the most important elements that make a city a city is its historical system. The concrete structures and street system are what best describe how it has evolved from the past to the present and the struggles it has endured along the way. One of the streets that fits this description for the city of Gaziantep is Karagöz. The street has a direct physical, historical, cultural, social, and economic relationship with the city. In terms of location, it is situated in the direction of the traditional and historical bazaar that the city has used for centuries. Used for commercial and social activities since its inception, this street is now a vital structural axis for the city.

3.1.3.City Memory and Karagöz Street

Memory is the social memory system that shapes the city's identity from past to future.City memory is not limited to physical elementsbut is also directly related to the socio-cultural and socio-economic infrastructure.It is organized by individuals' concrete or abstract experiences with the city,lifestyles and practices applied according to traditions and customs.Gaziantep, a city known for its cultural and historical richness, is of great importance for preserving memory, developing identity, and protecting social memory.Known for its cultural and historical richness,the city of Gaziantep is of great importance for the preservation of memory, the development of identity, and the protection of social memory. The street is located in a settlement pattern that intertwines traditional and modernstructures. With its change and development over time, it occupies an important place for the city's memory and identity.

The collective memory that encompasses the culture, history, identity, and values of societies stretching from the past to the future can be referred to as social memory. Memory exists in a visible, tangible form through cities, streets, buildings, and other concrete cultural assets. Gaziantep's Karagöz Street is one of the main elements that make up the city's social memory. This street bears traces that can be understood by the city's users or tourists visiting the city from outside. These traces are located on the Karagöz street axis as evidence of great struggles and successes.

The street reflects the social dynamics, cultural structure, and commercial life of the city. The commercial and social structures along Karagöz Street are user-oriented. It is located in a position that can be described as a gateway to the center of the city bazaar. It serves as a brief summary of the bazaar for users. The street axes branching off from the street are related to each other but do not run in the same direction. For example, one branch leads to the Nuri Mehmet Paşa Mosque, while another branch opens onto an area where an old synagogue is located. Similarly, the same situation may apply to the Nakıp Cinema and Paşa Hamam. Due to its comprehensive structure, the street remains dynamic and vibrant in the memory of the community (Karadayı Yenice, & Ararat, 2022).



Figure 2. View of Karagöz Street from Maarif Junction (1925) (Biçer, 2017)



Figure 3. View from a Location Similar to Karagöz Street (2024)

Preserving a community's memories, culture, and history is of vital importance. Memory is the fundamental element that dynamically connects the city, its individuals, and its structures, linking body and space. The streets of a city can convey the experiences of those who lived there before to its current users. Accordingly, the preservation of memory is achieved both through the continuation of cultural activities (customs and traditions) and through physical restoration.

Space has the ability to keep memories alive in the body. For this reason, the most important element in preserving memory is the restoration of historical structures and spaces. However, preservation can be achieved not only physically but also through the preservation of abstract values. The foundations of these abstract values are strengthened by giving them experience and vitality through traditional, commercial, and social structures located on the street.

Conclusion and Recommendations

When examining the historical development and spatial structure of the city of Gaziantep, it is evident that the relationship between the city's identity and its memory is most tangibly observed along historical axes such as Karagöz Street. Urban memory is not limited to physical structures; it is a dynamic system that reflects the sum of individuals' social, cultural, and economic relationships. In this context, Karagöz Street has become a focal point that nourishes the city's identity by carrying traces of the past.

The research highlights the importance of preserving historical fabrics, carrying out restoration work that reflects the original identity, and addressing traditional spatial organization in a manner consistent with modern planning approaches in order to ensure the continuity of urban memory and identity. Preserving the street as a "memory space" from both historical and social perspectives is critical to sustaining Gaziantep's local identity.

Ultimately, the city's identity and memory are shaped at the intersection of the physical environment and human experience. In this context, historical spaces such as Karagöz Street are not merely physical entities representing the past; they are also carriers of social memory and cultural bridges that ensure the continuity of identity. Preserving these axes and integrating them into urban life in planning processes for the city's future will strengthen both historical continuity and identity awareness.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Ahunbay, Z. (2009). *Protection and Restoration of Historical Environments* (5th Edition). Yem Publishing.

Bektaş, C. (2020). *Turkish House*. (8th Edition) İş Bankası Publications.

Biçer, H.Z. (2017). *Seyr-i Antep*. Gaziantep: Gazikültür A.Ş.

Çekindir, H. Y. and Aktan, S. (2021). The Relationship between Urban Identity and Collective Memory: The Example of Kemeraltı Meeting Points. *IEU KREA Creative Economy Journal,* 3(2–3), 26–32.

Eryazıcıoğlu, M. E. and Markoç, İ. (2014). The Problem of Dis-Identification in the Context of Urban Identity and Urban Projects, the Example of Istanbul. 1st International Congress of Urban Planning-Architecture-Design, 125-139. Kocaeli: UPAD2014.

Hasol, D. (2017). *Encyclopedic Dictionary of Architecture*. Yem Publications.

Jansen, H. (1938). Gesamtbebauungsplan, Gaziantep [Map].

Karadayı Yenice, T. and Ararat, M. (2022). Turkish bath tradition: The Gaziantep example. *International Journal of Intangible Heritage*, 17, 198–210.

Keleş, R. (1996). *Urbanization Policy*. İmge Bookstore.

Kuban, D. (2001). *On City and Architecture*. Yapı Kredi Publications.

Kuyucu, F. (2019). Continuous evaluation of the architectural structure of Gaziantep Urban Design during the Modern Architecture Period in Türkiye [Doctoral Thesis]. Yıldız Technical University.

Lefebvre, H. (1991). *The Production of Space*. Blackwell.

Lynch, K. (2016). *Urban Image* (8th Edition). Türkiye İş Bankası Culture Publications.

Özdeş, G. (1997). City. *Eczacıbaşı Art Encyclopedia* (Vol. 2, p. 983). In Istanbul: Yem Publications.

Relph, E. (1976). *Place and Placelessness*. Pion.

Utanır Karaduman, A. (2023). Urban Identity Construction and Entrepreneurial City Managements: The Gaziantep Example. *Gaziantep University Journal of Social Sciences,* 22(1), 1-11.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Analysis of Perception-Experience-Image-Memory Relationships in the Context of Fictional Spaces in the Film "Room"

Esra TOKUÇ [1*]

ORCID 1: 0009-0003-9708-0691
[1]Master's Thesis Student, Istanbul Sabahattin Zaim University, Graduate Education Institute, Department of Architecture, Architecture Master's Program, Istanbul, Türkiye
tokuc.esra@std.izu.edu.tr (Responsible Author)

Serhat ANIKTAR [2]

ORCID 2: 0000-0002-7727-5331
[2]Assoc. Prof. Dr., Istanbul Sabahattin Zaim University, Faculty of Engineering and Natural Sciences, Department of Architecture, Istanbul, Türkiye
serhat.aniktar@izu.edu.tr

Abstract

Cinema and architecture offer unique experiences to viewers or users by creating spatial narratives. Both disciplines consider space not only as a physical entity but also within an emotional and semantic context. The aim of this article is to analyze and interpret the perceptual, experiential, imaginative, and memorizational relationships of fictional spaces in the 2015 film "Room." More than half of the film takes place in a single location. In this context, the aim is to understand how a single space, the limited space within the room, is conveyed to the audience through the characters, through comparisons between the spaces of the outside world. Another aim of this article is to analyze the emotional and psychological impact of the differences between the spaces in the film and to reveal the contributions of space to the narrative and character development. The analyses were conducted by considering the factors that influence spatial perception, particularly the concepts of scale, experience, imagery, and memory. Using a literature review method, the study explores the physical and psychological factors that influence spatial perception, experience, imagery, and memory, and then explores how the fictional spaces in "Room" relate to these criteria. The film's main characters' emotional connections to places have been revealed. The results indicate that the characters' relationships with and perceptions of space vary significantly. This highlights how the perception of space is based on an experience imbued with personalized, memorized images and emotions.

Keywords: Cinema, fictional space, perception, image, memory

1. Introduction

Architecture has interacted with various disciplines since the past. Cinema, which emerged in the late 19th century and continues to develop with technological advancements, is a significant discipline intertwined with architecture through its treatment of space and time. Cinema's reconstruction of physical spaces on a digital platform, its characterization of architecture with its fictional structures, and its definition of spaces that do not exist in the real world as virtual architectural fields illustrate the interaction between cinema and architecture (Us, 2023).

Cinema is an art form created by combining many elements. One of these elements is the construction of space, a fundamental subject of architecture. Cinema always requires a space and organizes it in various ways. For example, cinema can design a new space, utilize or modify an existing space, and create space at the interior or urban level. Therefore, in every film, an architectural representation is created through the images of space presented (Yıldırım Yargıcı, 2021).

All events occur and develop within the framework of time and space. Space is a concept encountered in every field. Disciplines such as painting, philosophy, cinema, and architecture, influenced each other with their evolving understandings of space, considering the concept of

space and producing it in different ways. While architecture shapes spaces in the concrete world, cinema presents these spaces to the audience along with stories. Although processed differently in both disciplines, the concept of space forms a bridge between the two.

Cinema and architecture share similar characteristics in terms of conceptualization, production, planning, and presentation techniques (Güleç & Çağlar, 2014). As in architecture, in cinema, various dimensions of space -such as time, form, concept, and sensation- are constructed through space. Both disciplines utilize space and time. In cinema, space is sometimes used as a tool, and sometimes it can be the goal. In the early years of cinema, space was generally the focal point. However, over time, story became more prominent. With the rise of storytelling, space began to be used more as a tool (Akyol, 2019).

Just as each image in cinema has a purpose, each space also has a specific purpose and inherent meaning. The primary goal is to achieve effects appropriate to the script and to strengthen the narrative. Thoughts and emotions intended to be expressed are conveyed through spaces. For example, narrow, confined, and dark spaces can be used to convey negative emotions such as fear and tension, while spacious and bright environments are preferred to represent peace (Akyol, 2019).

Juhani Pallasmaa emphasizes that there is no film that cannot be connected to architecture. He states that the fundamental function of architecture is the production of space, and that the organization of space, scale, void, and light are intertwined with cinematic expression (Pallasmaa, 2007).

According to Graham Cairns, the moment cinema's visual narrative entered our lives, a new visual language emerged. This innovation influenced architecture and raised questions about how the environment is perceived. This has opened new perspectives in building design and presentation, while offering architects an area of experimentation at the interior and urban scales (Cairns, 2013). Consequently, many researchers recognize that cinema and architecture interact and influence each other.

Both disciplines have a way of influencing mental perception through the meanings they embody, as well as the physical characteristics of space. In the film "Room," the focus will be on the rendering of space and the perception of space conveyed from the visual to the mental.

The 2015 film "Room" is the primary focus of this study. The aim of this study is to examine how the intended message within the context of the relationship between cinema and architecture is conveyed through space and to evaluate the spaces used in the film in terms of perception.

2. Materials and Methods

2.1 The Use of Space in Cinema

The use of space in cinema is a fundamental element of filmmaking. Space is not just a physical location; it is also an emotional and semantic narrative tool. The careful selection and use of space in films offers the audience a profound experience and makes cinema a powerful means of expression.

The spaces seen in cinema can be real, existing spaces, or, depending on the director's wishes, virtual or recreated spaces. Existing spaces can be used in their original form or reorganized according to need (Us, 2023).

Cinema has the power to tell a story and create emotional engagement through the use of space. Space is one of the cornerstones of a film, and filmmakers aim to create the desired emotion in the audience by utilizing the physical characteristics and atmosphere of the space. The colors, textures, architecture, and lighting of the space determine the film's atmosphere and are used to convey a specific emotional state to the audience.

Fictional space is considered in two main categories: real and virtual space. In cinema, in addition to physical real spaces, sets and spaces designed within the virtual world are also used. These freely constructed spaces can be more creative because they are shaped independently of real-world constraints. Diverse architectural structures in film productions demonstrate the connection between architecture and various disciplines, environmental elements, and social structure. In cinema, space is a tool used to achieve realism. These environments determine the flow of time and the movements of the characters in the film (Selvitop, 2017).

When the use of space in cinema is evaluated from the perspective of the discipline of architecture, carefully designed spaces can evoke various sensory and cognitive perceptions in the viewer. Films created with these perceptual architectural approaches deepen the film's theme through the spaces created, contributing to the development of the story (Köseoğlu & Yücel, 2023). Cinematic space is not merely a physical location; it is also a tool that conveys the relationships, emotional states of the characters, and the fundamental elements of the story. The choice of location can emphasize the relationships between characters, increase tension, or convey a dramatic image.

Spaces are important elements that reflect the characteristics of society and the individual. This applies not only to everyday life but also to movies. In cinema, space is the cornerstone of visual structure and significantly influences a film's atmosphere, emotion, and story. Furthermore, locations play a critical role in shaping a film's atmosphere. For example, in horror films, dark and abandoned locations aim to heighten the tension and influence the audience. In a romantic film, warm and romantic settings facilitate the establishment of an emotional bond. Locations guide the audience in understanding the relationships between the film's events and characters (Ersoy, 2010).

2.2 The Perception of Space

An individual is in a complex network of relationships with their environment, with which they constantly interact. This process encompasses the behaviors behind the individual's responses, the needs that form the basis of these behaviors, and a series of processes and concepts within the perceptual system that aims to understand the environment. Individuals must recognize and understand their environment in order to make the most of it, adapt, or adapt it to their needs. Perception of the space we inhabit involves a complex process that begins with the emission of stimuli to various sensory organs (Koç, 2012). The way individuals understand the physical environment, the meaning they ascribe to it, and how these elements influence designs and behaviors play a significant role in determining an individual's interaction with their environment.

Perception, cognitive processes, and behavior constitute the main components of a complex interaction model. Perception involves acquiring environmental information through sensory stimuli, while cognition involves interpreting this information, storing it in memory, and understanding emotional states. Behavior refers to the process by which an individual uses this information to exhibit various responses aimed at achieving goals (Gür, 1996). Cüceloğlu

defines perception as the process of organizing and interpreting sensory data to give meaning to objects and events (Cüceloğlu, 1996).

Perception is an active process and does not assume a passive role. It acquires meaning by integrating with what is perceived and the behaviors that result from this perception. Perception cannot be explained simply by automatic responses to stimuli. Human-environment interactions are dynamic. An individual's perception of the environment depends on past experiences as well as current situations. Past experiences contribute to the individual's process of reconciling current situations with their own needs. Perception is shaped by expectations, experiences, and personality traits (Lang, 1987).

Perception is the process of processing information obtained through various senses and constructing a concept of the external world. This process is the result of an individual's effort to understand and interpret their environment. Perception has an ever-changing structure because it is a temporary system, open to new data and amenable to constant inquiry and experimentation. Perception can evolve and strengthen with incoming information, or it can weaken and give way to another theory. Individuals personalize their theory of perception based on their own experiences and experiences, emphasizing that perception is a highly subjective process. Concepts such as colors, sounds, time, and size vary from person to person (Aydoğan Şahin, 2019).

Perceived space does not merely refer to a physical environment; it can also be considered as a space observed, experienced, and perceived by the person in it. Space is not merely comprised of the physical characteristics of the external world; it is also shaped by internal experiences, subjective values, and personal meanings. In this context, perceived space is a rich and personalized field that emerges from the combination of both a stimulus reflecting the objective characteristics of the external world and the subjective experiences of the individual viewing this stimulus. This two-way interaction of perceived space encompasses not only the physical dimension of the space but also the emotional and mental experiences of the individual within it (Aydınlı, 1986).

Humans naturally desire to live in harmony with their environment. This tendency causes environmental influences to have a greater impact on individuals. Factors such as the color of a room, the lighting, and the size of the environment are factors that influence an individual's perception. Individuals acquire a wealth of information using visual perception and store this information in their memory. During this storage process, the mind evaluates the information obtained and shapes emotional responses. Scientific research has confirmed the emotional responses that design elements of architectural space, such as form, color, and texture, visually evoke in individuals. Human perception can be manipulated by shaping these effects in the desired way. The power of architectural space is highlighted by the role of visual elements in directing emotional responses (Aydoğan Şahin, 2019).

2.3 Spatial Experience, Image and Memory

Spatial experience is the totality of sensory, physical, and mental interactions an individual experiences during their perception, exploration, and time spent in a space. This experience provides insight into how an individual perceives a space, interacts with objects within it, and evokes an emotional response to the space. Imagery and memory play a key role in the formation of spatial perception. The ability of perception to integrate with the multifaceted

elements expressed reveals the interaction between concepts such as imagery and experience (Hekimoğlu, 2021).

Imagery can derive from different thinking approaches using an individual's memory. In the thought process, in addition to fundamental elements such as experience, memory, and knowledge, factors such as perception and the subconscious can also influence the internal dynamics of image formation. An individual's past experiences, learning, and emotional states can shape the content of the image created (Hekimoğlu, 2021). Although images contain the physical characteristics of their objects, they are shaped by the individual's internal experience and are distinct from the object itself. The image-making process is shaped by an individual's unique life experiences and knowledge (Burnett, 2007).

An image is a visual, auditory, or emotional representation that emerges in an individual's mind. In spatial perception, an image forms a mental map of a space. For example, when a person passes the entrance door to their home, an image of this passage is formed in their mind. This image is associated with their previous experiences with their home, their emotional attachments, and the design of the space. Imagery enriches the perceptual structure of a space and has the potential to add meaning to the user. An image is enriched by references from memory, and thus, the space becomes part of a personal story. For example, a café, which holds significant memories for a person, acquires meaning not only through its physical features but also through the special memories spent there.

Spatial memory refers to an individual's ability to recall experiences related to the spaces they have lived in and to make connections between these spaces. Memory contains the concrete traces of previous spatial experiences, combined with individual, social, and cultural values in the individual's thoughts, and constructs the spatial memory. Spatial memory emerges as a result of individuals' emotional and semantic experiences related to spaces. The stimuli that trigger a person's association with the mental and experiential experiences they have gained throughout life during the understanding of a space correspond to the traces left in the memory by the space. Therefore, a person's perception of space is not only mediated by visual perception, but also by their previous experiences and the characteristics and meanings of each stimulus they encounter (Sayar Avcıoğlu & Akın, 2017).

Memory is a mental archive that stores past experiences. In spatial perception, memory helps an individual recall experiences they have had in previous spaces and interpret new spaces within this context. For example, if a person remembers a park they frequently visited in childhood, this memory influences their mood when they step into a new park. By connecting a space with past experiences, memory contributes to deepening perception and gaining personal meaning.

3. Findings and Discussion

3.1 The Film “Room”

“Room” (2015) is a drama film directed by Lenny Abrahamson and adapted from Emma Donoghue’s novel of the same name. The film tells the story of a young woman, Joy (Brie Larson), and her five-year-old son, Jack (Jacob Tremblay), living in a confined room. Joy is kidnapped by a mysterious man they call Old Nick and imprisoned in the room for years. Jack was born and raised in the room, growing up with only what he saw on television about the outside world. Joy, unable to tell her son, who held her captive, that they were imprisoned here and that there was a world outside the room, created an imaginary world for him where only

the two of them lived. Unwilling to disappoint Jack by telling him a life she couldn't give him, she allowed him to believe the rest of the world existed only on television. Jack grew up believing that only he, his mother, and the room were real. The story is told through Jack's eyes, and his life in the room is the only place he believes represents the real world. When Jack turns 5, Joy tells her son the truth, but Jack can't believe there's a life outside the room. Joy devises a plan to escape. She tells Old Nick that Jack is dead, prompting Jack to escape. After escaping, Jack tries to tell the police what happened, and Joy is rescued. Later, Jack and Joy begin living at Joy's mother's house.

The film focuses on the room through Jack's eyes and how he perceives this limited space. It also emphasizes that our perception of life is limited by our experiences, but imagination knows no bounds. The room is Jack's universe, his world. His reality lies within the walls of this limited space. Everything within the room constitutes his perception of the real world. This limited space is the center of Jack's existence, and all his knowledge and perceptions come from it. However, Joy and Jack's escape attempt and subsequent reconnection with the outside world reshape his perception of the room and its reality. In this process, it becomes clear how limited the space actually is, yet how profoundly it impacts human perception. The room, in addition to being a protective space for Jack, can also be seen as an emotional and psychological prison.

The film "Room" goes beyond the physical boundaries of a space by examining how space shapes human perception and psychology. The room represents the characters' inner worlds, emotional bonds, and perspectives on life, while also showing the audience how human perception relates to space. Elements such as the room's structure, furniture, colors, and lighting shape the perceptual experiences of the characters and the audience. These elements reflect not only the physical boundaries of the space but also the characters' emotional states and mental processes.

47 minutes of the 117-minute film take place in the same room. This article also focuses on spaces belonging to the outside world, outside the room. The spatial elements that appeal to perception in the design of the space and how the space strengthens the story are examined. The spaces used have different qualities and meanings, and it is anticipated that the spaces discussed will provide various data for evaluating spatial perception. Jack is in direct relationship with the spaces. The room occupies a central position in the film, and Jack's relationship with these spaces is a focal point throughout the film. The room is also mentioned in dialogue between Jack and other characters. This demonstrates that film can explore not only the physical dimensions of space but also its mental and emotional dimensions. In this context, the film offers a significant opportunity for analysis of how space influences human perception and how it is represented in the human mind.

3.2 Evaluation of The Perception of Spaces in The Film "Room" in The Context of Experience, Image and Memory

The room, the characters' living space, is approximately 20-25 square meters. It contains a bed, television, nightstand, bathtub, toilet, sink, small kitchen area, table, and two chairs.

Pictures drawn by Jack are displayed on the wall. A skylight in the ceiling provides natural light. Jack and Joy's perceptions of space are quite different. From Jack's perspective, the room represents the entire world, while for Joy, it symbolizes a form of captivity. This contrast demonstrates how subjective perceptions of space can differ. In this context, it emphasizes how characters create meaning and value within a space beyond its physical dimensions. This

demonstrates to the audience that space is not only physically definable but also how it is reflected in a person's mental and emotional world (Figure 1).



Figure 1. The room interior

A dark theme is generally used in scenes set in a room. This creates a gloomy perception of the space. Colors are known to affect the perception of space's size. Therefore, when elements such as the walls and ceiling are of the same color tone, the viewer perceives the space as small. The colors used create a sense of space as cramped and cramped, far from spaciousness. The brown and tan tones seen throughout the room may be intended to emphasize the safety of Jack and Joy's family and the fact that this room is Jack's reality.

When examining the textures used, the first thing that strikes the eye is the soft sound-absorbing material covering the entire walls and ceiling. Rough and soft surfaces direct the perception of the space towards a warm atmosphere while simultaneously creating a sense of distance. These textures offer the viewer an emotional and perceptual experience of the space's characteristics. Different textures are known to contribute to children's sensory development and their interaction with the environment. In the film, there are scenes where Jack tries to recognize and make sense of his environment through tactile stimuli in his first encounters with the outdoors (Figure 2).



Figure 2. Jack's encounter with the outdoors

The room's elements, such as the small kitchen area, a single bed, and a small two-door closet, are in harmony with its size. The room's small size is evident by examining its constituent elements (Figure 3). The room's narrow and confined physical dimensions emphasize the

character's lack of freedom. The mental dimension of the space is more prominent than its physical dimensions. Because he hasn't experienced the outside world, Jack's room isn't confined to him. The space is his world. Despite its narrowness, some scenes, due to the shooting angle, make the ceiling appear high, emphasizing the inaccessibility of the outdoors—that is, freedom.



Figure 3. Elements in the room

Additionally, the colorful and childlike appearance of the plates in this scene strengthens the relationship between Jack and the room, but also gives the audience the impression that Joy doesn't belong there.

The skylight is a feature that helps the characters see the outside world. The light from the skylight and the shadows on the sides that aren't are used as important storytelling tools. Light is associated with freedom and the outside world (Figure 4).



Figure 4. The use of light in the room

Jack's reality in the room is limited to what he perceives from the outside world. This affects Jack's imagination and understanding of reality. Jack's knowledge and experiences of the real world are limited. He cannot conceive of a reality outside of his room. There is a potted plant in the room. He accepts the plant's reality, but since he has only seen trees on television, he doesn't believe it is real. His remark that the people on television are flat demonstrates that his three-dimensional perception is also underdeveloped.

Jack's statement demonstrates not only that Jack cannot physically see the outside world, but also that he has no mental perception or understanding of it. Because Jack grew up within the confines of his room, his perception of the world was shaped by his relationship with space. Joy's statement, comparing the room they were in to the outside world, highlights Jack's

limitations in terms of understanding. For him, the world, like space, can be an unknown and incomprehensible concept because he only knows the room. This comparison between the outside world and space demonstrates how limited Jack's perception of space is, and how, for him, the outside world is an incomprehensible and distant concept.

Because the room constitutes Jack's entire existence, it appears he cannot grasp the magnitude and diversity of the outside world. In this context, Jack's relationship with space has also influenced his perception of the concept of dimension.

For Jack, the room is his living space, his playground, and his entire universe. As a safe, familiar, and controllable space, the room plays a central role in Jack's perception. Jack finds the objects in his room familiar and meaningful. Every object in the room holds a significant place in his daily life, and he makes sense of the world through these objects. The room provides him with a controllable and safe haven, safe from danger. His desire to return to his bed the first moment he goes outside demonstrates this view. For Joy, the room is perceived as a factor that restricts her freedom. At the same time, living in the room carries a sense of danger for her and her son Jack's safety. This demonstrates that she perceives the room not only as a physical space but also in a psychological context, such as safety or danger.



Figure 5. View of the room from outside

During his escape with his mother, Jack encountered the outside world, entering different spaces, and these experiences led to a significant shift in his perception of space. The hospital room, the first space he encountered, is quite different from the space the characters had spent so long in. In this space, Jack experiences large windows, abundant daylight, and a large space for the first time, and he appears to have a reserved attitude toward other people. The light colors and lighting used in the space contrast with the other spaces. The smooth surfaces convey the viewer's sense of the cold atmosphere (Figure 6). While Joy feels familiar and safe in the hospital room, Jack feels cold, frightening, and unfamiliar. He still carries traces of the other space in his memory and interprets the new spaces he encounters according to this spatial memory. For example, he questions why the bathtub in the "room" is not present in this hospital room.



Figure 6. Hospital room

"I've been in the world for 37 hours. I've seen pancakes, stairs, birds, windows, and hundreds of colors. I've seen people of different faces, sizes, and smells talking together. The world is like a TV planet. All at once. That's why I can't look and listen. There are doors and more doors... and behind all those doors, there's another inside and outside. Something's constantly happening, and it never stops. Everything in the world gives way to brightness and harshness."

This line from Jack expresses his experiences and the shift in his perception of space after stepping outside the limited space he inhabits throughout the film. Encountering the stairs, birds, windows, and different colors causes Jack's perception of space to suddenly expand. These elements are real and concrete experiences, different from the world he had previously seen only on television. Jack's statement, "The world is like a TV planet. All at once," suggests that the world he sees through television is limited and orderly, while the real world has a complex and constantly changing structure. This represents a paradigm shift in spatial perception. The line, "There are doors and more doors, and behind all the doors, another inside and outside," demonstrates Jack's understanding that he is no longer simply inside a space, but in a world where spaces and passages are interconnected. This highlights the evolution of his perception of space to a complexity he had never experienced before and the shift in his perception of size. Jack's statement, "Everything in the world gives way to brightness and hardness," emphasizes the diversity and density of the outside world, in contrast to Jack's confined room. With these new experiences, Jack enriches his perception of space and realizes that the world is real, tangible, and multidimensional.

Jack's inability to figure out how to descend the stairs after going outside is an experience he hadn't experienced before in the confined space he had lived in. Jack is seen to be surprised by the staircase, which he sees for the first time. This scene illustrates the audience's reaction to a child's previously unfamiliar spatial element (Figure 7).



Figure 7. Stairs

Even though Jack experiences new environments, he remembers the room he grew up in, a place etched in his memory where he felt safe. It's known that children enjoy being in spaces that are appropriate to their own scale. However, because he feels comfortable in the familiar dimensions of the room in his spatial memory, he appears to prefer the dressing room, a smaller space than other rooms in the house, for play (Figure 8).

The color palettes, textures, spatial dimensions, lighting, and spatial elements used within the spaces also support the story being told. Dark color themes contribute to the perception that the space is narrow and cramped. It has been observed that the use of color affects the perception of size within the space. The color palette, created with brown and tan tones, is used to emphasize the family's security and Jack's reality. The light color themes used contrast with the "room" space, conveying the contrast between the spaces to the audience. Color, theme, textures, and visual elements reveal how the characters' unique perspectives influence the space, revealing that the space holds symbolic significance beyond being merely a physical space.



Figure 8. The dressing room where Jack plays

The relationship and perception of space between Joy and Jack, the main characters in the film "Room," are seen to be very different. For Jack, the physical and mental dimensions of the space are quite different. For Jack, the inside, the room, represents trust, the world, reality, and the bond of love between him and his mother, while for Joy, it evokes captivity, resistance, and fear. The outside, all spaces outside the room, For Jack, it evokes unfamiliarity, uncertainty, excitement, and fear, while for Joy, it evokes the real world, hope, and the security of being in familiar space. The outdoors represents freedom for both of them. The skylight in the room symbolizes freedom for Joy, while Jack, having not yet experienced the outdoors, symbolizes uncertainty. While the walls are a boundary that restricts Joy's freedom, they are a dream world where Jack hangs his drawings. The hospital room is a familiar space for Joy, but for Jack, it is

a space he feels unfamiliar with. This difference demonstrates how a space influences human perception and how it can be represented in different ways in the human mind (Figure 9).

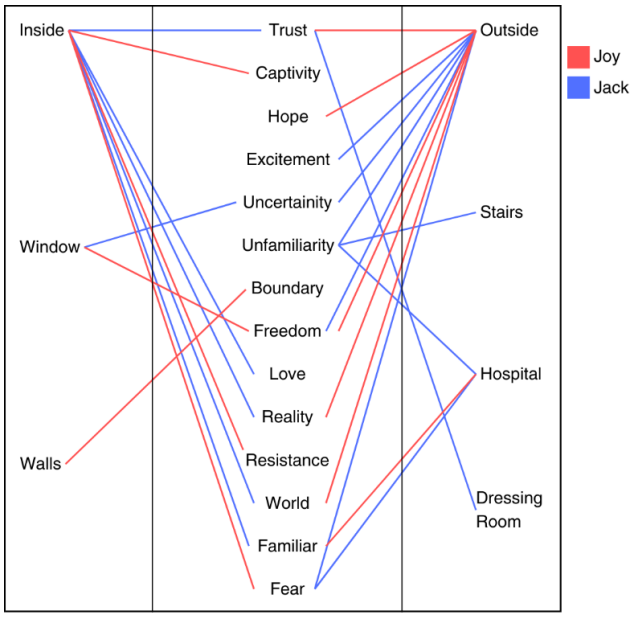


Figure 9. The relationship of the main characters with the space (Tokuç, 2025)

Conclusion and Recommendations

Cinema and architecture are two art forms that share similar characteristics in terms of the use and expression of space. Both aim to create atmosphere by influencing spatial experience. In cinematic works, space interacts with architecture through the representational power of cinema. Spaces are used as a significant tool in the cinematic language to strengthen fictional narratives and convey emotional expressions. In cinema, spaces can be used as a part of the story, reflecting the inner worlds and relationships of characters. At the same time, architectural elements and environmental details contribute to the audience's emotional connection and understanding of the story's atmosphere.

Space perception is a complex process that involves the integration of sensory information from multiple sources. It involves the process of evaluating the details, dimensions, colors, textures, sounds, and overall atmosphere within a space. Various elements such as space organization, color selection, lighting, sound, and smell can influence an individual's perception of space. Furthermore, factors such as an individual's personal history, cultural background, age, and emotional state can also determine spatial perception. This concept goes beyond the physical characteristics of a space and aims to understand and explain individuals' experiences related to that space. The perception of space offers an understanding of an individual's interactions with space, its meanings, and emotional responses.

In cinema, spaces function as carriers of the story told through their color palettes, textures, dimensions, lighting, and other elements. These elements determine the atmosphere of the space and the emotional states of the characters, imbuing the audience with a deeper meaning. In this

context, the spatial design and color palette used in the film "Room" serve to support the story and emphasize the characters' perception of space.

The film "Room," which serves as the sample for this research, emphasizes that spatial perception is a subjective and individual experience through Joy and Jack's relationship with space. For Jack, the room is not just a physical space but also a symbol of his world, his trust, and his loving bond with his mother. In this context, the interior is seen as an expression of security and belonging for Jack. Conversely, for Joy, the same space symbolizes captivity, resistance, and fear. For Joy, the exterior represents the real world, hope, and the security of a familiar space, while for Jack, it reflects unfamiliarity, uncertainty, and excitement. The research results demonstrate that the relationships and perceptions of space of Joy and Jack, the main characters in the film "Room," are quite different. This emphasizes that the perception of space is a personalized, emotional, and meaningful experience. In this context, the power of space to influence individuals' perceptions and the potential to explore different meanings associated with space itself come to the fore.

The findings of this study emphasize the personal and emotional dimension of space perception, providing a perspective on spatial design and use in architecture. Understanding how the spaces in the film are perceived by characters with different backgrounds and perspectives can contribute to the field of architecture by evaluating sensory elements and emotional experiences within space during design processes. In this context, understanding space not only through its physical boundaries but also through its emotional and semantic depths allows for more effective and meaningful design decisions. This article provides an important reference for researchers and designers seeking to understand the impact of space on individuals and integrate this knowledge into their design processes.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Akyol, Z. (2019). *Sinemada mekan kullanımı.* Retrieved: March 1, 2024, from http://projeksin.com/sinemada-mekan-kullanimi/

Aydınlı, S. (1986). *Mekansal değerlendirmede algısal yargılara dayalı bir model (Phd Thesis). İstanbul Technical University, Institute of Science, İstanbul.*

Aydoğan Şahin, N. E. (2019). *Çocuklarda mekan algısı ve mekansal imge zenginliği bakımından tasarımın önemi (Master Thesis). Mimar Sinan Fine Arts University, Institute of Science, İstanbul.*

Burnett, R. (2007). *İmgeler nasıl düşünür? (Çev. G. Pusar).* İstanbul: Metis Yayınları.

Cairns, G. (2013). *The Architecture of the Screen.* Chicago: Intellect Books.

Cüceloğlu, D. (1996). *İnsan ve davranışı, psikolojinin temel kavramları.* İstanbul: Remzi Kitabevi.

Ersoy, E. (2010). *Mimarlık ve sinema etkileşimi bağlamında mekansal imge kullanımıyla durağan mekanın dinamik mekana dönüşümü (Master Thesis). İstanbul Technical University, Institute of Science, İstanbul.*

Güleç, G. & Çağlar, N. (2014). Sinema ve Mimarlık Etkileşimi: Tim Burton Filmlerinde Modernizm Eleştirileri. *Mimarlık*, 51 (375), 45-49.

Gür, Ş. Ö. (1996). *Mekan örgütlenmesi*. İstanbul: Birsen Yayınevi.

Hekimoğlu, Y. (2021). *Sinemada mekânsal imgelerin mekân deneyimine etkisi: Akira Kurosawa filmleri üzerinden inceleme (Master Thesis). Eskişehir Osmangazi University, Institute of Science, İstanbul.*

Koç, B. (2012). *Çocuklar için tasarlanan mekanlarda bilişsel sınırlar (Master Thesis). İstanbul Technical University, Institute of Science, İstanbul.*

Köseoğlu, E. & Yücel, R. S. (2023). Analysis of the movie Ratatouille in the context of spatial scale. *Journal of Social Sciences and Education*, 6(1), 29-56.

Lang, J. (1987). *Creating architectural theory.* Newyork: Van Nostrad Reinhold Press.

Pallasmaa, J. (2007). *The Architecture of image: existential space in cinema / Juhani Pallasmaa; (translation and checking: Michael Wynne-Ellis).* Helsinki: Rakennustieto.

Sayar Avcıoğlu, S. & Akın, O. (2017). Kolektif bellek ve kentsel mekan algısı bağlamında İstanbul Tuzla Köyiçi Koruma Bölgesi'nin mekansal değişiminin irdelenmesi. *İdealkent*, 8(22), 423-450.

Selvitop, S. S. (2017). *Sinemada kurgusal mekan oluşumu ve yaratılan mekanların resimsel estetiği (Master Thesis). Mimar Sinan Fine Arts University, Institute of Science, İstanbul.*

Us, F. (2023). Sinemada kurgusal mekan kullanımı: Parazit filmi. *Uluslararası Sosyal Bilimler ve Sanat Araştırmaları Dergisi*, 2 (2), 134-151.

Yıldırım Yargıcı, C. (2021). *Sinema ve mimarlık ilişkisinin Fellini filmleri üzerinden değerlendirilmesi: tatlı hayat (la dolce vita) (1960) film örneği (Master Thesis). İstanbul Technical University, Institute of Science, İstanbul.*

Yurttaş, N. B. (2019). Mekansal algı kavramı ve iç mekan tasarımı ilişkisi. *Euroasia Journal of Sociak Sciences & Humanities,* 6(1), 27-34.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

GIS Tools Used in Spatial and Temporal Prediction and Analysis of Land Use/Land Cover Changes: MOLUSCE

Çağla AYDEMİR [1*]

ORCID 1: 0000-0003-3575-8957
[1]Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
caglaaydemir@sdu.edu.tr (Responsible Author)

Ömer Kamil ÖRÜCÜ [2]

ORCID 2: 0000-0002-2162-7553
[2]Assoc. Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
omerorucu@sdu.edu.tr

Seda ÖRÜCÜ [3]

ORCID 3: 0000-0003-1592-5180
[3]Assoc. Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
sedaorucu@sdu.edu.tr

Abstract

The rapid growth of the human population, its mobility, demand, and supply have a significant impact on land use/land cover (LULC) dynamics. Especially, LULC changes appear as biodiversity loss, deterioration of water quality, increase in greenhouse gas emissions, carbon cycle disruption, and decrease in livelihoods, and these changes are among the frequently discussed issues in scientific studies. Geographic Information Systems (GIS) are frequently used in scientific studies to predict the consequences of damage resulting from LULC and to reveal future management strategies. A new tool, Molusce (Land Use Change Assessment Modules), is used to understand the factors affecting historical, current, and future changes in LULC and the significance of these changes. Molusce is a plugin for QGIS that facilitates the exploration, modelling, and simulation of LULC changes. In this study, the aim is to reveal the importance of the QGIS plugin Molusce in spatial and temporal change analysis of land cover and future scenario modeling. In this context, the pros and cons of the Molusce tool in LULC change analyses were revealed and opened for discussion.

Keywords: Land use/land cover change (LULC), remote sensing, Molusce, QGIS

1. Introduction

Land cover is defined as the surface landscape, such as bare rocks, soil, vegetation, and water surfaces that can be seen with the naked eye and observed through satellite images, and is formed based on natural environmental features (Demir, 2021). Land use, unlike land cover, is difficult to observe and means that people utilize the surface landscape for specific purposes and through human activities such as agriculture, settlement, and mining (Ebenezer et al., 2018; Selcuk et al, 2021). Today, land cover data has an important place as a basic base of information for sustainable resource management, land use and planning, and land use data for strategy development and planning studies (Demir, 2021).

Humankind has directly or indirectly affected and changed the land cover (Buğday & Buğday, 2019). The rapid increase in the world population has caused the demand and supply of human beings on the existing land cover to diversify and increase day by day. However, land is a limited resource (Muhammad et al., 2022). Overexploitation of existing resources in land cover has significantly impacted ecosystem services worldwide (Polasky et al., 2011). For example, it affects many natural ecosystems such as the world's biogeochemical cycle, nutrient cycle, soil carbon structure, water availability, etc. (Song & Denk, 2017). Costanza et al. (2014)

examined land cover/land use (LULC) changes in forests and wetlands in China between 1997 and 2011. They found a 3.59% decrease in forest areas and a 0.14% decrease in wetlands. Deforestation, desertification, soil erosion, and other forms of environmental degradation in the world are caused by the overuse of land cover (Bhattacharya et al., 2020). This situation is increasingly important for determining the spatial and temporal changes of existing resources in comprehensive LULC for sustainable land resource planning and management to achieve local, national, and international targets of countries that provide food security, economic development, and energy supply in pristine lands.

Remote sensing (RS) and geographic information system (GIS) are the best tools used to manage LULC research and natural resources (Kamaraj & Rangarajan, 2022). In spatial and temporal analysis of LULC changes, UA and GIS help in efficient preparation of natural resources and also in land management and monitoring long-term change dynamics (Ebenezer et al., 2018; Bhattacharya et al., 2020). On the other hand, LULC is often an important tool in research to reveal when and how often changes will occur and to produce predictions for the future (Guidigan et al., 2019).

Remote sensing (RS) and geographic information systems (GIS) are fundamental tools used in many scientific studies and fields that enable the display, analysis, and interpretation of geographic data. GIS technology is a frequently used tool today due to its easy accessibility and functionality, open source software, and wide range of plug-ins. QGIS is an important GIS program known for its user-friendly interface, powerful features, and participatory development community (Albut, 2024).

Molusce (Land Use Change Assessment Modules) is a QGIS plugin designed for LULC analysis, modeling, and future LULC simulation using land cover images from various time periods (NetGıs, n.d.1). It is a QGIS plugin frequently used in LULC analyses today. Molusce, a QGIS plugin with an easy-to-use interface, is used by many researchers to investigate, model, and simulate LULC changes created with the Cellular Automata (CA) model. In this study, the QGIS plugin Molusce was examined and its place and importance in GIS system tools were tried to be revealed. The features of the plugin are mentioned, and the pros and cons it provides to researchers in LULC change analyses are mentioned.

2. QGIS plugin MOLUSCE

Scientific developments in Geographic Information Systems, as well as their methods, have gained momentum day by day. One such method is the Multilayer Perceptron (MLP) Neural Network. This method is used for various purposes, such as distinguishing surface changes, planning land suitability maps, and so on. It can be done using the Multi-Layer Perceptron (MLP) Neural Network method in the Geographic Information System. This method is performed in the QGIS software, which includes the Modules for Land Use Change Simulations (Molusce) modules.

Molusce is a QGIS plugin and stands for Land Use Change Assessment Modules. Molusce includes well-known algorithms used in LULC analysis. It is an open-access resource and has been developed for QGIS 2.0 and above by Asia Air Survey Co., Ltd (AAS) since 2012 (Gismondi et al., n.d.1).

Molusce is primarily used for the following (Thanekar & Krishna, 2021):

- Analyze land use and changes,

- Model land use transition potential and areas at risk,
- Create simulations of future land use/land cover changes.

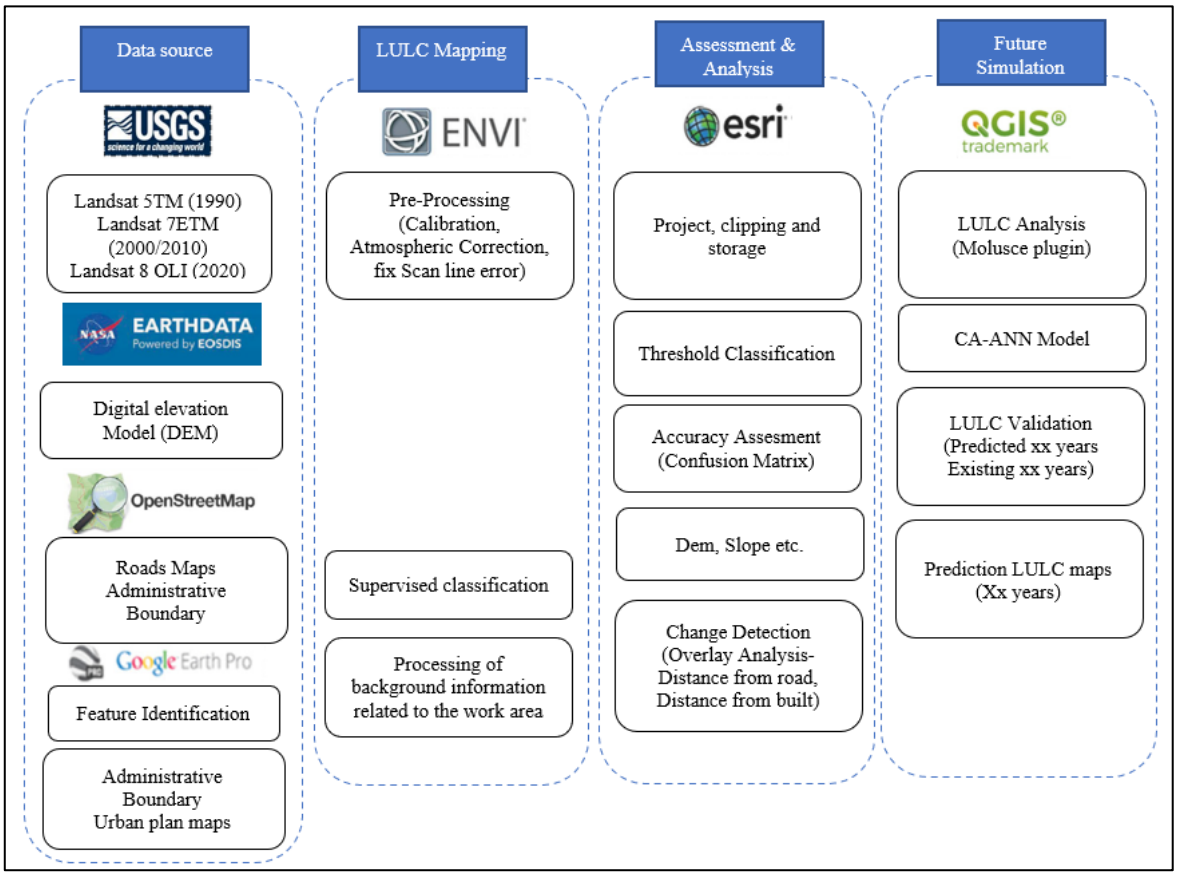


Figure 1. QGIS Molusce methodological workflow

Molusce is a software that simplifies LULC modeling and simulation processes. The software includes three algorithm plugins for modeling and simulation. The auxiliary modules incorporate several well-known algorithms, such as cross-tabulation techniques and algorithmic modules (e.g., Artificial Neural Networks (ANNs), Multi-Criteria Evaluation (MCA), Weights of Evidence (WE), Logistic Regression (RL), and Monte Carlo Cellular Automaton (MCA) models).

The program's interface consists of seven main components. These main components are (Gismondi et al., n.d.1):

1. Inputs
2. Evaluation correlation
3. Area change
4. Transition potential modelling
5. Cellular automata simulation
6. Validation
7. Messages'dır.

3. Using QGIS MOLUSCE: Data Loading and Model Training

Inputs: LULC maps for the initial (Time1) and final (Time2) periods, and spatial changes such as elevation, slope, population density, road networks, and demographic information are loaded into QGIS. All this data is used to model and simulate the LULC change. All spatial datasets loaded here must have the same geometry (coverage and spatial resolution). If the spatial data is not identical, a "Check geometry" function is available in the "Inputs" tab.

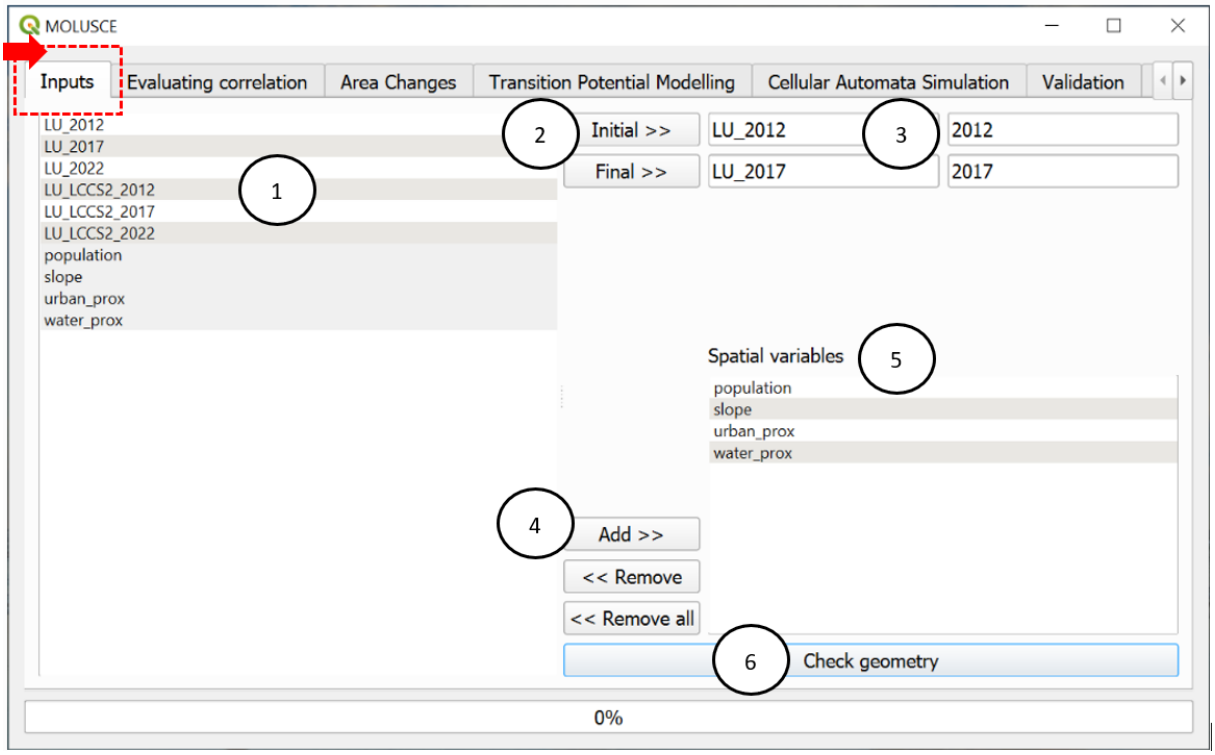


Figure 2. QGIS Molusce data loading phase

Step 1: This is the step where all raster data required for the LULC transformation is imported.

Step 2: This is the step where the Time 1 and Time 2 LULC maps are imported. The geometry of all files, including pixels, scaling, and projection, is created here.

Step 3: This shows the study years of the LULC transformation maps. If the plugin doesn't automatically add them, you can add them manually.

Step 4: This is the step where you add/remove the spatial variable data you want to add to the LULC transformation. This step includes adding or removing variables such as geographic data (slope, elevation, etc.) and cultural data (population, etc.).

Step 5: This is the tab where the LULC transformation spatial variables are displayed.

Step 6: This is the "Geometric Verification" button for the spatial data. This step checks whether the same geometry (spatial resolution) of the raster data is compatible.

Evaluation correlation: LULC checks the spatial changes correlation with three methods: Pearson Correlation, Crammer's Corfficient and Joint Information Uncertainty. In this tab, the extent to which spatial factors are related to each other is calculated. If the correlation between two factors is very strong, using only one may be sufficient.

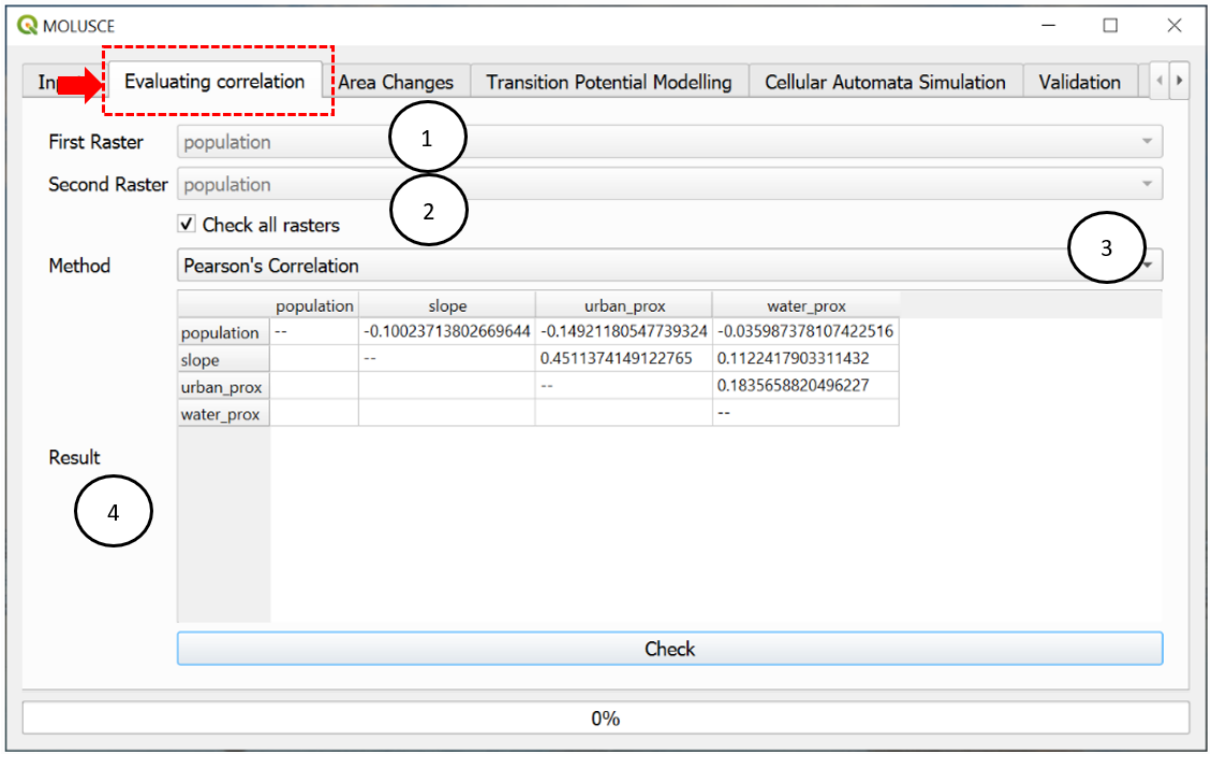


Figure 3. Calculating correlations of spatial data

Step 1: This is the step where the raster spatial data for the Time1 and Time2 periods are selected.

Step 2: This is the step where the spatial raster data for which the correlation is to be performed is selected.

Step 3: In the Method button, one of the three correlations is selected: Pearson Correlation, Crammer's Corfficient, and Joint Information Uncertainty.

Step 4: This is the tab where the correlation results for the spatial data are displayed.

Area change: It calculates the LULC change and transition probabilities between two time periods (T1 and T2). Transition matrices and land use change maps are generated for LULC. LULC data can be expressed in square meters, square kilometers, and hectares.

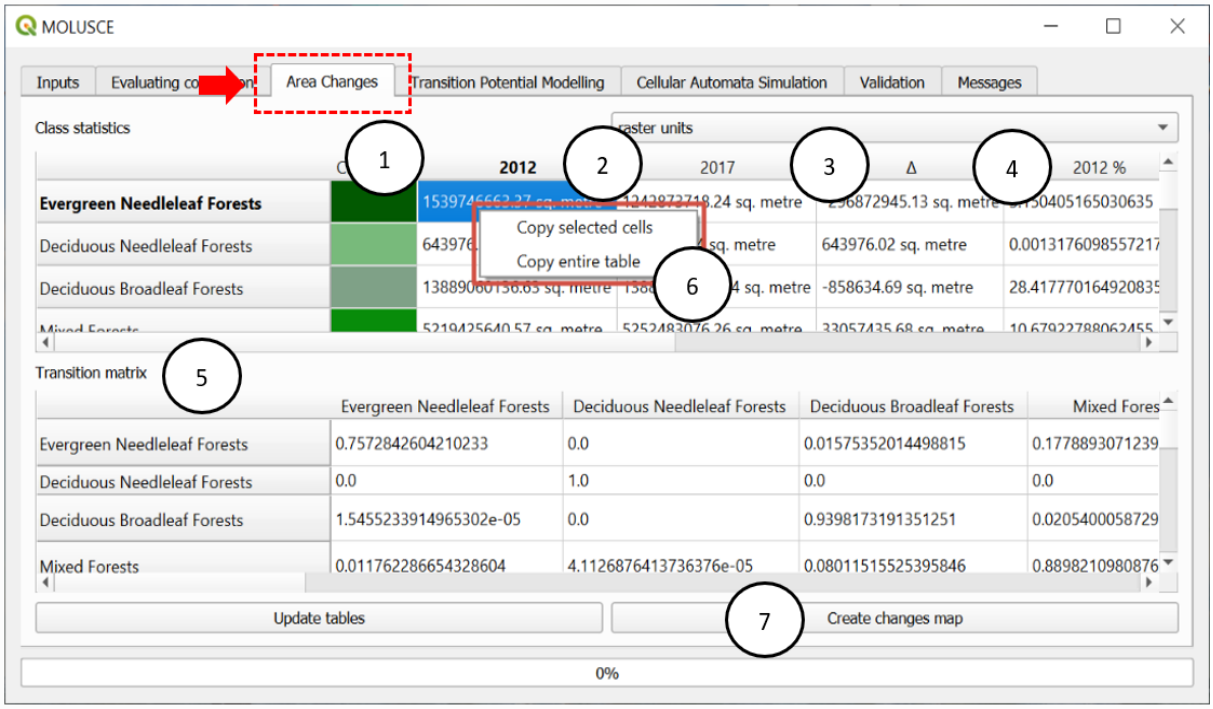


Figure 4. LULC area change table

Step 1: This gives the LULC areas at Time 1 in meters, hectares, etc.

Step 2: This gives the LULC areas at Time 2 in meters, hectares, etc.

Step 3: This gives the rates of LULC land cover changes at Time 1 and Time 2 in meters, hectares, etc.

Step 4: This gives the percentage of land cover changes between Time 1 and Time 2.

Step 5: This gives the percentage of land cover changes from Time 1 to Time 2, indicating the change in meters, hectares, etc. of each land cover.

Step 6: This shows the context menu by left-clicking on any cell, and the tables can be copied as a GeoTiff.

Step 7. This creates a map of LULC land change classifications from Time 1 to Time 2.

Transition potential modelling: One of four methods, namely Artificial Neural Networks (ANN), Logistic Regression (LR), Multi-Criteria Evaluation (MCE), and Weights Evidence (LR), is used to estimate the probability of LULC land cover transitions. Each method is used as input to calibrate and model the LULC spatial changes. The LULC estimate will ultimately show the value of kappa validation of the spatial change results.

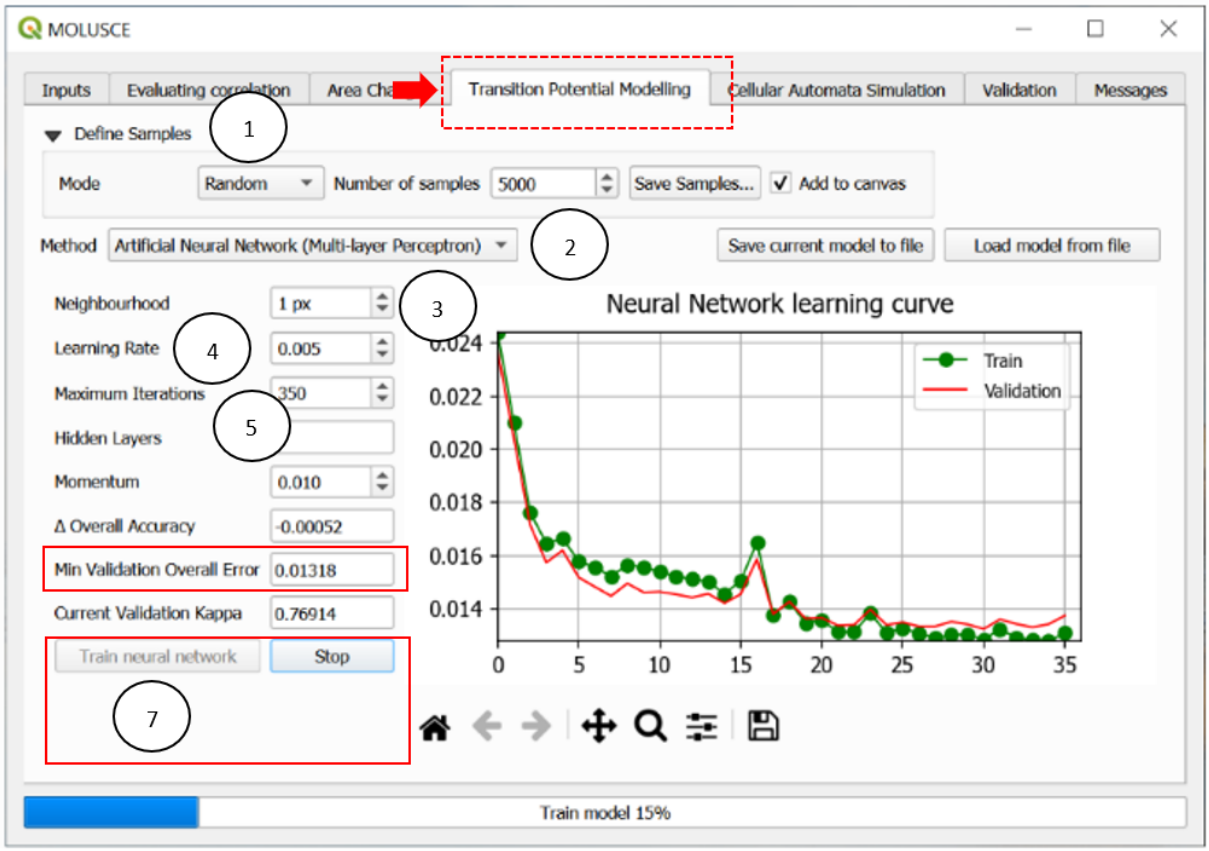


Figure 5. Training a neural network and typical learning curves

Step 1: This is the step where the model's sample parameters are selected to estimate the probability of land cover transitions. Here, the number of samples can be configured to configure the model's accuracy.

Step 2: Here, one of the four methods offered by the model is selected. Artificial Neural Networks (ANN) were selected in this step.

Step 3: Neighborhood; defines the number of neighboring pixels around the current pixel (typically, values of 1 or 0 are used).

Step 4: Learning rate (lower values result in a more accurate model).

Step 5: Maximum number of iterations; number of learning cycles. If the value is too high, overfitting may result.

Step 6: Hidden layers define the complexity of the model.

Step 7: Click Train neural network. You will see the learning curve and error curve in the graph. If you notice that training is not going well, you can click Stop and adjust the parameters. If training is successful, both curves will slope downward smoothly, and the current Validation Kappa value is around 0.8 or above.

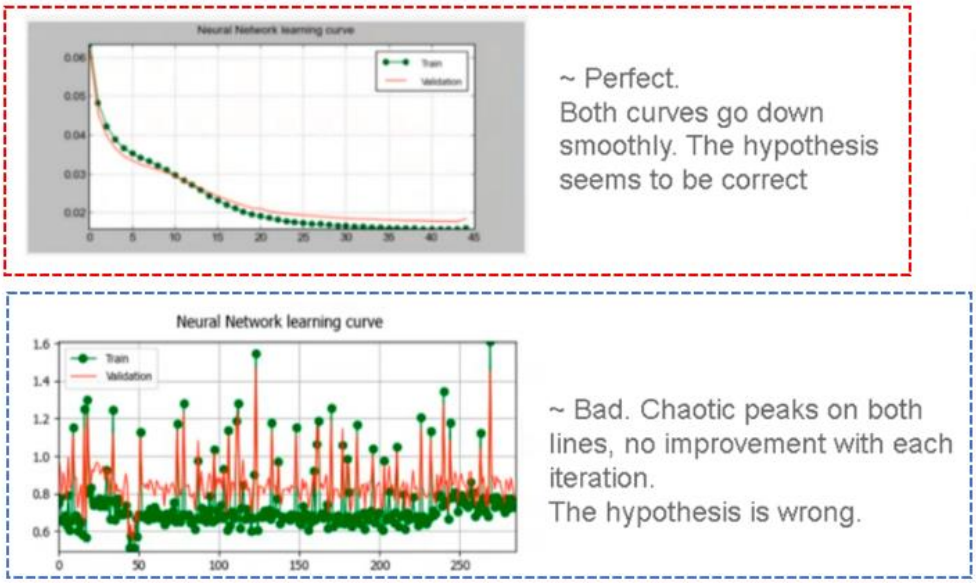


Figure 6. Typical learning curves (Source: NetGıs, n.d.1)

Cellular automata simulation: Shows transition potential maps, confidence function (experimental), and results of simulated LULC change maps. An estimated LULC map is produced by a modeling approach based on the Monte Carlo algorithm. This can be done after the kappa value in the previous stage meets the evaluation standard.

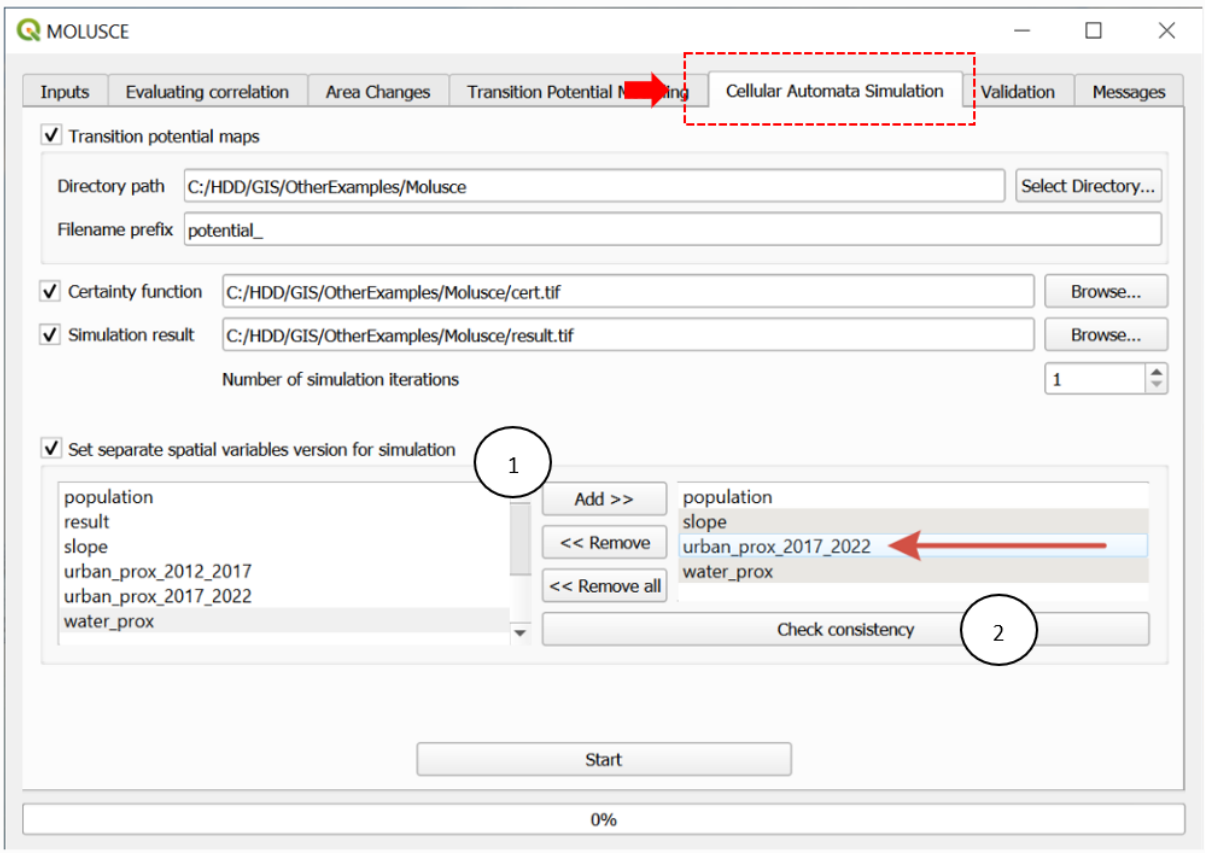


Figure 7. Simulation Settings

Step 1: LULC variables are selected in the input section.

Step 2: Click the start button to start the simulation. To start the simulation, the kappa value in the previous training model must be 0.8 or higher.

In this step, in addition to the simulated land use/cover map (NetGıs, n.d.1):

-The transition potential map indicates the probability or potential for a transition from one land use/cover class to another. Values range from 0 (low potential) to 100 (high transition potential).

-The precision function indicates the degree of estimation certainty. Values range from 0 (low precision) to 100 (high precision). A low precision probability means that a particular transition type was not sampled.

Validation: Verification of the performed transactions is determined by the Kappa statistics. Kappa values are a step that increases the transaction success statistic by alerting users to recalculate the accuracy of the transactions if they meet the standards.

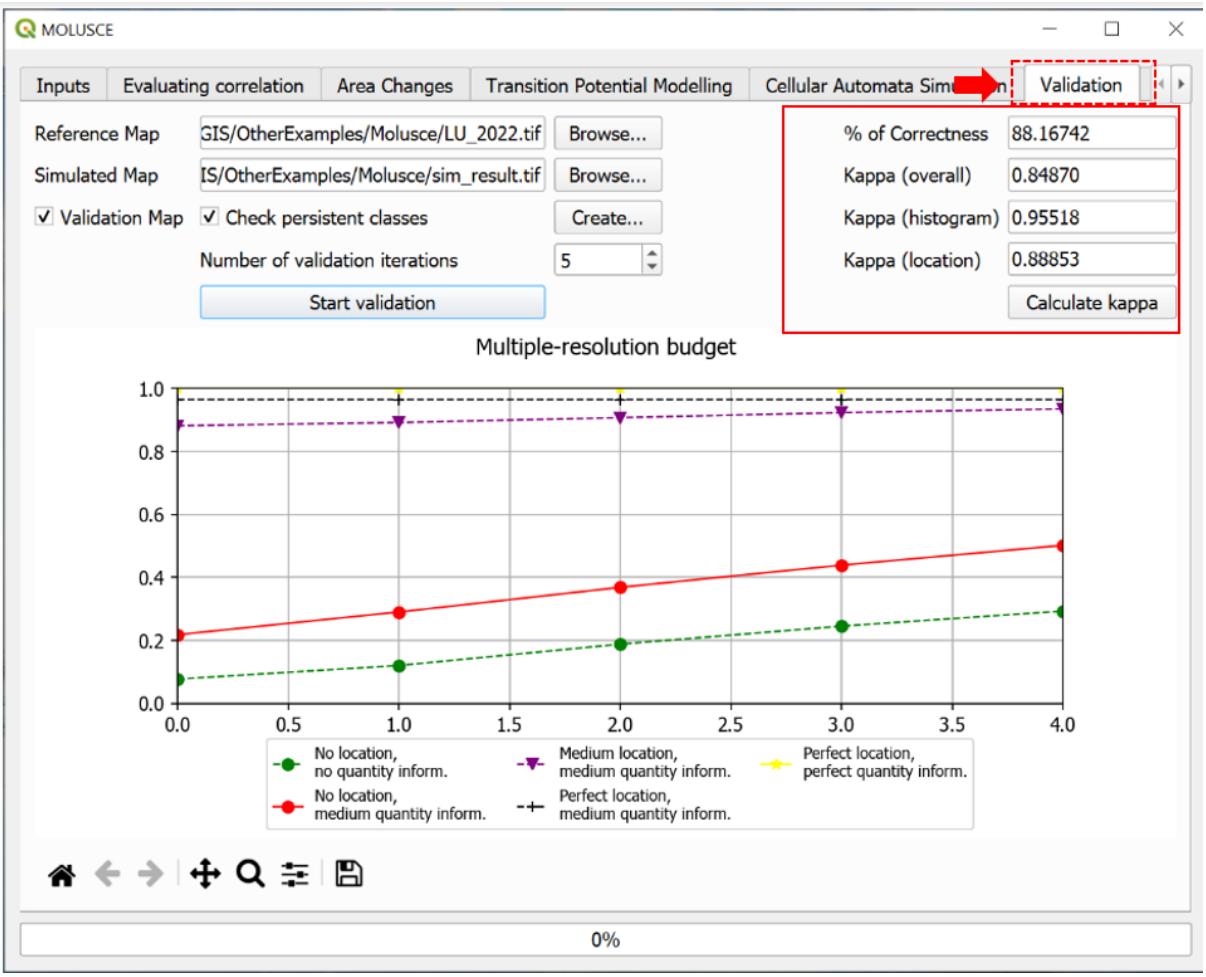


Figure 8. Mollusce kappa Validation

Messages: This tab is used to provide error messages or warnings to the user during modeling or simulation progress. It helps users access the margin of error and kappa success indicators by alerting them during process steps.

4. The pros and cons of the QGIS MOLUSCE plugin

Advantages offered to the user by the QGIS plugin Molusce:

- Molusce is an open-source software product of the QGIS program.
- Molusce is an easy-to-use and understandable software program.
- Molusce ASS is constantly developing the program. ASS offers new add-ons, technical support, and training opportunities.
- LULC provides convenience in determining temporal and spatial changes in change maps. It particularly enables the acquisition of data on temporal and spatial changes in land cover in terms of meters, hectares, or percentages.
- LULC facilitates the acquisition and creation of maps as well as statistical information for the future.
- LULC facilitates the acquisition of more accurate data by calculating not only high-resolution satellite images but also spatial changes such as elevation, slope, population density, road networks, and demographic information in obtaining spatial and temporal changes and future data.
- It includes Artificial Neural Networks (ANN), Logistic Regression (LR), Multi-Criteria Evaluation (MCE), and Weights Evidence (LR) methods that have been proven accurate and frequently used in scientific studies in obtaining future LULC data.
- Molusce warns the user when obtaining future data with LULC spatial and temporal change data, ensuring that the error margin and kappa success indicators ensure more accurate data acquisition.
- It presents data on future-oriented LULC maps in an easy-to-understand format. Providing tables of LULC data in meters, hectares, or percentage change significantly simplifies the interpretation of these data by urban planners, landscape architects, politicians, and decision-makers working in this field, making it easier to make sustainable urban planning decisions.

Disadvantages of the QGIS plugin Molusce:

- Preprocessing of the underlying spatial data used to generate LULC spatial and temporal data is necessary. For example, creating maps such as satellite imagery, DEM, and so on, based on the study area boundaries, land use classification of satellite imagery, processing into transportation maps, and other spatial map preprocessing are necessary.
- The pre-processing stages of the base spatial data used to create LULC spatial and temporal data are very time-consuming.
- The base used to create LULC spatial and temporal data causes the program to be unusable or take too much time if the spatial data is high resolution and there is not enough technical infrastructure.
- The geometric (coverage and spatial) resolutions of the underlying spatial data used to create LULC spatial and temporal data must be the same. Otherwise, Molusce LULC spatial and temporal data cannot be created.
- The Molusce program user must be proficient in one of the following methods: Artificial Neural Networks (ANN), Logistic Regression (LR), Multi-Criteria Evaluation (MCE), and Weights Evidence (LR).

5. Conclusion and Recommendations

In the 21st century, the increasing population, economic expansion, and the resulting urbanization process have seriously changed the existing land cover. The current change in land cover is primarily triggered by physical and socio-economic factors such as geography, increasing population, and economic expansion. However, socioeconomic development has a greater impact on urban expansion than overpopulation (Muhammad et al., 2022). The acceleration and growth of land cover change have raised concerns about climate change, food security, natural resource scarcity, etc. Therefore, LULC estimation plays a vital role in formulating plans to balance conservation, competing users, and development pressures (Kamaraj & Rangarajan, 2022). It is also inextricably linked to geography and development policies. Therefore, QGIS, a GIS tool, is an important tool for policy makers to analyze the change in LULC density and the socio-economic factors affecting it, with spatial and temporal land cover change and future LULC outcomes. Consequently, the QGIS plugin Molusce will help them to monitor spatial and temporal land cover change and future LULC data to promote environmental protection, sustainable development, and policies.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Albut, S. (2024). Land use land change utılızıng the QGIS Molusce plugın. Mimarlıkta ileri araştırmalar (Edt: Dr. Öğr. Gör. Saadet Gündoğdu). *Yaz yayınları*, Aralık 2024, Afyonkarahisar, E_ISBN 978-625-5547-31-6.

Bhattacharya, R.K., das Chatterjee, N., Das, K. (2020). Land use and Land cover change and its resultant erosion susceptible level: an appraisal using RUSLE and Logistic Regression in a tropical plateau basin of West Bengal, India, *Environment, Development, and Sustainability*. Springer Netherlands. https://doi.org/10.1007/s10668-020-00628-x

Buğday, E., & Buğday, S. E. (2019). Modeling and simulating land use/cover change using artificial neural network from remotely sensing data. *Cerne*, *25*, 246-254.

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., ... & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global environmental change*, *26*, 152-158.

Demir, M. (2021). CORINE sistemine göre Kars ilinde arazi örtüsü/arazi kullanımı, değişimi ve projeksiyonu. *Cografya Dergisi*, 43, 93-110. https://doi.org/10.26650/JGEOG2021-887753

Ebenezer, B., Geophery, K.A., Jonathan, A.Q.-B., & Emmanuel, A.D., (2018). Land-use change and sediment yield studies in Ghana: Review. *Journal of Geography and Regional Planning* 11, 122– 133. https://doi.org/10.5897/jgrp2018.0707

Gismondi, M., Kamusoko, C., Furuya T., Tomimura, S., Maya, M. (n.d.1). *Molusce*. https://www.ajiko.co.jp/download/pdf_tf2014/p62-63.pdf

Guidigan an M.L.G., Sanou, C.L., Ragatoa, D.S., Fafa, C.O., Mishra, V.N. (2019). Assessing Land Use/Land Cover Dynamic and Its Impact in Benin Republic Using Land Change

Model and CCI-LC Products. *Earth Systems and Environment* 3, 127–137. https://doi.org/10.1007/s41748-018-0083-5

Kamaraj, M., Rangarajan, S. (2022). Predicting the future land use and land cover changes for Bhavani basin, Tamil Nadu, India, using QGIS MOLUSCE plugin. *Environ Sci Pollut Res* 29, 86337–86348. https://doi.org/10.1007/s11356-021-17904-6

Muhammad, R., Zhang, W., Abbas, Z., Guo, F., & Gwiazdzinski, L. (2022). Spatiotemporal Change Analysis and Prediction of Future Land Use and Land Cover Changes Using QGIS MOLUSCE Plugin and Remote Sensing Big Data: A Case Study of Linyi, China. *Land* 2022, 11, 419. https://doi.org/10.3390/ land11030419

NetGıs. (n.d.1). *Molusce.* https://docs.nextgis.com/docs_ngqgis/source/molusce.html

Polasky, S., Nelson, E., Pennington, D., & Johnson, K. A. (2011). The impact of land-use change on ecosystem services, biodiversity and returns to landowners: a case study in the state of Minnesota. *Environmental and Resource economics*, *48*(2), 219-242.

Selcuk, S. F, Cebeci, M.S., Köker, B., & Yılmaz, Z. (2021). Konya İli Arazi Kullanım/Örtüsü Değişim Analizi. *Turkish Journal of Landscape Research,* 4 (2), 100-114, DOI: https://doi.org/10.51552/peyad.1033847

Song, W., & Deng, X. (2017). Land-use/land-cover change and ecosystem service provision in China. *Science of the Total Environment*, *576*, 705-719. http://dx.doi.org/10.1016/j.scitotenv.2016.07.078

Thanekar, G. S., & Krishna, R. V. (2021). *Land Use Land Cover Prediction Analysis.*

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Interior Architecture Design Suggestions in Traditional Urfa Houses: Re-Functioning

Ayşe Gül GÜZEL [1*]

ORCID 1: 0000-0002-7686-8338
[1] Asst. Prof. Dr., İstanbul Beykent University, Faculty of Engineering and Architecture, Department of Architecture, İstanbul -Türkiye
gulguzel@beykent.edu.tr

Abstract

Historical buildings are important works that provide information about the region's past, such as culture, architecture, socio-economic status, and way of life. However, these structures may experience material damage and deterioration over time. In this case, historical buildings can be re-functioned in a way different from their former use. In this study, traditional houses of Urfa were re-functioned for tourism and culture purposes and different design, function and concept suggestions were put forward. Şanlıurfa's historical architectural texture, consists of mansions and traditional Urfa houses. Urfa houses generally consist of two parts: the "harem" and the "selamlık" sections. In the selamlık section, there is a small courtyard, an iwan, and a large stable. The harem, the main section of the house where the household resides, is larger than the selamlık. Within the scope of this study, two separate registered houses were examined. These new functions include an ethnography museum, a restaurant and a boutique hotel. It is important that the interventions to be made are distinguishable from the original and preserve the characteristics of the historical building. In this regard, the designs have been made contemporary but compatible with the historical texture, identity, and culture of Urfa.

Keywords: Traditional Urfa Houses, re-functioning, interior architectural design

1. Introduction

Historical houses provide information on many topics, such as the architecture of the region where they are located, its past, the way of life of its people, its socio-economic status, the richness of its past living culture, and the level of technology achieved. However, these structures are not suitable for the contemporary life of today's people and cannot adequately meet their changing needs.

In order for these structures to keep pace with contemporary life, their layout plans are being disrupted by poor additions, many are being abandoned, and material damage is occurring. In this case, these historical buildings can be restored and re-functioned in a way different from their former use. These structures need to be protected to ensure their continuity and to be passed on to future generations, making them sustainable and livable. (Kutlu & Ergün, 2021, Hattap 2023, Aydın & Okuyucu, 2009).

In the re-functioning processes, the basis was to preserve the building in accordance with its original construction state and to determine compatible functions that would also carry the identity of its period. It is also important to preserve the characteristics of the historical building and to distinguish the interventions from their original state during the restoration and re-functioning processes. (Kutlu & Ergün, 2021).

In this study, traditional houses in the central Eyyubiye district of Urfa were re-functioned for tourism and culture purposes and different design, function and concept suggestions were put forward in accordance with the Conservation Development Plan.

Şanlıurfa is one of the oldest settlements in Mesopotamia, located in the center of GAP in the Southeastern Anatolia Region. Due to its proximity to rivers and its location on trade routes, it has maintained its strategic importance throughout history. (Yıldız & Rızvanoğlu 2012, p. 17,

Yıldız & Rızvanoğlu, 2014, p. 22). It has also gained importance in the field of tourism with its historical, cultural, and religious significance.

Excluding monumental structures the historical architectural texture of Şanlıurfa consists of mansions and traditional Urfa houses. More than 500 of these houses are registered as ancient monuments by the Ministry of Culture and Tourism (Kürkçüoğlu & Kürkçüoğlu, 2017, p.67). These structures have a history of 100-120 years.

Traditional Urfa Houses are located in a complex and adjacent layout. The width of the streets varies from 2.5 to 3.5 meters, which provides protection from high temperatures in summer. The houses in Şanlıurfa are entered through quite magnificent doors from narrow streets. (Akkoyunlu, 1988).

Urfa houses generally consist of two parts: the "harem" and the "selamlık" sections. In the selamlık section, there is a small courtyard called (hayat), an iwan, (eyvan), a large camel stable (develik) and a toilet. Urfa houses are planned as introverted, closed spaces. The harem section, which is the main part of the house where the household lives, is larger and more equipped than the selamlık section. In the middle of the courtyard, there is a marble pool, a well, and a "flower bed" containing one or more trees such as fig, mulberry, pomegranate, orange, oleander, and vine. (Kürkçüoğlu & Kürkçüoğlu 2017, p.67, Orhun, 1999).

The main determining element of the plan in the Traditional Urfa House is the iwan. The iwan is a rectangular space, a few steps above the courtyard level, with an open and arched facade facing the courtyard, windows on the side surfaces, a closed rear surface, and usually covered with a vault. On the north side of the harem courtyard, there is a “winter iwan” facing south with a room on either side, while on the south side, symmetrically, there is a “summer iwan” facing north with “living rooms” on either side. The iwans and rooms are sometimes 1-1.5 meters above the ground and in their lower parts there are cellar rooms called "zerzembe". In traditional Urfa houses, no other part of the house is given as much importance as the eyvan.

On the other sides of the harem courtyard, there are sections such as the kitchen (tandırlık), the bathhouse (hamam) and the woodshed. (Kürkçüoğlu & Kürkçüoğlu, 2017, p.67). The main building material of the load-bearing masonry walls of Urfa houses is white colored limestone. Windows and doors are wooden (Akkoyunlu, 1988).

2. Studio Works

Within the scope of this report, two separate houses named Abuzer Duran and Bakır Dellalbaşı, located in the areas specified as II. Group Registered Immovable Cultural Heritage in the Şanlıurfa Conservation Development Plans were examined.

Students of Akdeniz University Department of Interior Architecture and Environmental Design were asked to detail and re-function the restoration projects as interior architecture projects. As a result, Urfa's traditional houses were re-functioned for tourism and cultural purposes, and different design, function, and concept suggestions were put forward.

2.1. Abuzer Duran House

It is the first house examined.

It is a 2-storey building. On the ground floor, there are 3 iwans, 2 large living rooms, 2 cellars (one small and one large), a stable, a kitchen and a large courtyard. The terrace on the upper

floor is accessed via a stone staircase, and the main room is also accessed from this terrace. The other spaces have a soil roof.

There are two suggestions for this house. In the first suggestion, it was decided that the function would be an ethnography museum and its concept would be the tree of life. This choice was made because Urfa has hosted many civilizations, and the tree of life motif was used in these civilizations. The tree of life forms the vertical symbolism of life ever-evolving, ascending to heaven. Trees symbolize settledness and rootedness because they are rooted and settled in a certain area and cannot migrate. They symbolize life, beauty, eternity, the immortality of the universe and the axis of the earth. The tree of life form has been used in various stylized motifs in stone, wood, pottery, tile work, weaving, glass, illumination, miniature, literature and music. (URL 1) The tree of life motif has also been stylized and used in our carpets and rugs (Figure 1).

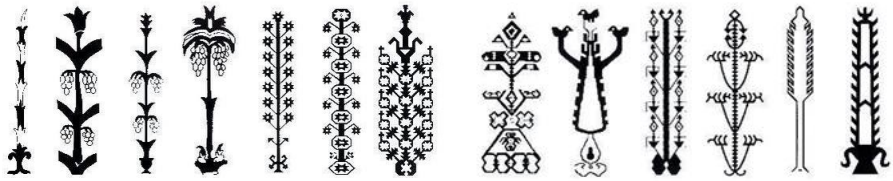


Figure 1. Tree of life motifs in Turkish carpets and rugs (URL 2)

The tree of life in this project, was used abstractly as a partial top cover of the courtyard and on the walls. (Figure 2, 3, 4, 5).



Figure 2. Section from the courtyard, Tree of life on the top cover and walls

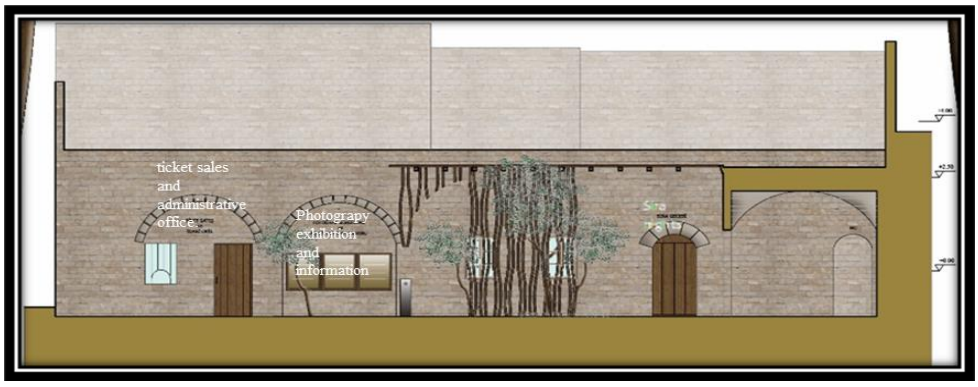


Figure 3. Section from the courtyard, Tree of life on the partial top cover of the courtyard and on the wall

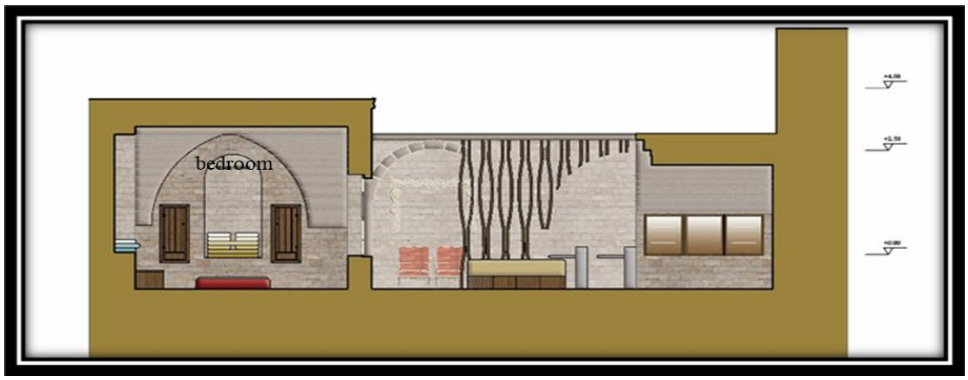


Figure 4. Section from the courtyard and iwan. Tree of life motif in the courtyard

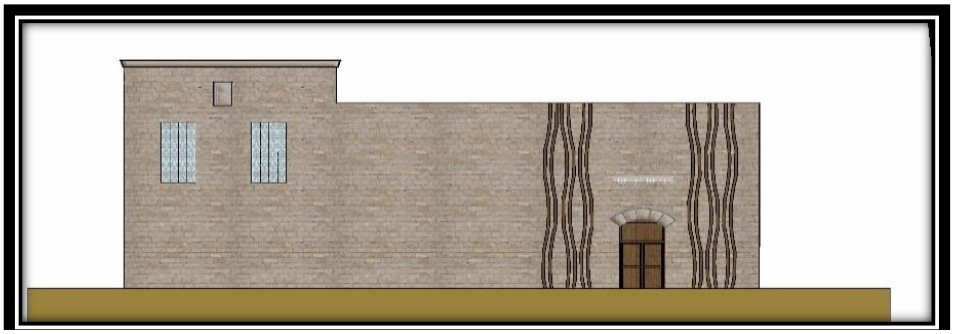
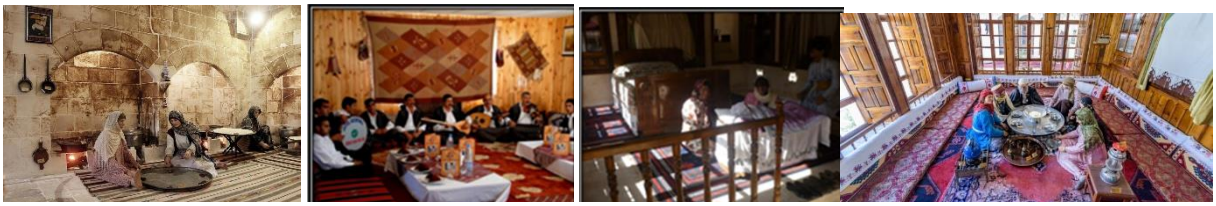


Figure 5. Elevation from the street. Tree of life motif on the outer wall

In this museum, an attempt was made to reflect the house culture of Urfa; kitchens, the sira nights (sıra gecesi), bedrooms, and living rooms held in Urfa were described (Figure 6). In Şanlıurfa, "sıra nights" refers to gatherings where a group of friends meet once a week. These gatherings are a learning environment where music is taught and performed according to the master-apprentice tradition (Kürkçüoğlu & Kürkçüoğlu 2017, p.93). The goal is to create a museum that appeals to all five senses rather than an ordinary museum.



Kitchen Sira Night Bedroom Living and

Figure 6. House Culture of Urfa (URL 3, URL 4)

In this project one of the three iwans on the ground floor has been preserved as a photography area with local costumes, the second as an exhibition area, and the third as a photography exhibition and information area. The small cellar was used as men's and women's toilets, and the stable was used as a place for sira night and folk dances. The living room is decorated as a dining and sitting, and the other living room is decorated as a bedroom. The large cellar was designed as a souvenir shop, and the kitchen was designed as a ticket sales and administrative office. The bathhouse is arranged as a local clothing wardrobe. There are orange, lemon and vine trees in the courtyard (Figure 7).

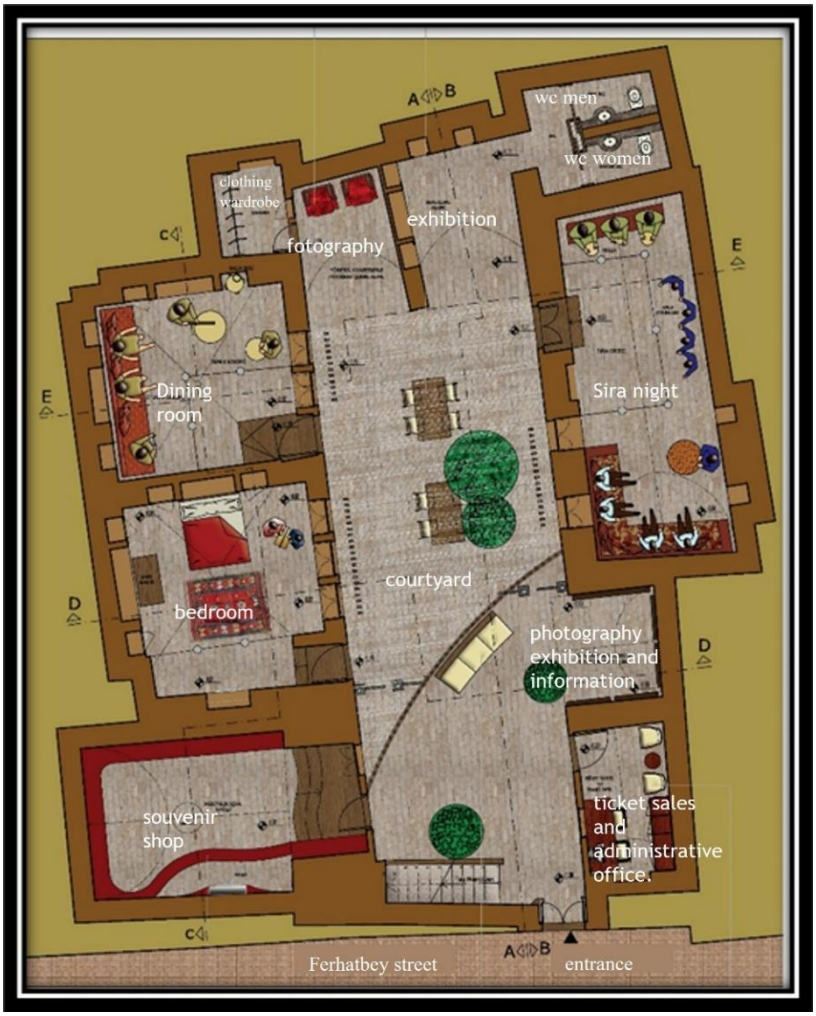


Figure 7. Ground Floor Plan

The main room on the upper floor is used as a food and beverage sales and the terrace in front of it is sherbet serving place. On this floor, the partial upper cover of the courtyard, symbolizing the tree of life, is also seen. (Figure 8)

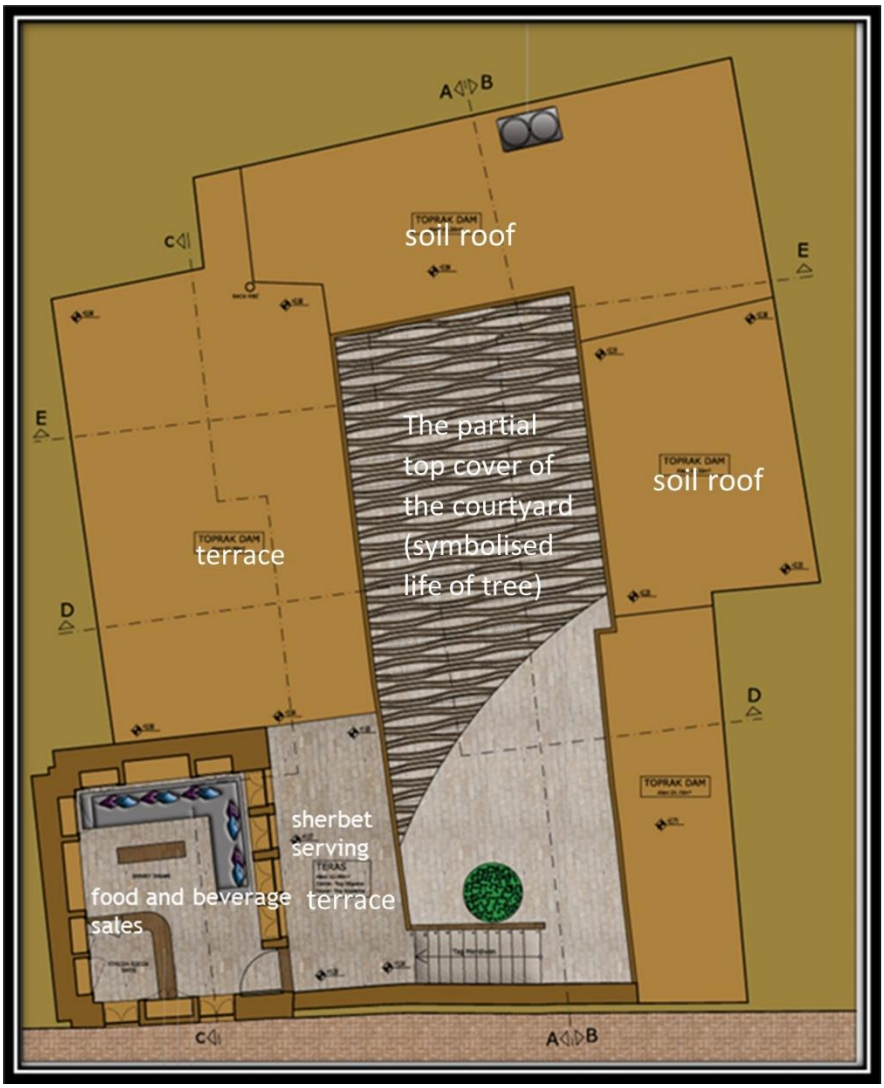


Figure 8. Upper floor plan

In the second suggestion for the Abuzer Duran House, it was decided that the function would be a restaurant and that its concept would include biorhythms and lines. This concept was chosen by establishing its association with food and beverage rather than with Urfa. When people are hungry, their biorhythm balance may change, they may have difficulty in mental perception, show physical weakness, and become aggressive in terms of sensitivity. Therefore, when people eat, their feelings of hunger disappear, and their mental and physical sensitivities improve. In the project, rhythmic line designs were also applied partialy to the cover of the courtyard, and walls, the interiors of the iwans, wall niches, and the legs of tables and coffee table, taking inspiration from biorhythm lines (Figure 9, 10, 11, 12).

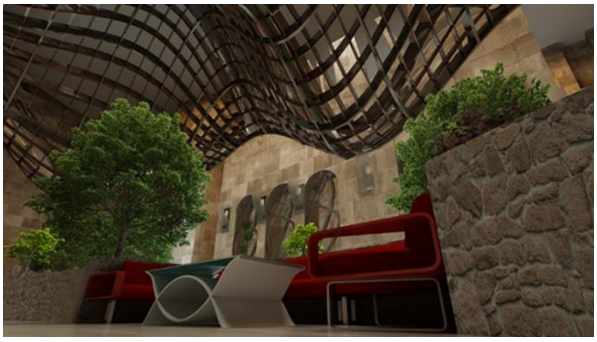


Figure 9. Elevation from the courtyard, biorhythm lines on the top cover



Figure 10. Biorhythm Lines in the Iwan

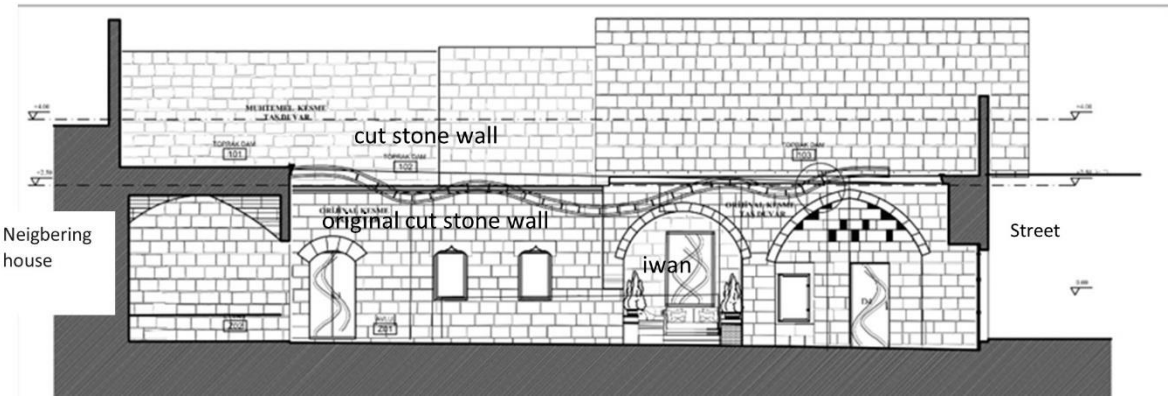


Figure 11. Section from the courtyard. Biorhythm Lines on the top cover and iwan

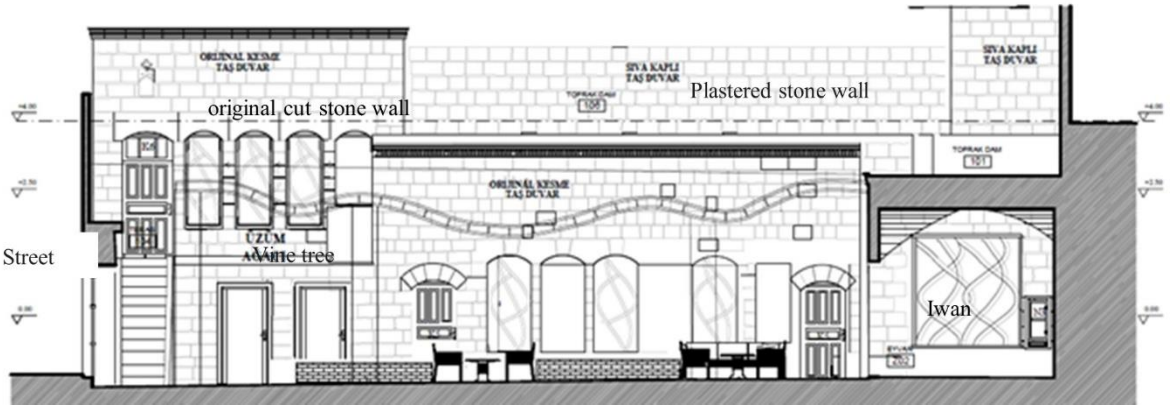


Figure 12. Section from the courtyard, biorythm lines on the top cover and iwan

Three of the iwans are designed as tea and coffee drinking and resting areas. The two living spaces were combined by opening a doorway in the wall between them and decorated as the main dining area. The front part of the large cellar is designed as a men's and women's toilets, the back part accessible from the main dining room is designed as a dining area with cedars (sedir). The stable was designed as the main kitchen, the small cellar designed in its original

function, the kitchen as the cass register place. The courtyard was also designed as an open eating and drinking area, preserving the trees (Figure 13)



Figure 13. Ground Floor Plan

The main room on the upper floor was used as the manager and accounting room (Figure 14).

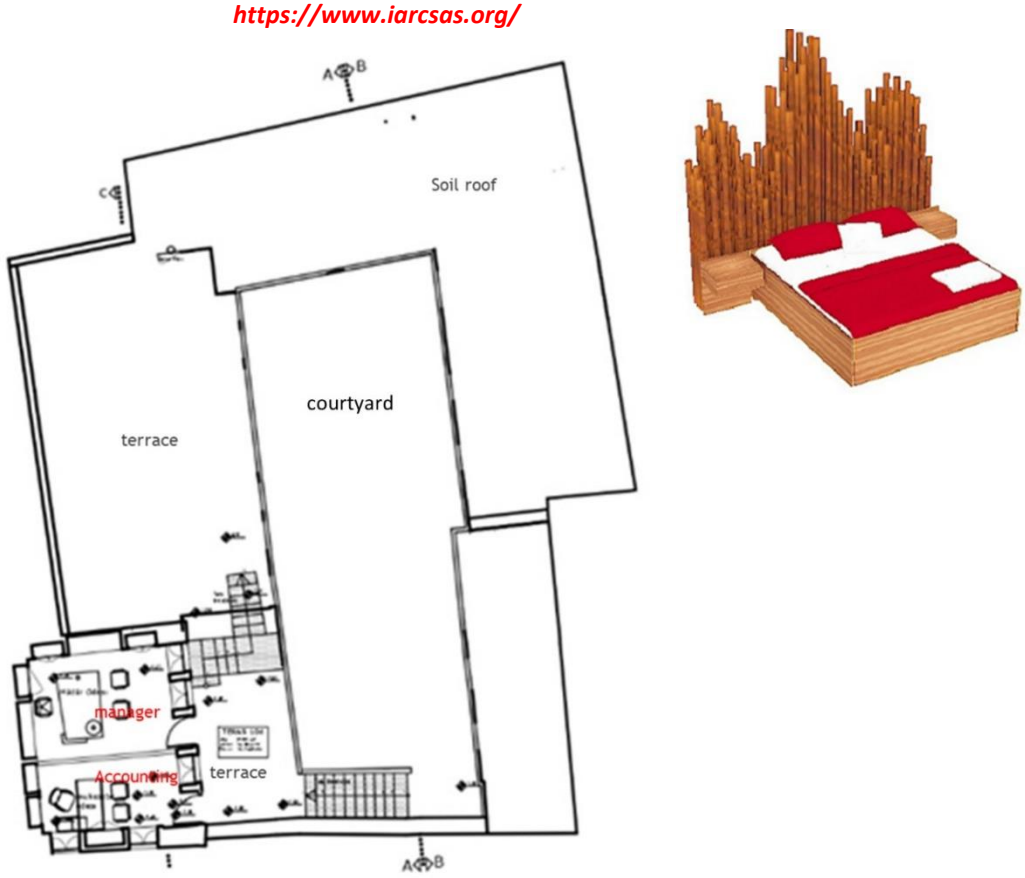


Figure 14. Upper Floor Plan

2.2. Bakır Dellalbaşı House

It is the second house examined.

It is a 3-storey building. On the ground floor, there is one iwan, two rooms on either side, six additional living rooms, a kitchen, a toilet and bathroom, and a large courtyard with a mandarin tree in the middle. Access to the upstairs rooms and terrace is provided by a stone staircase in front of the bathroom and toilet. The other rooms on the ground floor have a terrace above them. There is also a cellar in the basement, accessed via a stone staircase.

In this project, Boutique Hotel was chosen as the function and fire and water as the concept. According to the legend from the Babylonian period, Prophet Abraham was thrown into the fire by the Babylonian ruler Nimrod. When Abraham was about to fall into the fire, God said, "Send coolness and safety to Abraham," and the fire retreated in all directions and turned into water (Kürkçüoğlu ve Kürkçüoğlu, 2017, p.92). Based on this event, fire and water were symbolized in the design. While the spread of fire is from the ground upwards, the flow of water is from top to bottom. For this reason, fire form was used in the ground floor rooms and water form was used in the upper floor rooms.

Zigzag forms were obtained during the abstraction process, and these forms were achieved in the rooms on the ceilings with wooden pipes that create a warm effect. Wood has also been chosen for the furniture (Figure 15, 16)

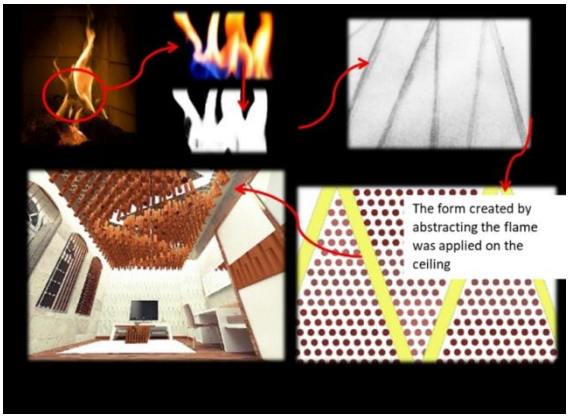


Figure 15. Fire abstraction process and design approach

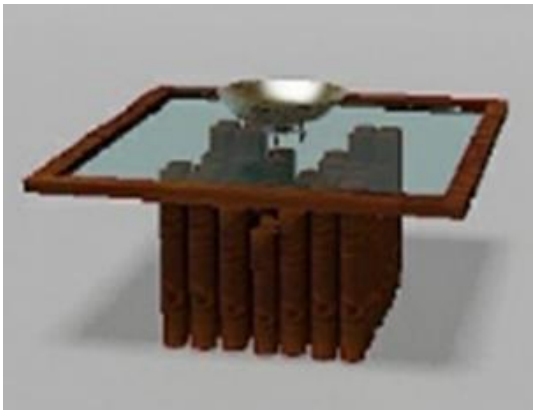


Figure 16. Wooden bed and coffee table symbolizing fire

The wave motion of the water theme is achieved with metal and glass materials on the ceilings and with light effects, aiming to create a water-like sensation. The furniture in these rooms is also made of metal and glass (Figure 17, 18).

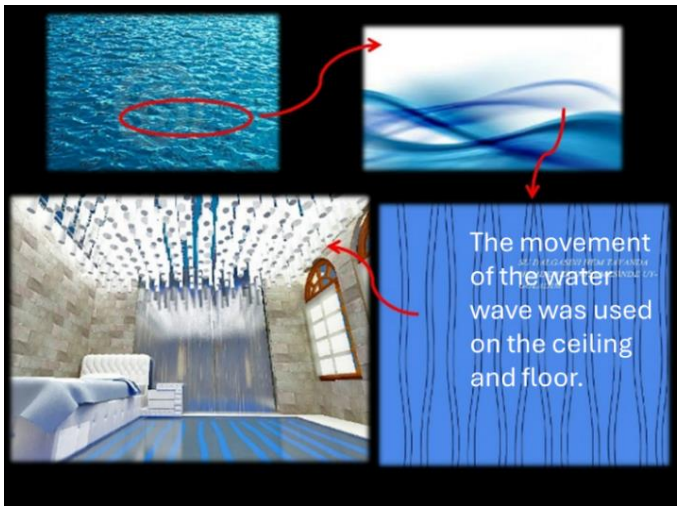


Figure 17. Water abstraction process and design approach

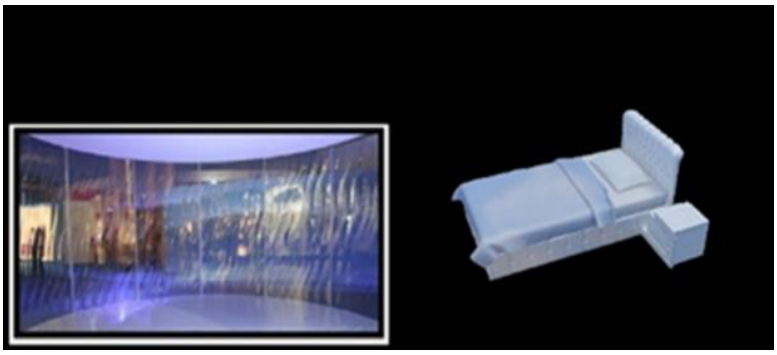


Figure 18. Metal and glass furniture symbolizing water

The rooms on the ground floor have been converted by adding a bathroom to each, resulting in two standard bedrooms and two suite rooms. The iwan has been preserved as a resting place, and one of the rooms on either side has been designed as an administrative office. The bathroom and toilet is arranged as a reception and a suite room's bathroom. The space that was originally a kitchen was left with the same function. Courtyard was preserved with the tree inside, creating an open dining area (Figure 19)

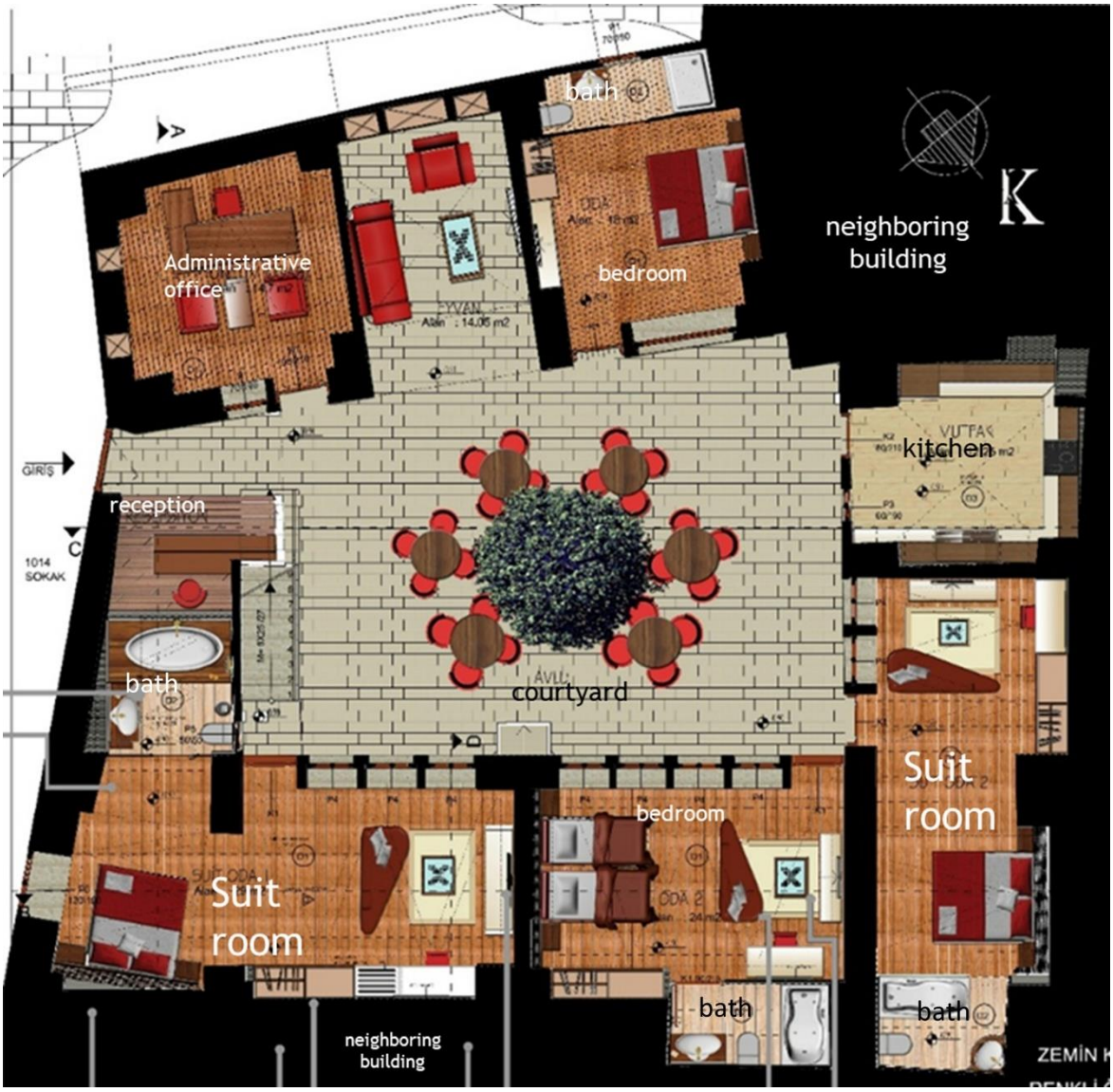


Figure 19. Ground Floor Plan

The two rooms on the upper floor are also arranged as bedrooms with bathrooms, and the water concept is also processed on the ceiling with tempered glass and metal suspended ceilings (Figure 20)

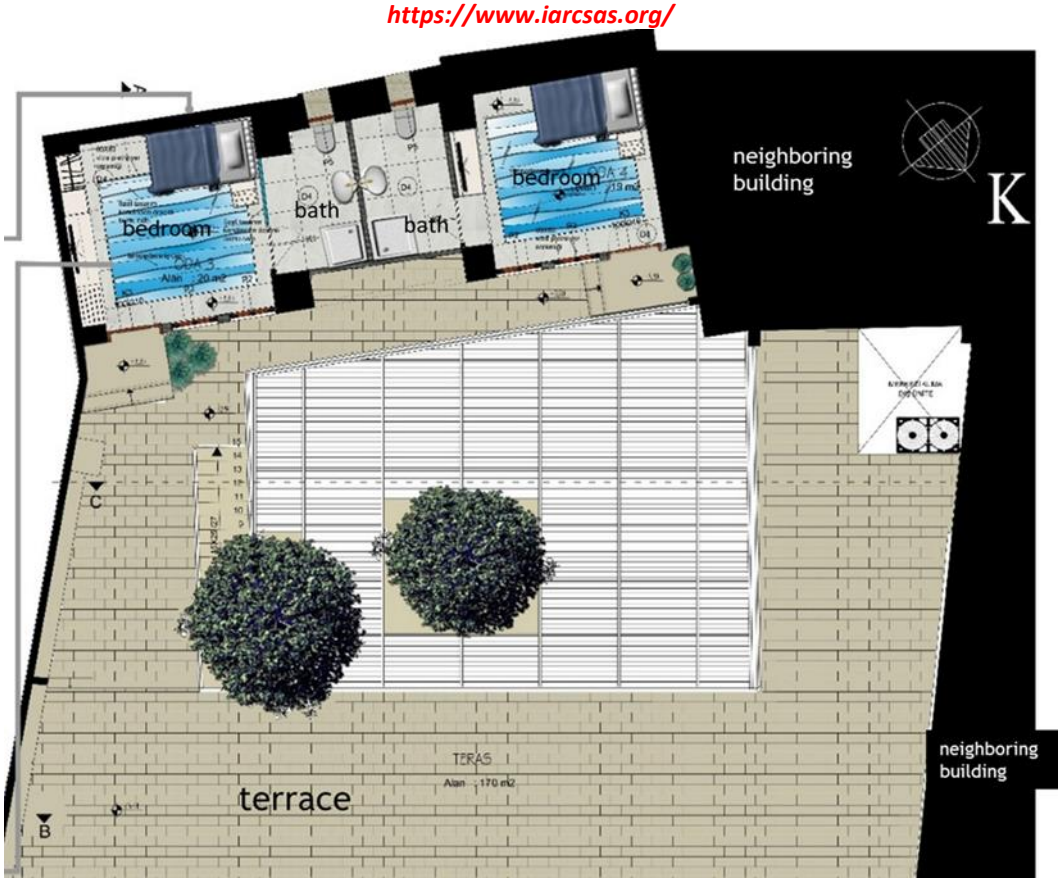


Figure 20. Upper Floor Plan

The cellar, which is descended from the courtyard via a stone staircase, is also furnished as the hotel's restaurant, with both table seating and corner seating (Figure 21)

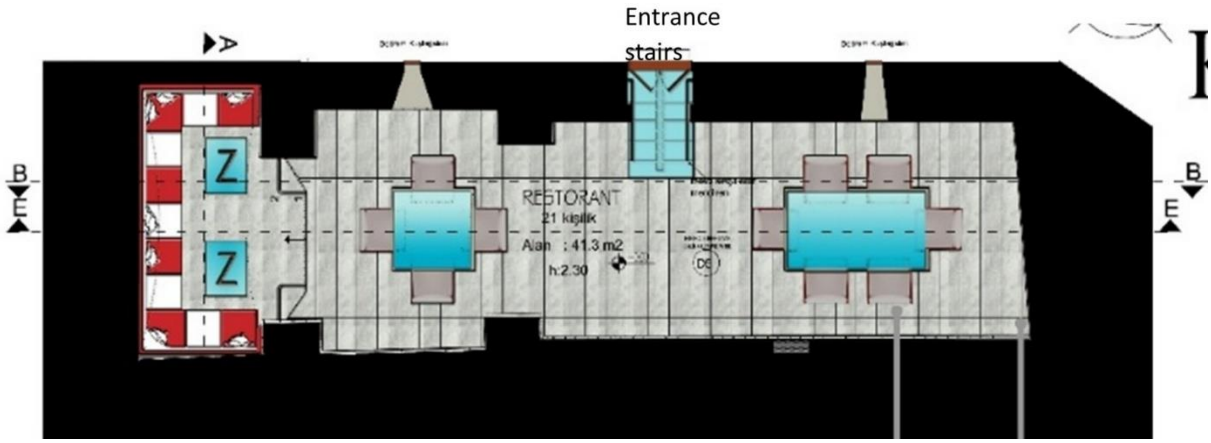


Figure 21. Basement Floor Plan

Findings and Discussion

Function and concept suggestions were made for two separate traditional Abuzer Duran and Bakır Dellalbaşı houses examined in the study. It is important that these suggestions comply with the traditional architecture of Urfa. The ethnographic museum, restaurant and boutique hotel suggestions have been re-functioned without changing the plan schemes but in accordance with modern life. If these houses are not restored and are abandoned, they are subject to structural deterioration. For this reason, it is important to restore these structures and introduce them to public and tourism. Therefore, in this study, interventions and functional changes appropriate to the architecture were made based on the characteristics of traditional Urfa houses with interior architectural designs.

- It was ensured that the selected concepts were specific to Urfa and compatible with the function.
- No load-bearing walls were demolished; Only in the main dining room of the restaurant project, a door has been opened in the wall between the two living rooms.
- The iwans were not closed and were carefully preserved.
- Only partial and perforated roof coverings have been added to the courtyard, the trees within have been preserved, and its contribution to the overall design has not been lost.
- An effort was made to ensure architectural compatibility of interventions and functional changes according to the characteristics of these traditional buildings.

Conclusion and Recommendations

Urfa traditional houses are generally low-comfort spaces where poor people stay as tenants. Many of the homeowners were forced to abandon their homes to their fate because their economic situation was inadequate and they were unable to carry out the restoration work required. (Aras & Yıldırım, 2003). Most of these houses were divided, especially due to inheritance, with the selamlık section remaining in the hands of one heir and the harem section remaining in the hands of another heir. As a result, unsanitary toilet, bathroom and kitchen extensions had to be built. If these houses are not restored and are abandoned, they are subject to structural deterioration. For this reason, it is important to restore these structures and introduce them to public and tourism. In Şanlıurfa, there are many examples of registered mansions and houses that have been converted into museums, boutique hotels, and restaurants. Some of these mansions and houses have been restored by the Şanlıurfa Education, Culture, Arts, and Research Foundation (Şurkav), some by the Şanlıurfa Governorship, and some by the Şanlıurfa Municipality.

The other unrestored residences should be taken up by relevant organizations or dedicated businesspeople as soon as possible, preserved as cultural heritage, and re-functioned when necessary, which will contribute to Urfa's identity as a tourism and cultural center.

In this study, re-functioning was carried out based on the principle of preserving the building in its original form and determining compatible functions that would also carry the identity of the period. It is of great importance that the interventions to be carried out preserve the characteristics of the historic building.

Finally, with new functions and concepts suitable for contemporary living we concluded that the design of the Ethnography Museum, Restaurant and the Boutique Hotel could contribute to the preservation and sustainability of the building and to culture and tourism.

Thanks and Information Note

I would like to thank Akdeniz University Interior Architecture and Environmental Design students for their dedicated work on this project.

References

Akkoyunlu, Z. (1988). *Geleneksel Urfa Evlerinin Mimari Özellikleri,* (Unpublished master thesis), Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Şubat 1988.

Aras, R., Yıldırım K., (2003). Sosyo-Kültürel Değişimin Geleneksel Urfa Evlerinde Mekân Organizasyonuna Etkisi*, G.Ü. Fen Bilimleri Dergisi*, 16(4): 779-787. ISSN 1303-9709

Aydın D., Okuyucu Ş. E., (2019). Yeniden Kullanıma Adaptasyon ve Sosyo Kültürel Sürdürülebilirlik Bağlamında Afyonkarahisar Millet Hamamının Değerlendirilmesi, *Megaron* 4(1): 35-44, Cilt Vol.4- Sayı No.1

Kutlu İ., Ergün R. (2021). Tarihi Yapılarda Yeniden İşlevlendirme Süreçlerine Sistematik Bir Yaklaşım; Atik Valide Külliyesi Örneği *Avrupa Bilim ve Teknoloji Dergisi* Sayı 25, S. 172-184

Kürkçüoğlu, A.C., Kürkçüoğlu, S. S., (2017). Şanlıurfa Kültür ve Turizm Varlıkları, s:67, *Şanlıurfa İli Kültür Eğitim Sanat ve Araştırma Vakfı Yayınları*, ISBN: 978-975-7394-44-0

Orhun, D., (1999). Spatial Themes Among The Traditional Houses Of Turkey, Space Syntax Second International Symposium Proceedings Volume II, 40 (p. 440.1-40.12), Brasilia.

Yıldız S., Rızvanoğlu M.S. (2012). Şanlıurfa Kültür Turizm Rehberi, *Şanlıurfa Valiliği İl Kültür ve Turizm Müdürlüğü Yayınları,* Şehir Kitaplığı Dizisi:5, ISBN:978-605-359-566-3, Bahçıvanlar Basım San. A.Ş, /Konya

Yıldız S., Rızvanoğlu M.S, (2014). Kültür ve İnançlar Diyarı Şanlıurfa , *Şanlıurfa Valiliği İl Kültür ve Turizm Müdürlüğü Yayınları*, Şehir Kitaplığı Dizisi:26, ISBN:978-605-359-520-5, Uzman Matbaacılık

URL1:https://www.google.com/search?sca_esv=4e1199e6e2dd9208&sxsrf=AE3TifM9z9iEn5bd_E9TRagsoj-zz3I8Q%3A1761569900256&q=hayat%20a%C4%9Fac%C4%B1%20sembol%C3%BC&ved=2ahUKEwiK6pqht8SQAxXlRvEDHegJKJMQmoICKAR6BQiFARAF&biw=1920&bih=911&dpr=1 Access Date: 20.10.2025

URL2: https://www.google.com/search?q=hayat+a%C4%9Fac%C4%B1+hal%C4%B1+motifi&oq=Hayat+a%C4%9Fac%C4%B1+kilim+motifleri&gs_lcrp=EgZjaHJvbWUqCggCEAAYgAQYogQyBggAEEUYOTIICAEQABgWGB4yCggCEAAYgAQYogQyCggDEAAYgAQYogQyCggEEAAYgAQYogTSAQkxNjI1N2owajSoAgCwAgE&sourceid=chrome&ie=UTF-8#vhid=MWlKtVi078vNoM&vssid=_lQAKaan0AY-Exc8P7euhkQk_98 Access Date: 20.10.2025

URL3: https://blog.biletbayi.com/sanliurfa-gezilecek-yerler.html/ Access Date: 03.10.2025

URL4:https://www.google.com/search?sca_esv=eb68ead9e93085bb&sxsrf=AE3TifPrDngJJcGO7ZwKzXttW7UISdWWBQ:1762424526091&udm=2&fbs=AIIjpHwSU0Xn4FRaYzhfgs1jmQvOnw1dDD9iiBulB2fsjeHv6Suaj0uWGr65idqq_D8h15FYdr_s8gfpDi9F22MhelAWr-

gOHRhtjlkztZoPF5qA6_Kq90Icqd9D9DN63zZ0mWEI3e0eeaXFfBKZfAfl0tUKLO7Ii8kYZsN5YuNTog9i6PsDyxoW1wFayUooxUsO500BQTa2XauiXlKsB0ByUWuQ81AxERR0xszSMaVbkVpIHF3S2L0jHDclEZ9fLChnQ-vs3b9_&q=%C5%9Fanl%C4%B1urfa+evleri+%C3%B6zellikleri&sa=X&ved=2ahUKEwjDscj-pt2QAxUFRfEDHYDfJ1YQtKgLegQIDBAB&biw=1920&bih=911&dpr=1#imgrc=CAFw7CHhwSqZJM&imgdii=iypLtOgLCYMgFM Access Date: 03.10.2025

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Investigating the Effects of Transport Factor on Structural Systems' Life Cycle Environmental Performance

Neriman Gül ÇELEBİ [1*]

ORCID 1: 0000-0003-0478-0449
[1] Mimar Sinan Fine Arts University, Graduate School, Department of Architecture, 34427, Istanbul/Türkiye
ngcelebi@gmail.com (Responsible Author)

Ümit ARPACIOĞLU [2]

ORCID 2: 0000-0001-8858-7499
[2] Prof. Dr. Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427, Istanbul/Türkiye
umit.arpacioglu@msgsu.edu.tr

Abstract

Life cycle assessment is an environmental management tool that holistically and systematically analyzes and evaluates the impacts on the environment of a product, system, or building elements. LCA includes all activities from raw material extraction to end-of-life disposal. The construction sector plays a significant role globally in terms of energy consumption and environmental emissions, and the contribution of transportation to environmental impact is a factor that must be considered. This study aims to examine the environmental impact of the transport factor in the context of transportation distances and to investigate the impact of transportation scenarios on the environmental impacts of load-bearing systems. In this study, alternative structural systems are analyzed for different transport distances. GaBi thinkstep LCA software is used as the analysis tool. The data obtained show that transportation distances have a significant impact on the environmental performance of structural systems. It is an important factor that affects the advantage of structural systems compared to each other. In this respect, the importance of including transport effects in LCA analyses is emphasized.

Keywords: Structural systems, life cycle environmental impact, transport factor.

1. Introduction

The construction industry accounts for 40% of carbon emissions and 36% of global energy consumption, and this rate is increasing. In addition, a significant part of the built environment consists of buildings. In this direction, the construction sector has great potential and importance in minimizing its carbon footprint and maximizing its environmental performance (Guggemos & Horvath, 2005; Kim et al., 2013; Oladazimi et al., 2020). Compared to other building elements, structural systems constitute the largest percentage of a building (Stek et al., 2011). In this respect, the evaluation of structural systems in terms of environmental impact is of great importance. Measuring and evaluating the environmental impacts of a building element or component is provided by life cycle assessment (LCA) as a powerful environmental management tool. Life Cycle Assessment Principles and System Boundaries are defined in EN 15978:2011 (Figure 1).

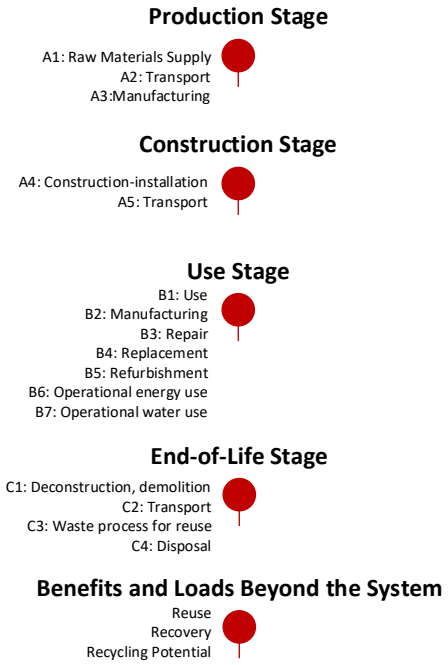


Figure 1. Life Cycle Assessment Principles and System Boundaries in EN 15978:2011 (European Committee for Standardization, 2011)

The transport factor, which is included in almost all modules of the life cycle systematics, is a parameter that must be clearly evaluated (Dvorsky et al., 2023). Transport factors can remain implicit in LCA studies. Studies evaluating transport effects are quite limited. In this respect, the study investigates the effect of the accessibility factor on the life cycle environmental performance of load-bearing systems.

2. Materials and Methods

First of all, the life cycle assessment system boundary for structural systems is defined. The basic modules and sub-parameters that constitute the system are explained. In line with the defined framework, two structural system alternatives, steel and reinforced concrete, are analyzed for two different transportation scenarios using GaBi thinkstep LCA software. Transport scenarios are shown in Table 1. The GaBi is an LCA software developed to contribute to sustainability and reduce environmental emissions (e.g., carbon emissions) (Sphera, n.d.). The findings obtained within the scope of environmental impact are evaluated and explained.

Table 1. Transport Scenarios for Structural Systems LCA Analysis

Scenarios	Transportation to Construction Site	Transportation to Recycling Areas	Transportation to Landfill Areas
Scenario 1	100 km	100 km	100 km
Scenario 2	1000 km	1000 km	1001 km

3. Findings and Discussion

The life cycle assessment framework for the structural systems defined within the scope of the study is shown in Figure 2. The framework does not include the use module (B1-B7). Structural systems do not directly affect the operational energy of a structure. Furthermore, the inclusion of modules such as maintenance and repair in the assessment requires a static performance analysis for structural systems. The International Energy Agency (IEA) states in its Annex 57 that scenarios regarding maintenance, repair, and reuse of structural systems must be planned (IEA ANNEX 57, 2016). In addition, the lifespan of a structural system is considered one hundred (100) years in international standards, and the lifespan is generally accepted as fifty (50) years in the life cycle approach. The framework defined from this perspective includes the production, construction, lifespan, LCA energy, and emission recovery modules.

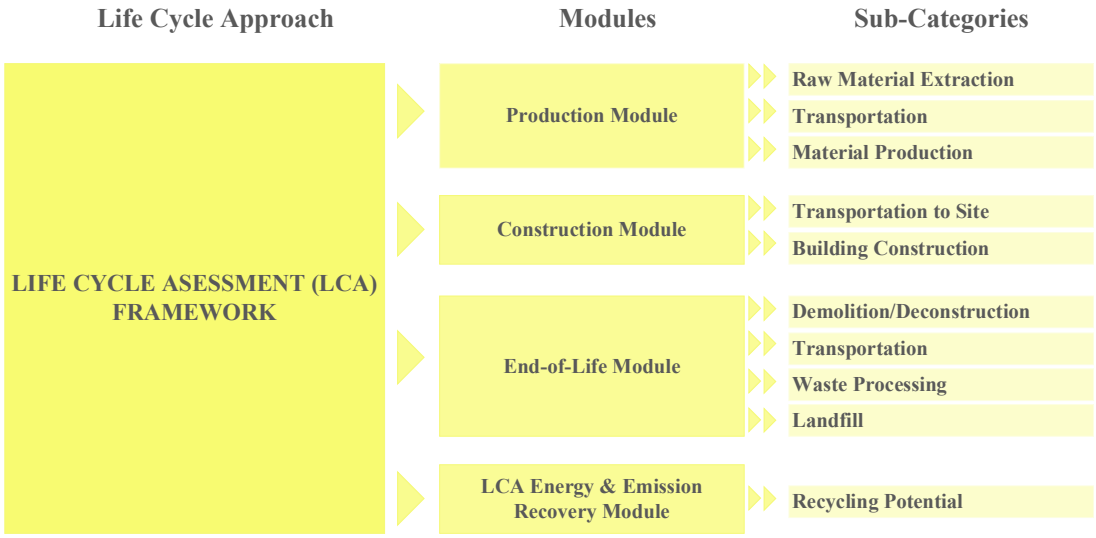


Figure 2. The life cycle assessment system boundary for structural systems (Created by the authors)

In line with the defined system, the steel and reinforced concrete structural system is analyzed in terms of lifecycle energy and carbon emissions using the GaBi thinkstep software. Information regarding steel and reinforced concrete frame structures is shown in Table 2. The modeling of the reinforced concrete structural system in the GaBi software is shown in Figure 3, and the modeling of the steel structural system is shown in Figure 4.

Table 2. The life cycle assessment system boundary for structural systems

Parameter	R.C. Framed Building	Steel Framed Building
Building type	Residential Building	Residential Building
Study period	50 years	50 years
Gross area	600 m^2	600 m^2
Building story and total height	8-story and 24m	8-story and 24m
Structural frame type	R.C. Frame	Steel Frame
Structural materials	Concrete, rebar	Structural steel, bolt

Building core	Reinforced Concrete	Steel
Core materials	Concrete, rebar	Steel, bolt
Flooring type	R.C. flooring	Composite flooring
Flooring materials	Concrete, rebar	Concrete, rebar, steel sheet
Concrete amount (t)	4726 tons	2000 tons
Rebar amount (t)	98 tons	33,9 tons
Structural Steel (t)	-	260 tons
Bolt connection amount (t)	-	0,5 tons
Steel sheet amount (t)	-	38, 4 tons

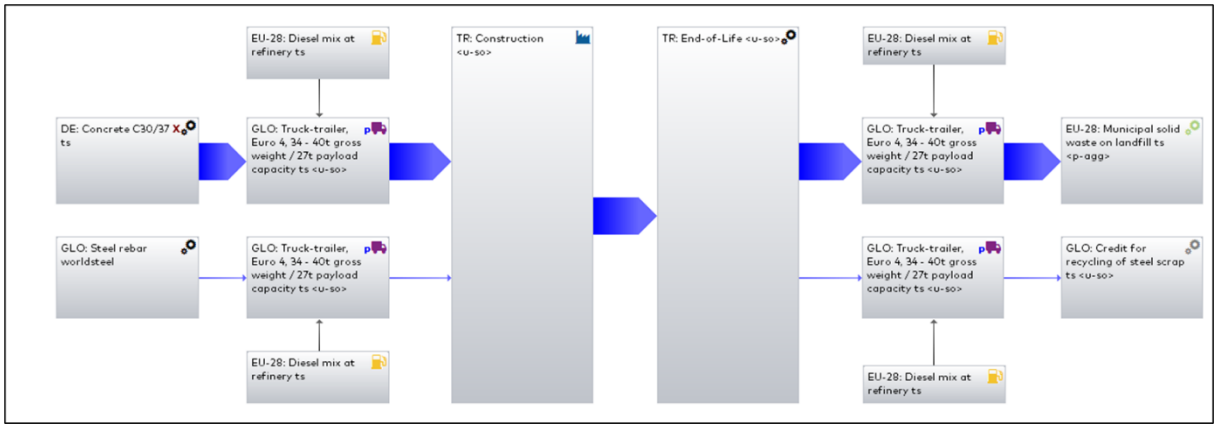


Figure 3. Reinforced Concrete Structural System Modeling in GaBi Software (Created by the authors)

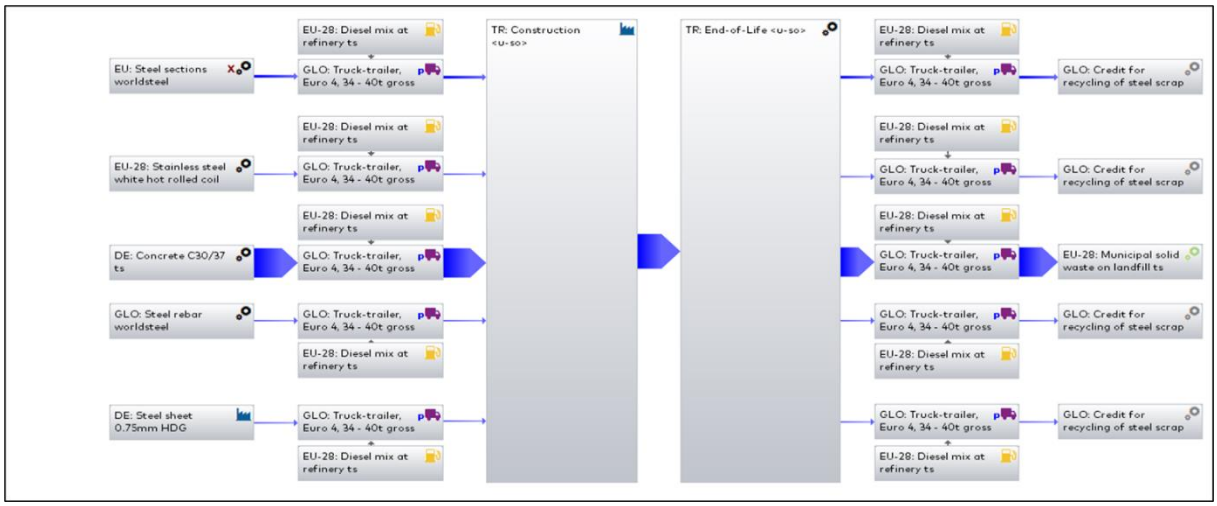


Figure 4. Steel Structural System Modeling in GaBi Software (Created by the authors)

The life cycle environmental performance results of steel and reinforced concrete structural systems for scenario 1 and scenario 2 are shown in Table 3. Annual embodied energy values per square tetrameter for scenario 1 and scenario 2 are shown in Figure 5, and embodied carbon values are shown in Figure 6.

Table 3. Alternative Structural Systems' LCA Results

Scenarios	Indicator	R.C. Framed Building	Steel Framed Building
Scenario 1	Embodied Energy (Mj)	8,54E006 Mj	8,57E006 Mj
	Global Warming Potential (GWP) (kgCO2-eq)	5,14E006 kgCO2-eq	2,65E006 kgCO2-eq
Scenario 2	Embodied Energy (Mj)	8,54E006 Mj	1,2E007 Mj
	Global Warming Potential (GWP) (kgCO2-eq)	5,14E006 kgCO2-eq	2,91E006 kgCO2-eq

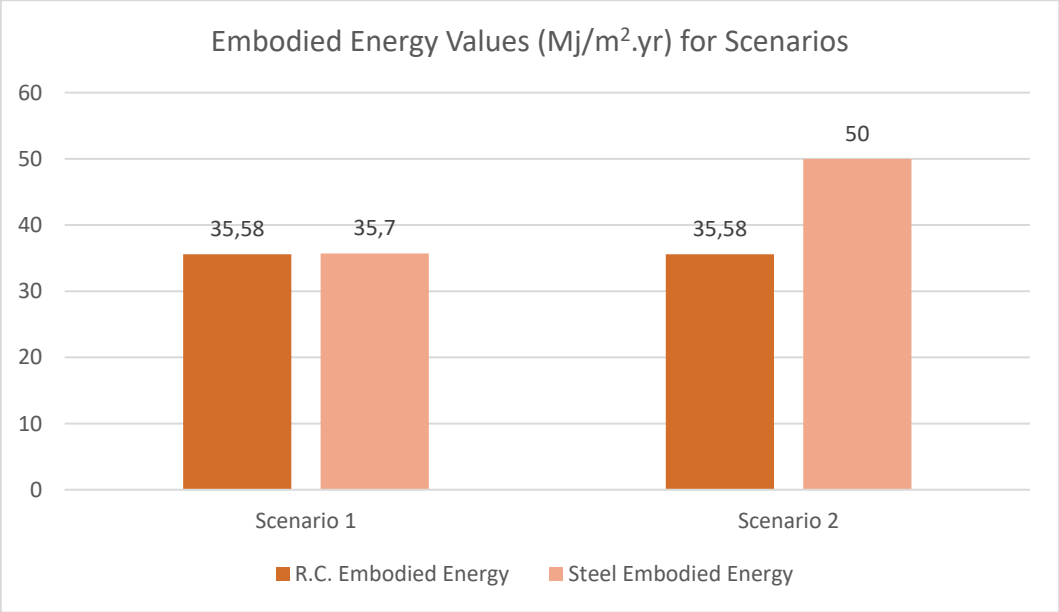


Figure 5. Structural Systems Embodied Energy Values for Scenarios (Created by the authors)

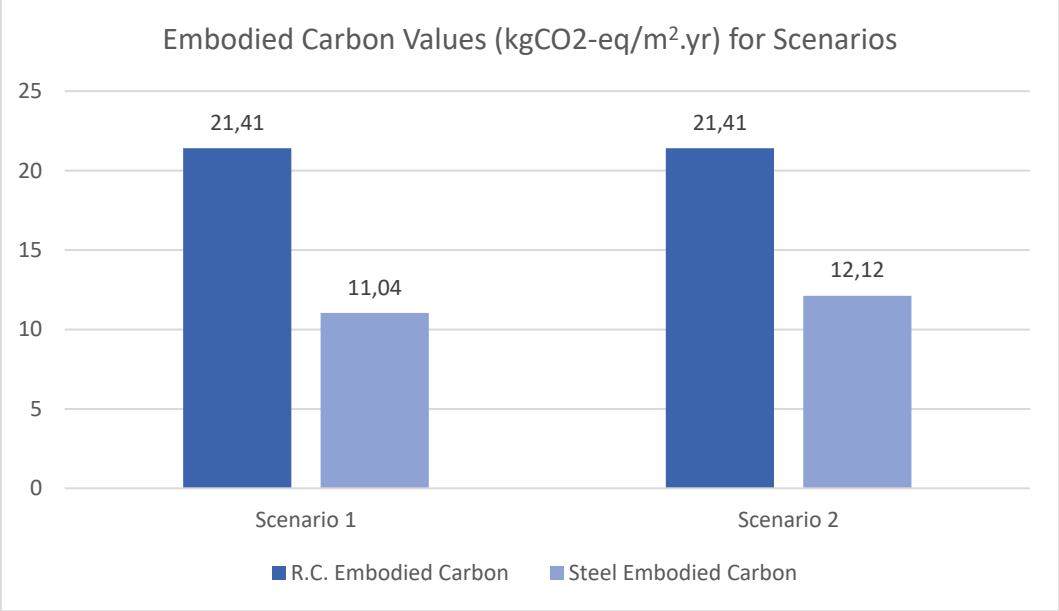


Figure 6. Structural Systems Embodied Carbon Values for Scenarios (Created by the authors)

In terms of embodied energy values, the structural systems have almost identical values in Scenario 1, while the reinforced concrete frame becomes more advantageous in Scenario 2. In terms of embodied carbon values, the values of the structural systems are similar in both scenarios. Here, energy consumption will influence whether structural systems are advantageous. The results indicate that the transport factor is a powerful parameter that can influence the selection of a structural system.

4.Conclusion and Recommendations

This study aims to contribute to a better understanding of the environmental impacts of transport factor in LCA analyses of structural systems. In this direction, LCA analyses are conducted for two different scenarios, and the findings show that the transport factor has a significant impact on the environmental performance of structural systems.

Consequently, transport distances have a significant impact on life cycle environmental performance. Local characteristics affect transport distances. Transport, on the other hand, has a significant impact on the decision-making mechanism for alternative structural systems. Therefore, it is an LCA parameter that should be evaluated in LCA studies.

Especially in a period where urban transformation is on the agenda and for Türkiye, which has a building stock that needs to be revised at a high rate, it is of great importance to select a structural system by evaluating its life cycle environmental performance with each parameter.

Thanks and Information Note

This study is produced within the scope of the project titled "Development of a Decision Support Model for Structure Selection in the Context of Earthquake and Environmental Impact (24/ÖAP/06)" supported by the Scientific Research Projects Coordination Unit of Mimar Sinan Fine Arts University, led by Prof. Dr. Ümit ARPACIOĞLU. We would like to thank the MSFAU Scientific Research Projects Coordination Unit for their contributions to the study.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. There is no conflict of interest.

References

Dvorsky, T., Vaclavik, V., Balintova, M., Eštoková, A., Fabianová, M., & Radačovský, M. (2023). Life Cycle Assessment and Environmental Impacts of Building Materials: Evaluating Transport-Related Factors. *Engineering Proceedings 2023*, Vol. 57, Page 5, 57(1), 5. https://doi.org/10.3390/ENGPROC2023057005

European Committee for Standardization. (2011). Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method, Brussels (Standard No. EN 15978:2011).

Guggemos, A. A. & Horvath, A. (2005). Comparison of Environmental Effects of Steel- and Concrete-Framed Buildings. Journal of Infrastructure Systems, 11(2), 93–101. Doi: https://doi.org/10.1061/(ASCE)1076-0342(2005)11:2(93)

IEA, ANNEX 57. (2016). Evaluation of Embodied Energy and CO2eq for Building Construction (Annex 57). Access Address (01.01.2025): https://www.iea-ebc.org/projects/project?AnnexID=57

Kim, S., Moon, J. H., Shin, Y., Kim, G. H. & Seo, D. S. (2013). Life comparative analysis of energy consumption and CO2 emissions of different building structural frame types. The Scientific World Journal, 2013. Doi: https://doi.org/10.1155/2013/175702

Oladazimi, A., Mansour, S. & Hosseinijou, S. A. (2020). Comparative Life Cycle Assessment of Steel and Concrete Construction Frames: A Case Study of Two Residential Buildings in Iran. Buildings 2020, Vol. 10, Page 54, 10(3). Doi: https://doi.org/10.3390/BUILDINGS10030054

Sphera. (n.d.). Life Cycle Assessment (LCA) Software. Access Address (01.01.2025): https://sphera.com/product-stewardship/life-cycle-assessment-software-and-data/?nab=1

Stek, E., Delong, D., McDonnell, T. & Rodriguez, J. (2011). Life Cycle Assessment Using ATHENA Impact Estimator for Buildings: A Case Study. Structures Congress 2011-Proceedings of the 2011 Structures Congress, 483–494. DOI: https://doi.org/10.1061/41171(401)42

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Role of Green Infrastructure in Improving Air Quality: A Case Study of Kocaeli Darıca Millet Garden

Kübra HANOĞLU [1]

ORCID 1: 0009-0001-4236-4801
[1]Master Student, Amasya University, Institute of Science and Technology, Landscape Architecture Master Program, Amasya-Türkiye
kubrahanogluu@gmail.com

Gülnur KARDAN [2]

ORCID 2: 0009-0006-0548-5993
[2]Master Student, Amasya University, Institute of Science and Technology, Landscape Architecture Master Program, Amasya-Türkiye
gulnurkardan@gmail.com

Sultan Sevinc KURT KONAKOĞLU [3*]

ORCID 3: 0000-0001-5383-0954
[3]Assoc. Prof. Dr., Amasya University, Faculty of Architecture, Department of Urban Design and Landscape Architecture, Amasya-Türkiye
sultansevinc.kurt@amasya.edu.tr (Responsible Author)

Abstract

The acceleration of rapid urbanization and intensive construction since the Industrial Revolution has caused significant ecosystem degradation, transformation of the urban landscape, and disruption to the environmental balance. These changes have a negative impact on both human health and urban quality of life. In this context, restoring green infrastructure and integrating blue, green and grey components into urban planning is essential for the sustainable development of cities. This study examines the spatial distribution of these infrastructure components and the impact of green cover on air quality in Darıca Millet Garden in Kocaeli, Turkey. A comprehensive literature review was conducted and ArcGIS 10.8 was used to map the park's blue, green and grey infrastructure elements. The results show that the green infrastructure covers 184,374 m², the grey infrastructure covers 77,576 m², and the Marmara Bay coastline represents the blue infrastructure. Ecological assessments using i-Tree Canopy reveal that approximately 91.6 tons of carbons are sequestered annually and significant amounts of air pollutants are removed. Specifically, the park removes 7.92 kg of CO, 31.30 kg of NO_2, 377.32 kg of O_3, 67.55 kg of SO_2, 19.70 kg of $PM_{2.5}$ and 151.30 kg of PM_{10} each year. These findings demonstrate that Darıca Millet Garden functions as both an urban recreational space and a vital green infrastructure element that contributes to improving air quality and promoting environmental sustainability.

Keywords: Darıca Millet Garden, air quality, ecosystem services, green infastructure

1. Introduction

Following the Industrial Revolution, rapid population growth and intense urbanization led to large-scale transformations in urban landscapes and significant disruptions to environmental balance. In particular, the rapid increase in the building stock reduced green spaces and destroyed natural ecosystems, thereby weakening ecological functions and diminishing the overall quality of urban life (Aktaş, Öztürkci & Tanyaloğlu, 2022; Kurt Konakoğlu et al., 2024). This process has not been confined to city centers; urban expansion has also affected peripheral rural areas, causing them to become rapidly urbanized and lose their natural characteristics (Bengston & Youn, 2006; Çatalbaş, 2016). As rural areas have gradually disappeared, environmental problems such as air and water pollution and biodiversity loss have increased, making it difficult to establish healthy and balanced living environments in cities (Tokuş, 2012; Selim, 2015; Shakouri, 2016; Aktaş, 2023).

To mitigate these adverse effects and ensure the sustainability of ecosystems, it is essential to adopt an ecosystem services approach, which emphasizes the benefits that nature provides to human life (Pamukcu, 2015; Uygur Erdoğan, 2020; Liu et al., 2021). Within this context, green infrastructure has emerged as a key planning concept for creating sustainable living environments, preventing environmental degradation, maintaining ecological balance, and establishing healthier, more livable spaces (Mell, 2009; Sokolova et al., 2024).

Ecosystem services represent a fundamental framework describing nature's multifaceted contributions to human well-being, highlighting the interdependent relationship between ecosystems and quality of life (Costanza et al., 2014; Tokgöz, 2018). These services encompass essential elements such as clean air and water supply, climate regulation, biodiversity conservation, and recreational opportunities—making them indispensable components of sustainable urban living. However, unplanned urbanization and rapid industrialization have degraded natural ecosystems and caused the loss of landscape areas, leading to a decline in the availability of ecosystem services as urban areas become increasingly covered with impermeable surfaces (Aksoy & Ergun, 2010; Temiz Topsakal & Sağlık, 2024). This in turn triggers environmental problems such as air, water, and soil pollution, the urban heat island effect, and climate change—all of which negatively affect human health and overall well-being.

The concept of green infrastructure has therefore emerged as a comprehensive planning approach designed to ensure the continuity of ecosystem services (Benedict & McMahon, 2002; Yaralıoğlu & Asilsoy, 2021). It provides an integrated framework that generates ecological, social, and economic benefits across multiple spatial scales, from city centers to rural landscapes, and is grounded in nature-based solutions (Shakouri, 2016; Serdar Yakut & Erdem Kaya, 2020; Akay, 2022). Green infrastructure aims to preserve the value that nature adds to urban life through the efficient use of natural resources (Parlak & Atik, 2020; Karaismailoğlu, 2024). By restoring the functionality of ecosystem services in cities, it helps reduce environmental problems and enhance human well-being. Thus, the interdependent relationship between ecosystem services and green infrastructure establishes a vital strategic foundation for sustainable urbanization and the creation of living environments that coexist harmoniously with nature (Tülek & Ersoy Mirici, 2019; Duru et al., 2022).

Green infrastructure enhances urban resilience and livability by generating economic, social, and ecological benefits aligned with the United Nations Sustainable Development Goals (SDGs) (Korkou et al., 2023; Ashinze et al., 2024). Economically, green infrastructure promotes the efficient and responsible use of natural resources, reduces energy consumption and costs, optimizes infrastructure investments, and ensures more efficient resource management (Gedik, 2020; Karaismailoğlu, 2024). Moreover, by increasing land value and minimizing environmental impacts and financial burdens through energy efficiency, it supports economic sustainability (Bolat, 2022; Akay, 2022). From a social perspective, green infrastructure contributes to improving quality of life and enhancing individuals' physical, emotional, and psychological well-being (Lehtonen, 2004; Güneş, 2017). It also strengthens social cohesion by creating healthier environments, expanding spaces for social interaction, and providing diverse recreational opportunities (Bramley & Power, 2009; Yıldırım, 2024). Ecologically, green infrastructure mitigates environmental degradation by maintaining natural balance, reducing the urban heat island effect, improving air quality, and conserving biodiversity (Bithas & Christofakis, 2006; Gómez-Baggethun & Barton, 2013; Tunç, 2023).

Importantly, green infrastructure represents a multi-layered, strategic approach that extends beyond merely quantifying natural elements in urban settings. It focuses on the ecological, aesthetic, and functional integration of these elements and their interconnections at various spatial scales (Monteiro et al., 2020; Arslan, 2022). At the micro scale, green infrastructure encompasses components such as green roofs, green walls, and rain gardens (Tzoulas et al., 2007; Demirören Civan, 2022). At the neighbourhood scale, it includes parks, roadside trees, permeable surfaces, and residential gardens. At the urban scale, it incorporates rivers, large public parks, cemeteries, and botanical gardens. At the regional scale, the focus shifts to forests, wetlands, and green corridors, which help reduce environmental threats, conserve biodiversity, and ensure ecosystem connectivity (Semiz, 2016; Özçelik, 2023). These systems are not merely physical components of the landscape—they function as critical urban infrastructure that delivers a range of ecosystem services (Baylan, 2025).

For example, they restore the natural water cycle through effective storm water management, thereby reducing flood risks and enabling the replenishment of groundwater resources (Kasprzyk et al., 2022). They also help regulate the microclimate by mitigating the urban heat island effect and improving air quality through the filtration of atmospheric pollutants (Aksu, 2021; Kayar & Kutlu, 2022). Thus, green infrastructure serves as a strategic element that enhances the resilience of urban ecosystems, promotes environmental sustainability, and directly contributes to human health and quality of life through its ecosystem services (Coşkun Hepcan, 2019; Ortaçeşme & Zeğerek Altunbey, 2022; Demirören Civan & Görmüş Cengiz, 2023).

This study focuses on Darıca Millet Park, located in the Darıca district of Kocaeli province. The research identifies the park's blue, green, and grey infrastructure components at the urban scale and evaluates their contribution to air quality. As part of the study, a comprehensive literature review was conducted, and the park's blue, green, and grey infrastructure elements were identified and analyzed using ArcGIS 10.8. The park's existing green cover was quantified using the i-Tree Canopy application, and its contribution to air quality was assessed. The spatial distribution of green areas and hard surfaces was also calculated to reveal the park's ecological and environmental contributions to the city's identity and urban life. Based on these findings, recommendations were developed to improve the management of the park's blue, green, and grey infrastructure and to enhance its ecosystem services-specifically improving air quality, increasing carbon storage capacity, and reducing the urban heat island effect.

2. Materials and Methods

The Darıca district is located in the province of Kocaeli, Türkiye, lying between 40°45'–40°46' N latitude and 29°23'–29°24' E longitude. Situated approximately 56 km from the central district of İzmit, Darıca covers a total area of 114 km² (Orman, 2023). The district has a 16 km-long coastline along the Sea of Marmara and is particularly renowned for its coastal landscape and zoological park (Figure 1). The terrain rises from the low-lying coastal areas towards the interior, displaying a gradual elevation pattern. The district experiences a hot and dry climate in summer and a cold and rainy climate in winter (Özyurt & Gürses, 2020; Darıca Municipality, 2025; Republic of Türkiye Darıca District Governor's Office, 2025).



Figure 1. Study area boundaries

This study focuses on the boundaries of Darıca Millet Garden (also known as *Martyr Er Gökhan Hüseyinoğlu Coastal Park*), which is located in the Darıca district of Kocaeli province. The park covers an area of approximately 261,950 m², situated between Darıca Beach and Eskihisar Beach. It features a variety of social and recreational spaces, including walking and cycling paths, viewing terraces, rest areas, themed 'hobbit' houses, sports fields, food and beverage areas, children's playgrounds, and beaches. The park was developed on land formerly used for military purposes, and during its design process, most of the existing mature trees were preserved. While the first and second phases of the park have been completed, work on the third phase is currently ongoing (Darıca Municipality, 2025; Kocaeli Metropolitan Municipality, 2025).

The main objective of this research was to evaluate the contributions of blue, green, and grey infrastructure components to air quality improvement within the first and second phases of Darıca Millet Garden. The study began with a comprehensive literature review to establish the theoretical and conceptual framework. Subsequently, spatial analyses were carried out using ArcGIS 10.8 software to examine the spatial configuration of the park's infrastructure components. The i-Tree Canopy online tool was employed to quantify the existing green cover, which was then used to assess its contribution to air quality. The distribution of green areas and impervious (hard) surfaces was also calculated to evaluate the park's ecological and environmental contributions to the urban fabric and city identity.

Based on these analyses, recommendations were formulated to enhance the management and sustainability of Darıca Millet Garden, with particular attention to the integration of its blue, green, and grey infrastructure components. In addition, quantitative assessments were performed to determine the ecosystem services provided by the park's green infrastructure, including air quality improvement, carbon storage enhancement, and mitigation of the urban heat island effect.

3. Findings and Discussion

The findings of the study are as follows:

The blue infrastructure of Darıca Millet Garden is represented by the Marmara Gulf, which defines the park's coastal boundary. The green infrastructure of the park consists of trees, shrubs, and grass areas, covering a total of 184,374 m². The grey infrastructure includes roads,

squares, and buildings, with a total area of 77,576 m². By analyzing the spatial distribution of green and hard surfaces within the park, the study revealed the ecological and environmental contributions of Darıca Millet Garden to the city's identity and urban life. Considering Darıca Millet Garden as both an urban park and a green infrastructure component at the city scale, spatial analyses were performed using ArcGIS 10.8 to identify the blue, green, and grey infrastructure components. The results are illustrated in Figure 2. Based on ArcGIS analysis, the park's green and grey infrastructure elements were classified into five categories, each represented by distinct colours.

- The Tree/Shrub category constitutes the largest area, covering approximately 93,445 m². These areas include former military zones where existing trees were largely preserved and complemented with newly planted tree and shrub species.
- The Grass/Grassland category covers approximately 77,846 m², consisting of extensive open green spaces designed for public use and recreation.
- The Hard and Soft Ground category includes pedestrian, bicycle, and vehicle paths, as well as squares and viewing terraces, covering an area of 71,979 m².
- The Unfinished Landscape and Sand Areas category, where planting arrangements have not yet been completed, covers 13,083 m².
- The Buildings category accounts for 5,597 m², representing structural elements such as service units and facilities within the park.



Figure 2. Darıca Millet Garden, ArGIS 10.8, Blue-Green-Grey Infrastructure Components, Area Distribution

The ecological benefits provided by the blue, green, and grey infrastructure components of Darıca Millet Garden were further evaluated using the i-Tree Canopy online tool. Random sampling points were distributed within the park boundaries to assess the proportion and contributions of these infrastructure elements to the urban ecosystem, particularly in relation to air quality improvement, carbon storage, and climate regulation (Figure 3).



Figure 3. Darıca Millet Garden I-Tree Canopy Point Distribution

Figure 3 presents the results of the land cover analysis conducted using the i-Tree Canopy application. An examination of 10,000 randomly distributed points within Darıca Millet Garden identified six distinct land-cover categories (Figure 4).

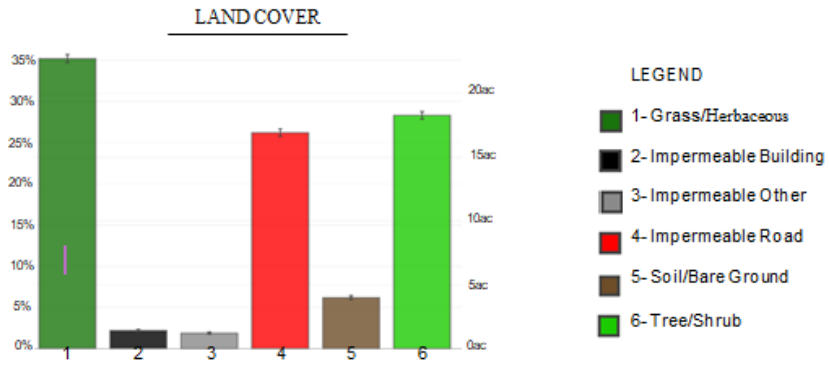


Figure 4. Distribution of 10,000 points randomly placed within the boundaries of the study area

The Grass/Herb category, representing green infrastructure, accounted for the highest proportion of points, with 3,521 points (35.21%) corresponding to extensive open green spaces suitable for public use and recreation. The Tree/Shrub category ranked second, with 2,832 points (28.32%), encompassing areas previously under military use where existing vegetation was largely preserved and supplemented with newly planted trees and shrubs.

The Impervious Road category, representing grey infrastructure, ranked third with 2,621 points (26.21%). This category includes pedestrian, bicycle, and vehicle paths, as well as squares and viewing terraces that provide access and circulation within the park.

Areas where planting arrangements have not yet been completed, along with sand-covered recreation zones, were classified as Soil/Bare Ground under green infrastructure. These accounted for 619 points (6.19%) of the total.

The Impervious Building category, also under grey infrastructure, comprised 220 points (2.20%), representing former military structures, daily service units, symbolic hobbit houses, certain residential areas, and security facilities within the park.

Finally, the Impervious Other category of grey infrastructure included rubber-coated surfaces, retaining walls, and other structural reinforcement elements, accounting for 187 points (1.87%).

Table 1. Areas Covered by Analyses Conducted Using ArcGIS 10.8 and I Tree Canopy

ArcGIS 10.8 (Blue-Green-Grey Infrastructure Components)	i-Tree Canopy (Ecosystem Services-Based on 10,000 Points)
Trees/Shrubs (93.445m2)	Grass/Herbaceous (%35,21- 3521 Points)
Grass/Herbaceous (77.846m2)	Tree/Shrub (%28,32- 2832 Points)
Hard/Soft Ground (71.979m2)	Impermeable Road (%26,21- 2621 Points)
Soil/Bare Ground (13.083m2)	Soil/Bare Ground (%6,19- 619 Points)
Building (5.597m2)	Impermeable Building (%2,20- 220 Points)
	Impermeable Other (%1,87- 187 Points)

Table 1 compares the results of the blue, green, and grey infrastructure component analyses conducted in ArcGIS 10.8 with those obtained from 10,000 randomly distributed points in the i-Tree Canopy online application.

In the ArcGIS 10.8 analysis, the spatial classification method (or "painting method") was used. In this approach, areas containing trees or shrubs were directly classified under the "Tree/Shrub" category, which led to an overrepresentation of this category in the final results. In contrast, the i-Tree Canopy application employed the point sampling method. When multiple points intersected a tree-covered area, both the tree canopy and the underlying grass or herbaceous vegetation was recorded separately. This approach provided a more realistic and detailed representation of the Grass/Herbaceous category.

As a result of these methodological differences, the ArcGIS analysis ranked the "Tree/Shrub" category first and the "Grass/Herbaceous" category second, while the i-Tree Canopy analysis produced the opposite order—placing "Grass/Herbaceous" first and "Tree/Shrub" second.

In both analyses, surfaces such as roads, squares, and viewing terraces were included under comparable categories: classified as "Hard/Soft Ground" in ArcGIS and as "Impervious Road" in i-Tree Canopy. The fourth category in both tools was "Soil/Bare Ground," and the fifth was "Structure." Unlike ArcGIS, however, the i-Tree Canopy application introduced an additional sixth category, "Other Impervious," which includes small-scale impermeable surface features such as walls, rubber-coated areas, and various structural elements identifiable at the point level. This distinction indicates that i-Tree Canopy provides a more detailed and nuanced classification of surface cover types within the study area.

Within the context of the Tree/Shrub category under the green infrastructure heading in Darıca Millet Garden, the preservation of existing olive trees and other native vegetation from the area's former use as a military zone was prioritized. In addition, the park's design incorporated newly planted tree and shrub species, thereby enhancing both ecological diversity and aesthetic value within the site.

The tree and shrub category within the green infrastructure component makes a significant contribution to urban ecosystem functionality. These plants absorb carbon dioxide from the atmosphere and release oxygen, acting as carbon sinks that play a critical role in mitigating climate change. In addition, they improve air quality by filtering harmful gases and particulates, and they help to alleviate the urban heat island effect, thereby reducing ambient temperatures and lowering energy consumption. From an aesthetic perspective, trees and shrubs enhance the visual diversity of the urban landscape and provide spaces for relaxation and recreation. Interaction with nature has been shown to produce psychological benefits, including reduced stress and improved mental health. Thus, trees and shrubs simultaneously contribute to both environmental sustainability and social well-being.

Within the scope of green infrastructure in the study area, the grass/herbaceous category comprise open green spaces, including flat grass areas, picnic sites, resting zones, and viewing terraces. These areas not only enhance the aesthetic quality of the urban landscape but also provide essential ecological services, such as improving air quality, supporting biodiversity, and preventing soil erosion. Owing to its coastal location, Darıca Millet Garden exhibits a natural transition from green to blue infrastructure, creating a visually harmonious environment. Furthermore, these grass and herbaceous zones contribute to social functionality by supporting recreational activities such as sitting, walking, exercising, eating, and socializing. Consequently, this category enhances urban livability from ecological, aesthetic, and functional perspectives.

The grey infrastructure components within the study area include walking and cycling paths, children's play areas, sports fields, squares, viewing terraces, amphitheater zones, and car parks, collectively classified as hard or soft ground. These areas meet the recreational and social needs of urban residents by providing spaces for walking, cycling, sports, and entertainment, thereby improving the social quality of urban life. However, most of these surfaces are impermeable, including parking lots, paths, rubber-coated play areas, amphitheater, and sports fields. In contrast, permeable pavements are used in squares and stepping-stone pathways, allowing rainwater infiltration. The prevalence of impermeable surfaces in Darıca Millet Garden restricts water absorption, which may increase the risk of flooding and surface runoff. Therefore, the use of permeable materials is vital for sustainable urban water management and environmental resilience.

Within the green infrastructure category, areas of bare ground, vegetated soil, and sand-covered zones—such as beaches and open parks—provide spaces for various recreational activities, including walking and swimming, which enhance physical health and promote social interaction. The permeability of the soil enables rainwater infiltration, supporting natural drainage and groundwater recharge, while also reducing flood risks. Additionally, soil surfaces can absorb and dissipate heat through evapotranspiration, thereby lowering environmental temperatures, mitigating the urban heat island effect, and improving the microclimate. These functions demonstrate how soil-based surfaces contribute to urban ecosystem resilience and enhance environmental sustainability.

In the grey infrastructure areas of Darıca Millet Garden, there are former military structures as well as food and beverage facilities, hobbit houses, toilets, and a mosque. These structures meet basic daily human needs, such as access to food, water, and sanitation, thereby ensuring the continuity of social life and improving urban quality of life. Architecturally, the hobbit-house structures are particularly noteworthy for their green-roof designs, which blend harmoniously

into the landscape and contribute to energy efficiency and microclimate regulation—thus serving as an example of integrated green infrastructure within the built environment.

From a holistic perspective, Darıca Millet Garden functions as a significant urban park that enhances psychological and physical well-being through its wide range of recreational activities and green open spaces. Spending time in such environments positively affects individuals' mental state, helping them cope with urban stress and social isolation, while also encouraging physical activity and healthier lifestyles. Urban parks like Darıca Millet Garden play a vital role in supporting environmental sustainability by providing ecosystem services such as heat island mitigation, local climate regulation, air purification, and biodiversity conservation.

In this context, Table 2 presents the amounts of carbon captured and stored through canopy cover as part of the regulating ecosystem services in Darıca Millet Garden, as calculated using the i-Tree Canopy application. The amount of carbon (C) sequestered annually by trees in the study area was found to be 24.98 tonnes, while the total carbon storage was estimated at 627.40 tonnes. These findings confirm the park's important role in urban carbon management and its contribution to climate regulation.

Table 2. i-Tree Canopy application benefit estimates and analysis results

DEFINITION	C (Carbon) QUANTITY(t) ± SS	VALUE ($) ± SS
It is stored in trees every year	24.98± 0,40	10.811 $ ± 172
It is stored in trees	627.40± 9,98	271.495$ ± 4.319

Table 3. i-Tree Canopy application benefit estimates and analysis results

ABBREVİATİON	POLLUTANTS	QUANTİTY (kg) ± SS	VALUE ($) ± SS
CO	Carbon Monoxide (Annual)	7,92 ± 0,13	$12 ± 0
NO_2	Nitrogen Dioxide (Annual)	31,30 ± 0,50	$5 ± 0
O_3	Ozone (Annual)	377,32± 6,00	$243 ± 4
SO_2	Sulphur Dioxide (Annual)	67,55 ± 1,08	$1 ± 0
PM2.5	Particulate Matter (Annual)	19,70 ± 0,31	$511 ± 8
PM10*	Particulate Matter (Annual)	151,30 ± 2,41	$1127 ± 18
TOTAL		**655,08 ± 10,42**	**$1899 ± 30**

According to the assessments presented in Table 3, the tree and shrub cover within the study area removes approximately 655 kg of atmospheric pollutants each year, providing a key ecosystem service that contributes to the improvement of urban air quality in Darıca Millet Garden.

Among the pollutants removed, the quantities of carbon monoxide (CO) and nitrogen dioxide (NO_2)—both primarily emitted from motor vehicle traffic (Korkmaz, 2023; Dikenli, 2024)—were found to be 7.92 kg and 31.30 kg, respectively. The amount of ozone (O_3), a major pollutant contributing to global warming (Nur Aydın, 2024), removed from the atmosphere was determined to be 377.32 kg. In addition, sulphur dioxide (SO_2), which forms mainly as a result of the combustion of fossil fuels, was removed at a rate of 67.55 kg.

Particulate matter emissions ($PM_{2.5}$ and PM_{10}) originate from both natural sources (e.g., volcanic activity, dust, and sea salt) and anthropogenic activities such as industry, fossil fuel combustion, and waste management (Çakır Göktepe, 2024). The respective quantities of these particulates removed from the atmosphere were 19.70 kg for $PM_{2.5}$ and 151.30 kg for PM_{10}.

In a comparative study, Pace et al. (2018) used the i-Tree Canopy model to analyses Munich's Englischer Garten, a 330-hectare park, and determined that it stores 6,225 tonnes of carbon and captures an additional 214 tonnes annually. In comparison, Darıca Millet Garden, covering an area of 28 hectares (approximately 12 times smaller), was found to store 627.40 tonnes and capture 24.98 tonnes of carbon per year. When these values are normalised according to area, the results obtained for Darıca Millet Garden are proportionally similar to those of Englischer Garten, suggesting that the park exhibits high ecological efficiency relative to its size.

Pace et al. (2018) also assessed air pollutant removal, reporting that Englischer Garten removed 2,610 kg of O_3, 845 kg of NO_2, 186 kg of $PM_{2.5}$, 171 kg of SO_2, and 62 kg of CO, with O_3 and NO_2 identified as the leading contributors. In the present study, the respective pollutant removal values for Darıca Millet Garden were 7.92 kg of CO, 31.30 kg of NO_2, 377.32 kg of O_3, 67.55 kg of SO_2, and 19.70 kg of $PM_{2.5}$, with O_3 and SO_2 showing the highest contributions. The consistency between the two studies indicates that ozone (O_3) is the most effectively removed pollutant in both cases, reflecting similar vegetation-based pollutant absorption dynamics. However, while SO_2 ranked second in the Munich study, NO_2 was the second-highest contributor in Darıca Millet Garden, likely due to its proximity to urban traffic sources.

Similarly, in a study conducted at Altınpark, located in the Altındağ district of Ankara, Şahin Körmeçli (2023) employed the i-Tree Canopy application and determined carbon sequestration and storage values of 74.58 tonnes and 1,873.10 tonnes, respectively. In comparison, the corresponding values for Darıca Millet Garden were 24.98 tonnes (sequestration) and 627.40 tonnes (storage). Although Darıca Millet Garden is approximately half the size of Altınpark, the carbon values obtained are proportionally lower, indicating lower vegetation density and reduced carbon storage potential.

When comparing pollutant removal capacities, Altınpark was found to remove 24.63 kg of CO, 134.32 kg of NO_2, 1,377.85 kg of O_3, 84.65 kg of SO_2, 65.01 kg of $PM_{2.5}$, and 448.11 kg of PM_{10}, with O_3 and PM_{10} contributing the most. A similar trend was observed in Darıca Millet Garden, where O_3 also showed the highest removal rate. However, the overall pollutant removal quantities were significantly lower in Darıca Millet Garden, a difference likely attributable to variations in vegetation cover, climatic conditions, and urban air pollution intensity.

4. Conclusion and Recommendations

Rapid urbanization today continues to exacerbate environmental problems such as air pollution, climate change, and the urban heat island effect, all of which have significant adverse impacts on urban livability. Increasing population density and the concentration of employment in city centers, coupled with the ongoing loss of natural areas, have intensified traffic congestion and motor vehicle use, thereby worsening air quality. These challenges negatively affect human health and threaten the sustainability of ecosystems. Consequently, adopting ecologically based planning approaches has become essential to enhance the environmental resilience of cities and improve quality of life.

Green infrastructure represents one of the key strategies of such approaches. It contributes to mitigating air pollution by creating carbon sink areas, moderates microclimatic conditions, and

reduces the urban heat island effect, while also serving as a strategic tool for achieving sustainable urbanization goals. Within this context, Darıca Millet Garden stands as a significant example of an urban park that enhances the urban ecosystem through its diverse green infrastructure components. Furthermore, technological tools such as the web-based i-Tree Canopy application, developed by the United States Department of Agriculture Forest Service, enable the environmental benefits of urban green spaces to be assessed scientifically. By quantifying trees' carbon storage capacity and their potential to remove atmospheric pollutants, these tools support more informed and sustainable urban planning processes.

Urban parks provide recreational spaces and social interaction areas, while simultaneously supporting environmental sustainability through the ecosystem services they deliver. They help regulate local climate conditions, reduce air pollution, and contribute to biodiversity conservation. In addition, parks have profound psychological and physical health benefits—reducing stress, alleviating social isolation, and encouraging healthy, active lifestyles through outdoor activities such as walking, cycling, and sports.

Darıca Millet Garden offers a wide range of recreational opportunities, including walking, cycling, sports, picnicking, and social gatherings, which enhance both the physical and social well-being of residents. The park's diverse tree and shrub species also enrich the urban ecosystem and promote biodiversity conservation, demonstrating its dual function as both a recreational space and an ecologically valuable green area that contributes to environmental sustainability.

The integration of ArcGIS 10.8 and i-Tree Canopy analyses provides a multidimensional perspective on the environmental contributions of urban parks by assessing the blue-green-grey infrastructure components. The results from Darıca Millet Garden indicate that the existing green infrastructure—particularly the mature tree canopy inherited from its former military use—possesses high carbon storage and pollutant filtration capacity. Newly planted vegetation, while not yet mature, is expected to significantly enhance the park's ecosystem service potential over time.

This finding suggests that the park's ecological contributions will increase as the vegetation develops, thereby strengthening its role in urban environmental sustainability. The park's blue infrastructure (water features) and grey infrastructure (paths, terraces, and seating areas) complement the green components by enhancing user experience and functional diversity. However, to improve comfort and resilience, it is recommended to increase tree planting along walkways and resting areas to provide additional shading, which will reduce heat stress during the summer months and increase park usage efficiency.

Analyses further reveal that while the park's green infrastructure is robust in environmental, aesthetic, and functional terms, improvements are needed to reinforce sustainability and ecosystem service provision. Increasing the diversity of tree and shrub species would strengthen biodiversity, enhance carbon sequestration and air filtration, and contribute to visual richness. Conversely, assessments of the grey infrastructure indicate that many paths and open spaces are composed of impermeable surfaces, limiting natural water infiltration and elevating flood risk. Replacing these with permeable materials would restore the natural hydrological cycle and improve environmental sustainability.

Overall, Darıca Millet Garden has the potential to significantly enhance urban quality of life by combining ecological functionality, aesthetic value, and public health benefits. This study

underscores the critical role of urban parks in mitigating air pollution, heat island effects, and climate change, especially in densely built environments where natural green spaces are diminishing. Strengthening urban green infrastructure—by increasing park numbers, enhancing vegetation density, and diversifying plant species—is therefore vital to achieving sustainable urban development goals.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Akay, O. (2022). Examination of Green Infrastructure Systems and Their Components at the Landscape Design Scale: The Case of the Düşler Vadisi Riva Project (Istanbul). Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Aksoy, Y. & Ergun, N. (2010). A Study on Urbanisation and the Green Space Problem: The Case of Bakirkoy District in Istanbul. *TUBAV Science Journal,* 2(4), 426-438.

Aksu, G. A. (2021). Evaluation of Roadside Green Spaces in Urban Landscapes within the Framework of the Urban Ecosystem. *European Journal of Science and Technology,* (25), 736-748. https://doi.org/10.31590/ejosat.944343.

Aktas, R., Ozturkci, A., & Ersoy Tonyaloglu, E. (2022). Assessment of Multiple Ecosystem Services in Urban Areas: The Case of Didim/Aydın. Journal of the Faculty of Agriculture, Adnan Menderes University, 19(2), 275-281. https://doi.org/10.25308/aduziraat.1162860.

Aktas, S. (2023). Proposed Solutions for Climate Change in Urban Tourism-Recreation Corridors. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Arslan, Z. (2022). The Role of Blue-Green Infrastructure in Creating Sustainable and Resilient Cities. The Case of Istanbul Maltepe. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Ashinze, U. K., Edeigba, B., Umoh, A. A., & Biu, P. W. (2024). Urban Green Infrastructure and its Role in Sustainable Cities: A Comprehensive Review. *World Journal of Advanced Research and Reviews,* 21(02), 928–936. Doi: 10.30574/wjarr.2024.21.2.0519.

Baylan, E. (2025). 'Opportunities Provided by Rural Landscapes for Cultural Ecosystem Services': The Socio-Cultural Contributions of Rural Areas'. *Kent Academy,* 18(2), pp. 1137–1158. DOI: https://doi.org/10.35674/kent.1618430.

Benedict, M. A. & McMahon, E. T. (2002). Green Infrastructure: Smart Conservation for the 21^(st) Century. Green Infrastructure Monograph.

Bengston, D. N. & Youn, Y.-C. (2006). 'Urban Containment Policies and the Protection of Natural Areas: The case of Seoul's greenbelt'. *Ecology and Society*, 11(1), p. 3.

Bithas, P. K. &Christofakis, M. (2006). 'Environmentally Sustainable Cities: Critical Review and Operational Conditions'. *Sustainable Development*, 14(3): 177–189. Doi: 10.1002/sd.262.

Bolat, Y. D. (2022). 'The importance of green infrastructure systems in urban areas: The case of Corlu (Tekirdag). Master's thesis. Access address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Bramley, G. & Power, S. (2009). Urban Form and Social Sustainability: The Role of Density and Housing Type'. Environment and Planning B: Planning and Design, 36(1), pp. 30–48. *Environment and Planning B: Planning and Design*, 36(1), pp. 30–48. Doi: 10.1068/b33129.

Catalbas, F. (2016). Major Urbanisation Problems and Proposed Solutions for Yozgat City Centre. *Erciyes University Journal of Science*, 32(1):38-47.

Civan, D., & Gormus Cengiz, S. (2023). Green Infrastructure Applications for the Development of Urban Sustainability. *Inonu University Journal of Art and Design* (27), 72-84. https://doi.org/10.16950/iujad.1316489.

Coskun Hepcan, C. (2019). Climate Change Education Modules Series 12: Green Infrastructure Solutions for Combating Climate Change in Cities. Republic of Turkey Ministry of Environment and Urbanisation General Directorate of Environmental Management, Ankara.

Costanza, R., De Groot, R., Sutton, P., Van Der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S.R.K. & Turner, R.K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26(1), pp.152–158.

Demiroren Civan D. (2022). Opportunities Provided by Green Infrastructure in Integrating the City with Nature. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Duru, M. A., Hos, F., & Ersoy Tonyaloglu, E. (2022). Evaluating the urban landscape with a green infrastructure approach: The case of Cankaya / Ankara. *Artvin Coruh University Faculty of Forestry Journal,* 23(1), 135-143. Doi: https://doi.org/10.17474/artvinofd.1097688.

Gedik, Y. (2020). Sustainability and sustainable development in social, economic and environmental dimensions. *International Journal of Economics, Politics, Human and Social Sciences,* 3(3), 196-215.

Gómez-Baggethun, E. & Barton, D. N., (2013), Classifying and valuing ecosystem services for urban planning. *Ecological economics,* 86, 235-245. Doi: https://doi.org/10.1016/j.ecolecon.2012.08.019.

Gunes, M. (2017). An Examination of the Interaction Between the Green Network Plan and Urban Identity within the Scope of Green Infrastructure: The Case of Ankara's Republican Era Boundaries. (Doctoral Thesis). Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Karaismailoğlu, B. (2024). Evaluation of Blue-Green Infrastructure and Sustainable Mobility Elements for Sezova Science, Culture and Art Park (Eskisehir) According to Eco-City Criteria. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Kasprzyk, M., Szpakowski, W., Poznanska, E., Boogaard, F. C., Boblowska, K., & Gajewska, M. (2022). Technical Solutions and Benefits of Introducing Rain Gardens – Gdańsk Case

Study. *Science of The Total Environment*, 835: 155487.Doi: 10.1016/j.scitotenv.2022.155487.

Kayar, I. & Kutlu, S. Z. (2022). An Assessment of the Relationship Between Urban Resilience and Environmental Sustainability. *TroyAcademy,* 7(2), 178-204. https://doi.org/10.31454/troyacademy.1088372.

Korkou, M., Tarigan, A. K. M., and Hanslin, H. M. (2023). The Multifunctionality Concept in Urban Green Infrastructure Planning: A Systematic Literature Review. *Urban Forestry & Urban Greening*, 85:127975, 1-9. Doi: 10.1016/j.ufug.2023.127975.

Kurt Konakoğlu, S.S., Celik, K.T., Üstün Topal, T., Demirel, O., & Bingül Bulut, M.B. (2024). Examination of Ecosystem Services: A Case Study of Amasya University Hakimiyet Campus. *J. Anatolian Env. and Anim. Sciences*, 9(4), 521–527. https://doi.org/10.35229/jaes.1555094.

Lehtonen, M. (2004). The environmental-social interface of sustainable development: capabilities, social capital, institutions. *Ecological Economics*, 49(2), 199–214. Doi: 10.1016/j.ecolecon.2004.03.019.

Liu, R., Dong, X., Wang, X., Zhang, P., Liu, M., & Zhang, Y. (2021). A Study on the Relationship between Urbanisation Process, Ecosystem Services and Human Well-being in an Arid Region in the Context of Carbon Flow: The Case of the Manas River Basin. *Ecological Indicators*, 132, 1-16. Doi: https://doi.org/10.1016/j.ecolind.2021.108248.

Mell, L. (2009). Can Green Infrastructure Promote Urban Sustainability? Proceedings of the Institution of Civil Engineers: *Engineering Sustainability*, 162(1), 23–34. Doi: 10.1680/ensu.2009.162.1.23.

Monteiro, R., Ferreira, J. C., & Antunes, P. (2020). Green Infrastructure Planning Principles: An Integrated Literature Review. *Land*, 9(525), 1-19. Doi: 10.3390/land9120525.

Ortacesme, V. and Zegerek Altunbey, P. (2022). Green Infrastructure as the Key to Climate Adaptation: Urban Nature and Climate Change. *Landscape,* 4(2), 123–132. https://doi.org/10.53784/peyzaj.1220747.

Ozcelik, O. (2023). Examining Cemeteries within the Scope of Green Infrastructure: The Case of Kusadası. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Pamukcu, P. (2015). Integration of Ecosystem Services into the Landscape Planning Process. (Doctoral Thesis). Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Parlak, E. & Atik, M. (2020). Blue-Green Infrastructure Applications from Around the World and Our Country. *PEYZAJ*, 2(2), 86-100.

Selim, S. (2015). Planning Framework for the Koycegiz-Dalyan Basin in the Context of Green Infrastructure. Doctoral Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Semiz, M. (2016). The relationship between green infrastructure systems and urban sustainability. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Serdar Yakut, S. E. & Erdem Kaya, M. (2020). A Parametric Model Proposal for the Optimisation of Urban Open Spaces in the Context of Green Infrastructure. *Landscape,* 2(1), 1-11.

Shakouri, N. (2016). A Green Infrastructure Landscape Planning and Design Approach within the Scope of Rainwater Management in Cities: The Case of Sakarya Hendek. Doctoral Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Sokolova, M. V., Fath, B. D., Grande, U., Buonocore, E., & Franzese, P. P. (2024). The Role of Green Infrastructure in Providing Urban Ecosystem Services: Insights from a Bibliometric Perspective. *Land*, 13(10), 1-20. DOI: 10.3390/land13101664.

Temiz Topsakal, M. & Saglık, A. (2024). Evaluation of Biomimetic Cities through Green Infrastructure Management. *GSI Journals Series A: Advancements in Tourism Recreation and Sports Sciences,* 7(1), 239-259. https://doi.org/10.53353/atrss.1397762.

Tokgoz, G. (2018). Evaluation of Ecosystem Services-Based Urban Planning in the Case of Adana-Karaisalı. (Doctoral Thesis). Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Tokus, M. (2012). Urban Green Networks: The Case of Istanbul Sarıyer. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Tulek, B. & Ersoy Mirici, M. (2019). Green Infrastructure and Ecosystem Services in Urban Systems. *PEYZAJ*, 1(2), 1-11.

Tunc, H. (2023). Determination and Evaluation of Green Infrastructure Components in Duzce City Centre. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting Ecosystem and Human Health in Planning, Urban Areas Using Green Infrastructure: A Literature Review. *Landscape and Urban*. 81(3), 167-178. Doi: 10.1016/j.landurbplan.2007.02.001.

Uygur Erdogan, B. (2020). Integration of the Concept of Ecosystem Services into Planning by Evaluating it at the Watershed Scale. *Duzce University Faculty of Forestry Journal of Forestry*, 16(2), 196-216.

Yaralıoglu, İ. and Asilsoy, B. (2021). Evaluation of the Concept of Green Infrastructure within a Theoretical Framework. *YDU Faculty of Architecture Journal*, 3(1), 46-58.

Yildirim, B. (2024). Development of an Application Guide for the Use of Green Roofs, Green Walls, and Rain Gardens: The Case of Ordu University's Cumhuriyet Campus. Master's Thesis. Access Address: https://tez.yok.gov.tr/UlusalTezMerkezi/.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Assessment of Green Infrastructure Systems Based on Ecosystem Services: The Case of Amasya University

Mustafa Taha KESKİNER [1]

ORCID 1: 0000-0002-3128-3889
[1]Master Student, Amasya University, Institute of Science and Technology, Landscape Architecture Master Program, Amasya-Türkiye
mustafatahakeskiner@hotmail.com

Alper Kaan KALKAN [2]

ORCID 2: 0009-0007-9365-7130
[2]Master Student, Amasya University, Institute of Science and Technology, Landscape Architecture Master Program, Amasya-Türkiye
akk192102003@gmail.com

Sultan Sevinc KURT KONAKOĞLU [3*]

ORCID 3: 0000-0001-5383-0954
[3]Assoc. Prof. Dr., Amasya University, Faculty of Architecture, Department of Urban Design and Landscape Architecture, Amasya-Türkiye
sultansevinc.kurt@amasya.edu.tr (Responsible Author)

Abstract

This study focuses on the Amasya University campuses located within the central district of Amasya, including the Hakimiyet, Yeşilırmak and İpekköy campuses. Situated in the interior of the Central Black Sea region, the city spans 5,628 km² with an average elevation of 1,200 m and a population of 148,908 (2023). Using Google Earth imagery and Adobe Photoshop, the spatial distribution of green, grey, and blue infrastructure components was mapped, followed by ecological assessments with the i-Tree Canopy application to evaluate ecosystem services. Green infrastructure covers 235,088 m², including forested areas, open green spaces, and afforested areas, while grey infrastructure comprises buildings, social facilities, and sports units; no blue infrastructure elements were identified. i-Tree Canopy analyses revealed that these green areas annually sequester 17.15 tons of carbon, store a total of 430.71 tons, and remove significant amounts of air pollutants: CO (5.14 kg), NO_2 (25.74 kg), O_3 (237.75 kg), SO_2 (25.71 kg), $PM_{2.5}$ (13.53 kg), and PM_{10} (97.28 kg). The total annual economic value of ecosystem services provided by campus green areas was estimated at $194,122. These findings highlight the critical role of green infrastructure in mitigating air pollution, supporting sustainable urban development, enhancing biodiversity, and improving quality of life. The study emphasizes the need to integrate quantitative assessments of ecosystem services into spatial planning, expand nature-based solutions, strengthen management capacity, and promote participatory design to maintain ecological integrity, carbon storage, and the social, environmental, and economic benefits of campus green areas.

Keywords: Amasya University, ecosystem services, green infrastructure

1. Introduction

Green infrastructure is defined as a network of strategically planned and interconnected green spaces composed of natural habitats, parks, green corridors, and conservation areas. Designed and implemented by considering the ecological, social, and economic benefits derived from the natural resource values it contains, this system aims to strengthen the ecological structure of cities. In contemporary urbanization processes, green infrastructure emerges as a holistic planning approach with objectives such as protecting ecosystem health, maintaining biodiversity, and enhancing urban quality of life. This approach contributes to the integration of the ecosystem services perspective into spatial planning processes by ensuring the

preservation of ecological balance and enabling the services provided by urban ecosystems to become more visible and manageable (McMahon & Benedict, 2000; Yanık, 2023).

The primary advantage of green infrastructure planning lies in its emphasis on connectivity and multifunctionality. This structure, which ensures the continuity of ecological corridors, contributes to the conservation of natural and cultural resources at the urban scale, strengthens local landscape character, and enhances the sense of place (Güneş & Şahin, 2015; Demirkır, 2019). Considering that cities have historically evolved in line with changing settlement values and functions, open and green spaces have become a determining factor in shaping urban character. In contemporary cities, the spatial diversity that supports essential activities such as living, working, resting, and recreation is directly related to urban quality of life. The quality and quantity of open-green spaces, therefore, constitute significant indicators of this quality (Gül & Küçük, 2001; Geray, 1998; Yakın İnan & Sönmez, 2019).

Open-green spaces are critical not only due to their recreational functions but also because of the ecological roles they assume in maintaining the sustainability of the urban ecosystem. Through functions such as air quality regulation, carbon sequestration, microclimate control, biodiversity support, and the continuity of ecological networks, they contribute to the integrity of the urban ecosystem (Keleş, 1998; Öztürk & Özdemir, 2013). Since urban ecosystems are shaped by human–nature interactions and integrated with socio-economic and cultural processes, the accurate assessment of ecosystem services within these areas is a vital requirement for effective planning and management (Degefu et al., 2021; Görmüş et al., 2021).

In this context, the Millennium Ecosystem Assessment (MEA) categorizes ecosystem services into four main groups: provisioning, regulating, cultural, and supporting services. These services encompass a wide range of functions, from food and raw material supply to climate regulation, from recreational opportunities to the sustainability of biological processes (Pamukçu et al., 2015; Felipe-Lucia & Comín, 2015; Akkurt & Akten, 2021; Çağlayan et al., 2020; Esringü et al., 2021).

In today's cities, where the pressures of urbanization are increasing, scientifically evaluating the ecosystem services provided by large open spaces—such as university campuses—offers valuable insights for sustainable planning. Accordingly, the Hâkimiyet, Yeşilırmak, and İpekköy campuses of Amasya University present a suitable study area for assessing the spatial distribution of green infrastructure and identifying ecosystem services. In this regard, the aim of the study is to identify the green infrastructure components within the Amasya University campuses, quantitatively evaluate the ecosystem services provided by these areas, and offer implications for sustainable campus planning based on the findings obtained.

2. Materials and Methods

This study covers the Hâkimiyet, Yeşilırmak, and İpekköy campuses of Amasya University, located within the boundaries of the central district of Amasya province. Situated in the inland part of the Central Black Sea Region, Amasya is bordered by the provinces of Yozgat, Tokat, Çorum, and Samsun. The total surface area of the province is 5,628 km², and according to the Address-Based Population Registration System dated 31 December 2023, the population of the central district is 148,908. The city center has an average elevation of 392 m, while the

provincial average is 1,200 m; the highest point in the province reaches 2,061 m. Amasya is located in the valley formed by the Yeşilırmak River between the Canik Mountains, offering a characteristic settlement pattern at the regional scale due to its topographic and hydrological features (Republic of Türkiye Amasya Governorship, 2024) (Figure 1).

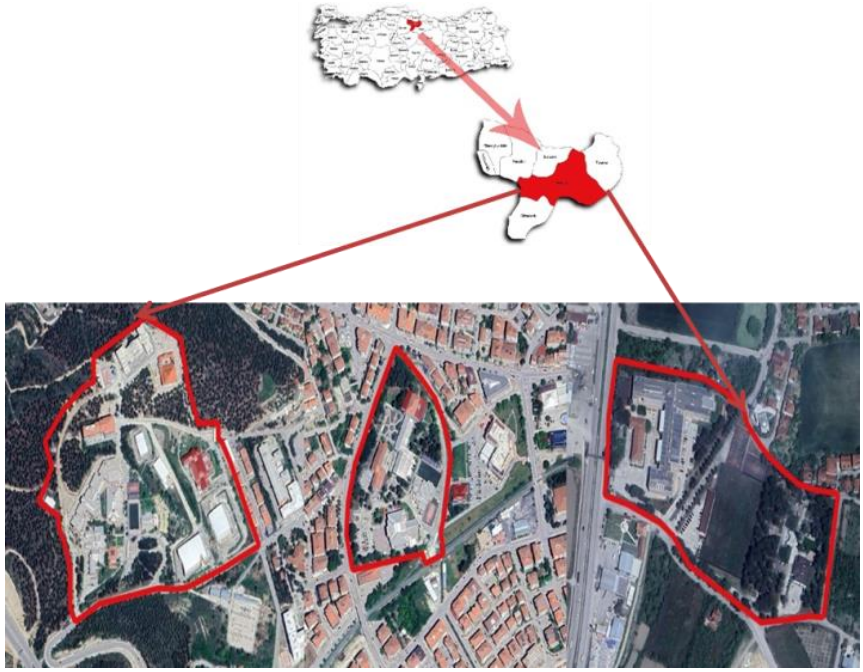


Figure 1. Yeşilırmak, Hakimiyet and İpekköy Campuses located in the Central District of Amasya

The primary materials of the study consist of boundary data for the Hâkimiyet, Yeşilırmak, and İpekköy campuses, Google Earth satellite images, and supporting visual materials used for land cover classification of the study area through the i-Tree Canopy software.

In this research, the i-Tree Canopy model—developed by the United States Department of Agriculture Forest Service (USDA) and based on a random point sampling approach—was employed. The method consists of three main stages:

1. Defining the Study Area Boundaries: Campus boundaries were digitally delineated using the i-Tree Canopy interface.

2. Identification of Land Cover Classes: Six land cover classes available in i-Tree Canopy and suitable for the study area were evaluated:

(1) Tree/Shrub: Tree and tall shrub vegetation,

(2) Grass/Herbaceous Plants: Areas covered by herbaceous vegetation,

(3) Soil/Bare Ground: Soil surfaces with little or no vegetation cover,

(4) Impermeable Buildings: Built-up areas,

(5) Impermeable Roads: Asphalt- or concrete-covered transportation units,

(6) Other Impermeable Surfaces: Parking lots, sidewalks, and similar impermeable areas.

3. Random Point Sampling and Classification: The software performs the analysis by assigning each randomly generated point within the study area boundary to one of the defined land cover classes. Through this process, land cover ratios were determined, and ecosystem service outputs—such as carbon sequestration, carbon storage, and removal of air pollutants—were generated using i-Tree Canopy's automatic calculation modules.

3. Findings and Discussion

In this study, green, gray, and blue infrastructure components were identified at the campus scale using the example of Amasya University's Hâkimiyet, Yeşilırmak, and İpekköy Campuses, and the land cover distribution was analyzed through the i-Tree Canopy application. Satellite images obtained from Google Earth Pro were processed in Adobe Photoshop to classify the infrastructure components within the campuses. The findings provide important insights into the ecosystem service potential of the campus areas.

The analyses reveal that green infrastructure occupies a considerable portion of the campuses. Specifically, green infrastructure components include 185,576.99 m² of forested areas, 22,538.93 m² of open-green spaces, and 26,971.68 m² of afforested areas. In contrast, gray infrastructure elements consist of 6,010 m² of social facilities, 9,590 m² of sports units, and 38,700 m² of built-up areas. No data corresponding to blue infrastructure components were identified within the study area, indicating a limited capacity of the campuses in terms of water-based ecosystem services.

A total of 10,000 random points were evaluated in the i-Tree Canopy application, and land cover was analyzed across six classes. The distribution of these points is as follows (Figure 2-3, Table 1):

- Tree/Shrub: 1,845 points
- Grass/Herbaceous: 2,094 points
- Impermeable Buildings: 1,925 points
- Impermeable Roads: 2,732 points
- Other Impermeable Surfaces: 348 points
- Soil/Bare Ground: 1,056 points

Based on this distribution, the percentage of land cover across the campus is as follows:

27.32% impermeable roads, 20.93% grass/herbaceous vegetation, 19.25% impermeable buildings, 18.45% tree/shrub areas, 10.56% soil/bare ground, and 3.49% other impermeable surfaces. These results indicate that impermeable surface areas are particularly high across the campuses, while vegetation cover is distributed at varying proportions.



Figure 2. Amasya University Yeşilırmak, Hakimiyet and İpekköy Campuses i-Tree canopy point distribution

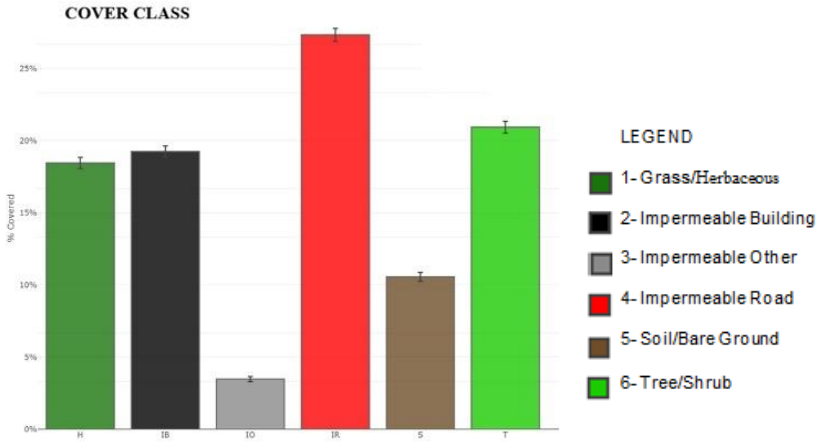


Figure 3. Distribution of total 10,000 points randomly placed within the boundaries of the campuses

Table 1. Land cover analysis results of the i-tree canopy application

Abbreviation	Cover Class	Definition	Number of Points	% Cover ± SE/Standard Deviation	Area (m²) ± CI
H	Grass/Herbaceous	Grass and herbaceous vegetation cover	1845	18,45 ± 0,39	44.839
IB	Impermeable Building	Buildings and structures	1925	19,25 ± 0,39	46.781
IO	Impermeable Other	Overhead cover, concrete walls, electrical panels, and similar areas	348	3,48 ± 0,18	8.457
IR	Impermeable Road	Asphalt, concrete, or pedestrian paths	2732	27,32 ± 0,45	66.368
S	Soil/Bare Ground	Bare soil or unvegetated ground surfaces	1056	10,56 ± 0,31	25.657
T	Tree/Shrub	Tree and tall shrub vegetation areas	2094	20,93 ± 0,41	50.828
TOTAL	-	-	10000	100	242.930 m²

In addition, the green infrastructure analysis revealed that the existing 235,087.602 m² of green areas remove a total of 405.15 kg of pollutant gases and particulate matter annually, as calculated through the i-Tree Canopy tool. According to the results, trees capture 17.15 tons of carbon per year, while the total amount of carbon stored reaches 430.71 tons. The amount of Carbon Monoxide (CO) removed from the atmosphere is 5.14 kg, and Nitrogen Dioxide (NO_2) is 25.74 kg. Ozone (O_3), which contributes to climate change and poses long-term atmospheric threats, was removed at a rate of 237.75 kg according to the analysis. This improvement in air quality represents a significant contribution to the urban environment. Another major air pollutant, Sulfur Dioxide (SO_2), was removed at a level of 25.71 kg, attributed to the extensive canopy coverage of trees within the study area. Furthermore, existing plant species were found to remove 13.53 kg of PM2.5 and 97.28 kg of PM10 particulate matter annually. These findings demonstrate the significant role of vegetation in mitigating air pollution and highlight its benefits for human health. The study concludes that the ecosystem services provided by the campus vegetation contribute a total annual economic value of $194,122 to Amasya University (Table 2).

Table 2. Ecosystem services provided by tree cover in Yeşilırmak, Hakimiyet and İpekköy Campuses

Pollutants	Quantity	±SS	Value (USD/$)	±SS
Carbon Monoxide - CO (Annual)	5,14 kg	± 0,22	2 $	± 0
Nitrogen Dioxide - NO_2 (Annual)	25,74 kg	± 1,10	1 $	± 0
Ozone- O_3 (Annual)	273,75 kg	± 11,73	35 $	± 1
Sulphur Dioxide – SO_2 (Annual)	25,71 kg	± 1,10	$ 0 $	± 0
Particulate Matter - $PM_{2.5}$ (Annual)	13,53 kg	± 0,58	73 $	± 1
Particulate Matter - PM_{10} (Annual)	97,28 kg	± 4,17	210 $	± 4
TOTAL	405,15 kg	± 18,90	321 $	± 6
It is stored in trees every year	17,15 ton	± 0,33	7,421 $	± 144
It is stored in trees	430,71 ton	± 8,37	186.380 $	± 3623

* The monetary values are expressed in USD and have been rounded. The standard errors of removal and benefit estimates are based on the standard errors of sampled and classified points. The amount of carbon sequestered is based on **1.365 tons (T) of carbon or 5.005 tons of CO_2 per acre per year**, rounded to the nearest value. The amount of carbon stored is based on **34.281 tons of carbon or 125.697 tons of CO_2 per acre**, also rounded. The economic value (USD) is based on **$170.55 per ton of carbon** or **$46.51 per ton of CO_2**, rounded accordingly. (English units: T = ton (2,000 pounds), ac = acre)

The proportion of tree cover and the potential regulating ecosystem services obtained for the campuses of Amasya University can be considered at a moderate level when compared with similar campus-based studies in the literature. Coşkun Hepcan and Hepcan (2017) reported that, in the Ege University Housing Campus, trees removed 289,266 kg of air pollutants annually, captured 321.57 tons of carbon per year, and stored a total of 8,107.86 tons of carbon. Dilaver et al. (2017) calculated that trees in Ankara University's Tandoğan Campus annually removed 17,935,304 kg of pollutants and stored 160,813.239 tons of carbon in total. Ersoy Tonyaloğlu (2023), in a study conducted at Aydın Adnan Menderes University Central Campus, found 77,152 kg of pollutant removal, 34.98 tons of annual carbon sequestration, and 878.44 tons of total carbon storage. Kurt Konakoğlu et al. (2024) determined that the tree and shrub cover, accounting for 31.30% of Amasya University's Hakimiyet Campus, annually removed 261.53

kg of gaseous and particulate pollutants, sequestered 36.57 tons of carbon, and stored 918.42 tons of carbon in total. Compared with these studies, Amasya University shows a certain level of potential regarding tree cover and carbon storage capacity; however, expanding green areas and increasing tree species diversity would strengthen its regulating ecosystem services. Furthermore, the high proportion of impermeable surfaces indicates the need to enhance green infrastructure, as such surfaces influence local hydrological processes, rainfall runoff, heat island effects, and overall microclimatic conditions across the campuses.

4. Conclusion and Recommendations

This study examined the green, grey, and blue infrastructure components of Amasya University's Hâkimiyet, Yeşilırmak, and İpekköy Campuses, revealing the current potential of their ecosystem services. The findings indicate that tree cover within the campuses is limited, constituting a major constraint for regulating ecosystem services. However, the existing open-green spaces and areas suitable for afforestation point to a high potential for increasing tree cover. If this potential is utilized, the campuses—and the city as a whole—could achieve enhancements in climate regulation, air quality improvement, carbon storage, and related economic benefits.

Although improving and expanding tree cover requires significant investment, the results of this study demonstrate the necessity of such analyses for campus-scale and large-area planning. Considering that campuses function as "small urban models," protecting existing trees and shrubs, increasing species diversity, and prioritizing native species are critical for supporting biodiversity and ensuring the sustainable enhancement of ecosystem services. While young trees and shrubs provide lower levels of ecosystem services compared to mature individuals, increases in their number and species diversity will raise overall contributions.

The contribution of existing vegetation to air pollution reduction and carbon storage is a fundamental component of sustainable urban development and healthy living environments. In this context, green infrastructure must be addressed not only from an environmental standpoint, but also through its social and economic dimensions. Strengthening green infrastructure systems offers significant opportunities for climate change mitigation, biodiversity conservation, ecological resilience, and the implementation of nature-based solutions.

Future studies should focus on the quantitative assessment of green infrastructure service levels, the improved integration of these services into spatial planning processes, the development of ecosystem-service-based performance indicators, and the exploration of financial incentive mechanisms. Additionally, participatory design processes that enhance cultural and social ecosystem services, the establishment of biological corridors, and the reinforcement of ecological integrity within campuses stand out as priority areas for sustainable campus management.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Akkurt, Y., & Akten, M. (2021). Kent parklarında ekosistem hizmetlerinin rolü. *Mimarlık Bilimleri ve Uygulamaları Dergisi, 6*(1), 348–357.

Çağlayan, S. D., Balkız, Ö., Arslantaş, F., Sanalan, K. C., Lise, Y., & Zeydanlı, U. (2020). Şehir planlama aracı olarak ekosistem hizmetleri: Çankaya ilçesi örneği.

Degefu, M. A., Argaw, M., Feyisa, G. L., & Degefa, S. (2021). Dynamics of urban landscape nexus: Spatial dependence of ecosystem services in rapid agglomerate cities of Ethiopia. *Science of the Total Environment, 798*.

Demirkır, M. G. (2019). *Kentsel altyapı sistemi olarak sürdürülebilir peyzaj: Trabzon sahili örneği* (Yüksek lisans tezi). Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü.

Esringü, A., Toy, S., & Çağlak, S. (2021). Sağlıklı kentlerde ekosistem hizmetlerinin önemi. *Climate and Health, 1*(2), 72–77.

Felipe-Lucia, M. R., & Comín, F. A. (2015). Ecosystem services–biodiversity relationships depend on land use type in floodplain agroecosystems. *Land Use Policy, 45*, 201–210.

Geray, C. (1998). Kentsel yaşam kalitesi ve belediyeler. *Türk İdare Dergisi, 421*, 323–345.

Görmüş, S., Oktay, E., & Cengiz, S. (2021). Kentsel ekosistemin dayanıklılık hedefini karşılamada ekolojik planlama yaklaşımları. *Peyzaj Eğitim Bilim Kültür ve Sanat Dergisi, 3*(2), 122–134.

Gül, A., & Küçük, V. (2001). Kentsel açık-yeşil alanlar ve Isparta kenti örneğinde irdelenmesi. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi, Seri A*(2), 27–48.

Güneş, M., & Şahin, Ş. (2015). Yeşil altyapı ve kent kimliği ilişkisi: Ankara kent merkezi örneği. *I. Ulusal Ankara Üniversitesi Peyzaj Mimarlığı Kongresi*.

Keleş, R. (1998). *Kentbilim terimleri sözlüğü*. Ankara: İmge Yayınevi.

Kurt Konakoğlu, S. S., Çelik, K. T., Üstün Topal, T., Demirel, O., & Bingül Bulut, M. B. (2024). Examination of ecosystem services: A case study of Amasya University Hakimiyet Campus. *Journal of Anatolian Environmental and Animal Sciences, 9*(4), 521–527. https://doi.org/10.35229/jaes.1555094

McMahon, E. T., & Benedict, M. (2000). Green infrastructure. *Planning Commissioners Journal, 37*(4), 4–7.

Öztürk, S., & Özdemir, Z. (2013). Kentsel açık ve yeşil alanların yaşam kalitesine etkisi: Kastamonu örneği. *Kastamonu Üniversitesi Orman Fakültesi Dergisi, 13*(1), 109–116.

Pamukçu, P., Serengil, Y., & Uzun, A. (2015). Soil conservation and water production services of ecosystems and their inclusion into landscape planning in sprawling cities. In *IUFRO Landscape Ecology Working Group Conference: Sustaining Ecosystem Services in Forest Landscapes – Concepts, Research, and Applications* (p. 120). Tartu, Estonia.

T.C. Amasya Valiliği. (2024). Nüfus. Erişim tarihi: 03.05.2024, http://www.amasya.gov.tr/nufus

Yakın İnan, Ö., & Özdemir Sönmez, N. (2019). Kentsel yaşam kalitesi ölçüm yöntemleri geliştirilmesi. *International Journal of Economics, Politics, Humanities & Social Sciences, 2*(3), 184-198.

Yanık, S. (2023). *Kentlerde iklim değişikliğine uyum çerçevesinde yeşil altyapı uygulamaları: Avrupa ve Türkiye yeşil başkentlerinin irdelenmesi* (Yüksek lisans tezi). Selçuk Üniversitesi, Fen Bilimleri Enstitüsü.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

3D Construction Technology for Building Elements

Berrin ŞAHİN DİRİ [1*]

ORCID 1: 0009-0009-6436-2549
[1]Assist. Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, İstanbul-Türkiye
berrinsahindiri@outlook.com **(**Responsible Author)

Abstract

Technological innovation has always played a key role in advancing architecture, providing new tools with which to solve current design industry problems. The 20th century demonstrated the impressive mechanical properties concrete can achieve when combined with steel. Similarly, the use of this material in digital manufacturing represents a promising future for the construction industry, offering the potential to transform it through the investigation of 3D printing techniques. There are currently multiple approaches to layer printing on concrete, depending on the construction system, the chemical properties, and the scale of the printing. The rapid growth of 3D concrete printing is delivering mechanical efficiency and challenging the boundaries of construction design. Printable concrete, which is made from a mixture of ordinary Portland cement, aggregates and admixtures, is attractive due to its widespread availability and low cost. Most people agree that digital and mechatronic technology is about to have a huge impact on manufacturing and industry as a whole. This paper examines the processes involved in creating different structural elements using various construction techniques with 3D printers. The purpose of this article is thus to divulge the most promising techniques and applications that have been derived from additive printing. Research conducted for this purpose has shown that, aside from pouring the entire building in one go, the columns, beams, stairs, walls and flooring elements can be poured in various ways using a multi-arm or multiple robotic system.

Keywords: Additive manufacturing, 3DC printing, printed structural elements, printing materials

1. Introduction

Concrete is utilised globally as one of the pre-eminent construction materials, both in-situ and prefabricated. There are several reasons for this. It is a construction material with a low production cost, it can be moulded into various shapes, it has high thermal resistance and it is relatively durable. Typically, reinforced concrete construction can be divided into three components: concrete, formwork, and reinforcement. The cost of formwork can account for between 35 and 54 per cent of the total construction cost, and it can take between 50 and 75 per cent of the total construction time.

The aims and benefits of smart construction are to effectively tackle the persistent issues in the construction industry, such as decreased productivity, ecological contamination, and excessive energy consumption. The implementation of sophisticated mass production, computer-based intelligence, and automation technology will lower labor requirements, enhance workplace safety, and assure construction quality and dependability (Liu et al., 2022).

The extraordinary achievements of accelerated industrial development in various regions worldwide can be credited to the automation procedures that have created a more rapid and cost-effective manner of production. However, the concrete construction industry has not experienced automation in a comparable fashion or to the same degree as other industrial domains. Over the past two decades, the traditional method of mixing and pouring concrete on-site has largely been replaced by pre-cast or prefabricated building techniques in several developed and newly industrialized nations. Nonetheless, the construction industry stands to gain significantly from the ongoing automation of procedures, leading to a decrease in labor and construction duration, improved quality, and a reduced ecological impact. The emergence

of three-dimensional printing (3DP) as a technique for rapid prototyping can be traced back to 1987 (Hull, 1986; Chua and Leong, 2014). The fundamental principle of 3DP is additive manufacturing (AM), which implies that material is added layer by layer. This contrasts with most conventional manufacturing methods, which involve the removal of material. While various 3DP techniques exist today, the core principle remains unchanged (Paul et al., 2018).

It is believed that AM and 3D printing will be significantly important in the future because they can create highly intricate items and can be modified to meet customer specifications, utilizing various materials in the process. This substantial transformation in the design and fabrication of objects presents considerable opportunities for the building and construction (B&C) sector (Gardiner, 2011).

AM processes typically utilize computer-aided design (CAD) models as molds to produce complex three-dimensional shapes in a layer-by-layer manner. The initial applications of 3DP were for modeling and prototype creation, but due to advancements in material science, it has since been employed in numerous industrial fields, including automotive, aerospace, military, and medical domains (Bak, 2003; Gibson et al., 2015). The successful implementation of this form of automated construction has been demonstrated by several 3D-printed construction initiatives (Khoshnevis, 2004; Khoshnevis et al., 2006).

Concrete is a substance characterized by its distinct properties, such as shrinkage, creep, and age-dependent strength, which differ from the characteristics of other materials. Despite thorough research on common concrete applications, the exploration of these properties in relation to 3D printing has been quite limited (Bos et al., 2016). What stands out most about 3D concrete printing (3DCP) compared to other industrial and consumer 3D printing methods is, of course, its scale. For instance, they even introduced a 12×12×12 m 3D polymer printer based on Fused Deposition Modelling (FDM) by Qindao Unique Technology (Liang and Liang, 2014). Unlike other 3D printing methods, Additive Manufacturing construction concrete techniques (AMoC) are primarily characterized by the linear deposition of filament. The filament introduces a directionality, which can represent a directional dependency—if not in the properties of the final product, then at least in the printing approach. This has a significant impact, for instance, on angles in a shape, which often appear as curves (with a minimum radius) in the tool path. Utilizing a pixel-based approach grounded in an x, y, z space with equal division in all orientations is not suitable. Moreover, the inclusion of materials like fibers further increases the directional dependence. In conclusion, we can assert that for many 3D printing methodologies, the printer head moves and rotates in the x and y directions, whereas the print surface shifts and rotates in the z direction (Bos et al., 2016).

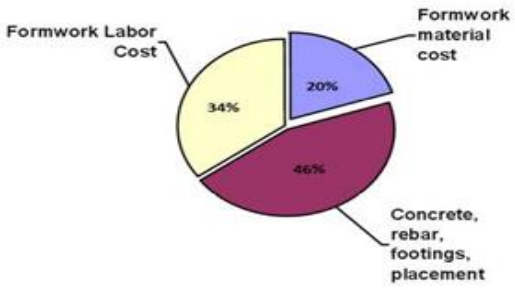


Figure 1. This is an estimate of how the cost of building a concrete structure is shared (Jha, 2012)

2. 3D Printing Production

Towards the end of the 20th century, digital production techniques began to be used in the construction industry. These techniques, which are now being used in building construction, can be examined in three groups (Hauschid, 2011):

1) Additive: Creating components by shaping a formless raw material.
2) Subtractive: Creating the desired component by removing parts from a formed raw material.
3) Transformative: Creating components through permanent shape changes while preserving the integrity of the material.

Although subtractive and transformative processes have been numerically controlled since the 1980s, the capability and ease of use of production techniques continues to improve over time. Examples of subtractive manufacturing include CNC (computer numerical control), punching, laser cutting and water jet cutting (Artuğ and Altun, 2019). CNC folding and bending, flexible roll forming and linear flow splitting are transformative production technologies, especially for steel elements (Hauschid, 2011). In the long term, additive technologies offer the greatest potential in digital production (Hauschid, 2011). "3D printing", an additive manufacturing technology, is being used in medicine, the automotive industry, education, art, textiles, and industrial products. It has recently been adopted in the construction sector and is expected to become widespread in the coming years. Various sources have offered different definitions of 3D printing. Micallef (2015), for example, defines it as a layered production system that converts digitally designed geometries into physical objects by producing them layer by layer using various materials. Kocovic (2017), on the other hand, states that 3D printing is a process that typically creates a physical object from a three-dimensional digital model by successively depositing thin layers of material.

Construction using a 3D printer is based on classic 3D printer logic. A crane equipped with a computer-controlled nozzle that dispenses concrete moves forwards and backwards, left and right, and up and down according to the programme's commands in order to produce the structure (Figure 2) (Khosnevis, 2004).

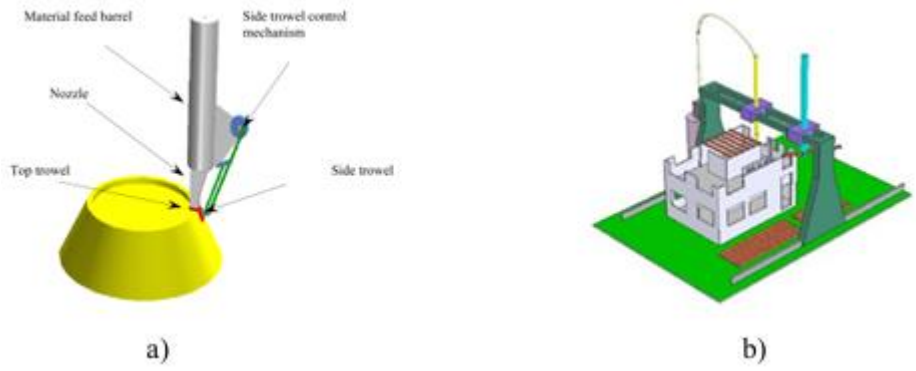


Figure 2.a) Concrete pouring nozzle tip, b) Building production using 3D printer manufacturing technology (Khosnevis, 2004)

The concrete emerging from the nozzle is smoothed using a small finishing process (see Figure 3). The system works with special concrete to create a computer-generated model. The system produces structural elements that do not require moulds or moulding work. Steel reinforcement

is not used. Furthermore, surfaces ready for painting can be obtained without plastering. This results in significant labour cost savings (Çerçevik et al., 2018).



Figure 3. Structures produced layer by layer using a 3D concrete printer (Futurist Speaker, n.d.)

There are three categories of 3D concrete printers: gantry systems, robotic systems, and crane systems (see Figure 4). These printers are utilized in both academic institutions and the industry (Paul et al., 2018). One variant of crane systems is the gantry printer, which is distinguished by its fixed height, as shown in Figure 4.a. In contrast, the crane system illustrated in Figure 4.b offers vertical adjustability. The advantage of employing gantry and crane printers lies in their simplicity of scalability. On the other hand, robotic printers typically have a fixed size, making them more challenging to expand. Nevertheless, a 6-axis robot can perform numerous functions that a 4-axis gantry printer cannot achieve. This capability arises from the 6-axis robot's ability to move more rapidly and with greater versatility (see Figure 4.c).

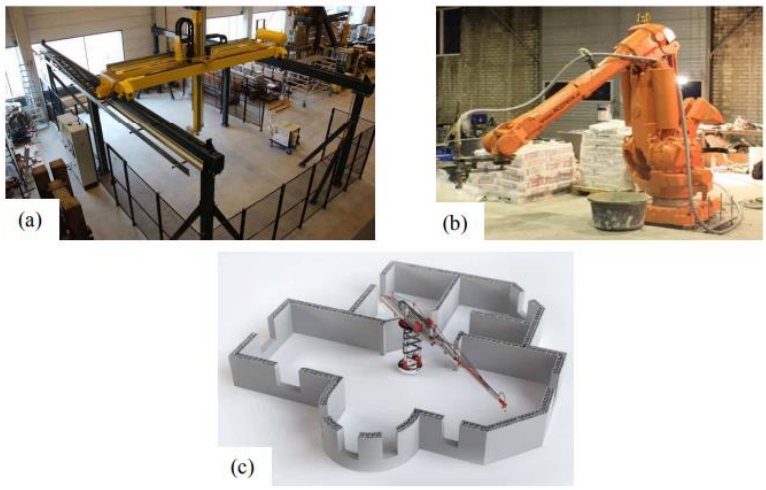
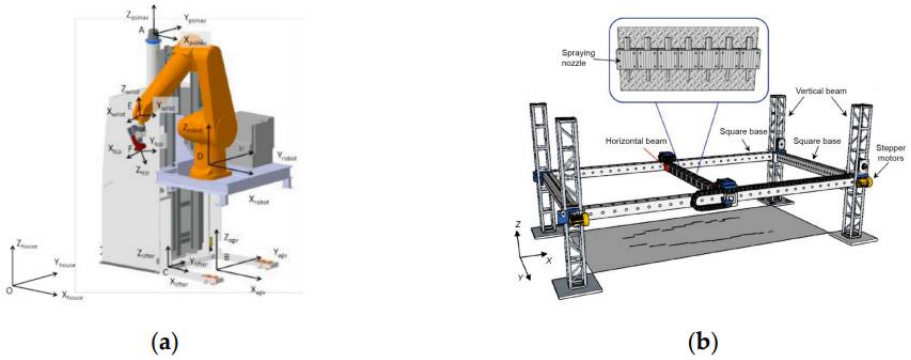


Figure 4. There are three types of 3D concrete printer: a) Four-axis gantry printer, b) Six-axis robotic printer and crane printer, c) Crane printer (Paul et al., 2018).

CyBe Additive Industries, a company based in the Netherlands, has also adopted the contour crafting (CC) technique. They have developed a mortar that achieves workable strength in just 5 minutes. CyBe has conducted experiments using a print head mounted on an imprecise 6-axis robotic arm (see Figure 5.a), which provides a wide range of printer speeds and operational strategies (Paul et al., 2018). The additional rotational axis of the robot, combined with gantry printers, grants designers greater flexibility to create complex shapes. The robotic printer's 6-meter diameter reach facilitates the rapid production of relatively large elements.

In parallel, the Russian company Apis Cor has developed a crane-type printer (see Figure 5.b) that offers a substantial printing area of up to 58 m², without significant height restrictions. As indicated in Figure 4, the printing head can be mounted on either a gantry system or a frame, and it may include one or multiple nozzles along with a binder supply tube (Relefors et al., 2019). Binder material can be supplied either through a premixed binder or via an on-site mixing container (Tay et al., 2017; Sweet, 2018). 3D printing technology presents a viable solution to address labor shortages and construction costs, making it a convenient, low-maintenance, and cost-effective method. However, it's crucial that the 3D printing robots utilize a specific blend of chemicals to ensure strength and minimize shrinkage. The use of 3D printing technology in constructing concrete structures is a compelling advancement in the construction industry, representing one of the most promising avenues for increasing automation and intelligence in this field (Liu et al., 2022).



(a) (b)

Figure 5. The 3D printer has two different types of nozzle: **a)** one nozzle on a robot arm, **b)** many nozzles on a frame (Liu et al., 2022)

The dominance of concrete in 3D printing for building structures is significant, although other materials such as ceramics, metals, and polymers are also employed for structural components. A critical requirement for 3D printing with concrete is its ability to be extruded, alongside essential properties like rigidity post-extrusion and layer adhesion, which are vital for the integrity of printed structures. Therefore, the ideal concrete mixture should exhibit high viscosity and low yield strength, promoting high plasticity and workability. Additionally, concrete must achieve quick strength gain to facilitate the construction of tall buildings efficiently (Perrot et al., 2016).
Kazeminan et al. (2017) proposed a laboratory testing-based framework for assessing the printability of concrete specifically for 3D printing applications. To meet the necessary criteria for printable concrete, Gosselin et al. (2016) developed an innovative system, illustrated in Figure 6. This system separates the concrete premix, which has high workability, from the hardening agent. The components are combined at the extrusion nozzle, thereby enhancing the rheological properties of the premix. This method ensures optimal workability and extended setting time during mixing and storage while enabling high early strength and rapid setting duration (Liu et al., 2022). This advancement represents a significant step toward improving the viability of concrete for 3D-printed construction, addressing critical operational challenges and paving the way for more sophisticated applications.

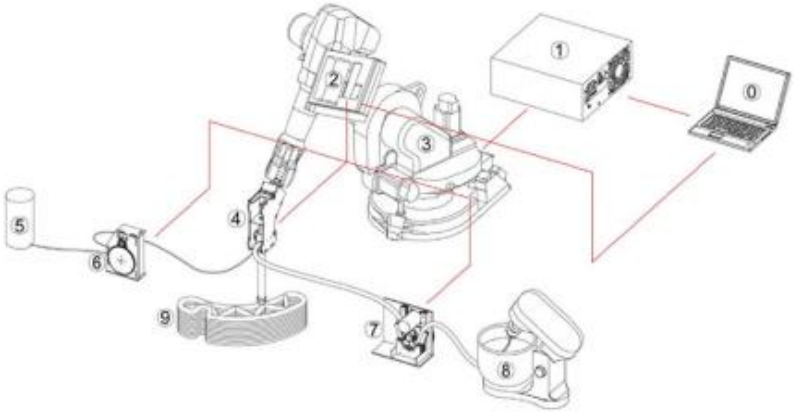


Figure 6. This is an image of a 3D concrete printing setup; 0. System command; 1. Robot controller; 2. Printing controller; 3. Robotic arm; 4. Printhead; 5. Accelerating agent; 6. Peristaltic pump for accelering agent; 7. Peristaltic pump for premix; 8. Premix mixer; 9. 3D printed object. (Gosselin et al., 2016)

There are three main approaches to where 3D printing can be conducted: on-site (direct printing), in a mini factory (indirect printing), and in a prefab factory (indirect printing). The first method refers to direct printing in situ, where the object is created without any additional handling. The second method involves printing in a controlled environment, such as a mini factory set up on the construction site, allowing for regulation of factors like temperature and humidity. The third method is traditional prefab factories, which often face challenges related to the handling and transportation of printed components (Duballet et al., 2017).

When utilizing concrete printing in a building system, certain assembly steps may be necessary. This often involves the movement of large components using machinery. Items that can be incorporated into the extruded mortar, such as polystyrene beads or fibers, are referred to as 'macroscopic elements.' In this context, it is typically accepted that the secondary robotic apparatus, or printing head, should be viewed as the primary performer of the tasks at hand, meaning it should not be considered part of the assembly process. Instead, the assembly phase is conducted either by human workers or additional robotic systems. Figure 7 illustrates the four types of assembly involved in this process (Duballet et al., 2017). This organization of tasks highlights the collaboration between technology and human effort in advancing the efficiency and effectiveness of concrete 3D printing in construction.

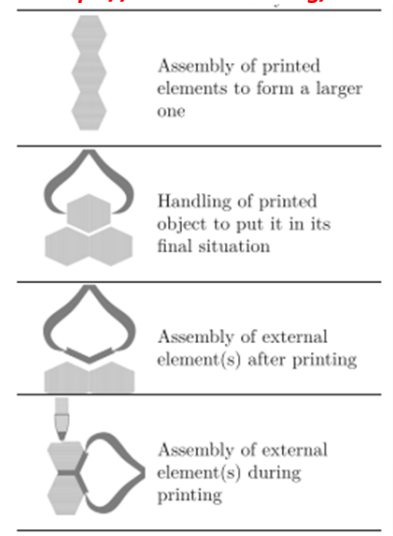


Figure 7. Variation of assembly parameter (Duballet et al., 2017)

To effectively print over an already established surface, the nozzle must navigate the contours of the surface, which involves mapping its shape prior to the printing process. Generally, this support structure is installed manually to accommodate the upcoming layers. Printing on a flat existing surface, like a reusable plank, offers a cost-effective solution; however, the true advantage of 3D printing lies in its ability to create complex, non-flat shapes. This necessitates adapting the existing surface support to match the intended design, which can be labor-intensive and time-consuming. The challenge of constructing complex surface supports can also introduce complications during printing, such as extended delays between the application of subsequent layers and the support structure (Tay et al., 2019). Figure 8 illustrates an innovative roof design that does not rely on traditional supports. This concept, first proposed by Khoshnevis in 2004, draws inspiration from ancient construction techniques. It is based on vault construction methods, where bricks and mortar are used to create a parabolic-shaped roof, inclined at about 20° to the perpendicular along the vault's longitudinal axis, as documented by Dahmen and Ochsendorf (2012). In this approach, the previous sections of the roof help support following sections, eliminating the need for extensive formwork. This unique angle facilitates the integration of the support system into the main structure. The parabolic design not only contributes to aesthetic quality but also allows for the arrangement of the bricks in a manner that puts the entire structure into compression, enhancing its overall stability and integrity.

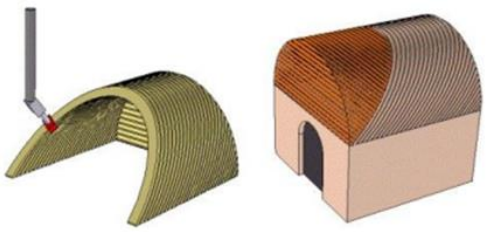


Figure 8. A method of making structures without using supports is called contour crafting (Khosnevis, 2004)

The initial phase in creating a support structure is to assess whether support is necessary for the surface in question. Once determined, the support geometry is calculated and printed using a weak infill pattern, as noted by Strano et al. (2013). Some fused filament fabrication (FFF)

techniques, as well as jetting-based additive manufacturing methods, incorporate dual-nozzle printers (illustrated in Figure 9). This design facilitates the simultaneous use of primary materials for the main structure and distinct support materials, which serve as temporary structures that can be removed during post-processing. In the context of multijet printing methods, Stansbury and Idacavage (2016) demonstrated the use of a UV-curable material that enables the production of smooth components with highly intricate geometries. Additionally, some techniques employ gel-like support materials, such as wax, which can be deposited alongside the main material and subsequently removed through heating. In contrast, Fahad et al. (2013) investigated support materials with alternative properties, specifically targeting the FFF technique with polyvinyl alcohol (PVA). This water-soluble thermoplastic dissolves easily in water, simplifying the support removal process. For jetting-based techniques, materials such as propylene glycol are favored for their ability to withstand higher temperatures, allowing them to effectively melt away during post-processing (Tay et al., 2019). These methods are particularly useful for printing multi-piece assemblies, where significant attention must be given to ensuring accessibility for the removal of residual material between components (as shown in Figure 9). The advantage of using dissolvable or meltable support materials lies in the reduction of human error, as the removal process leaves the main features of the printed structure intact and undamaged.

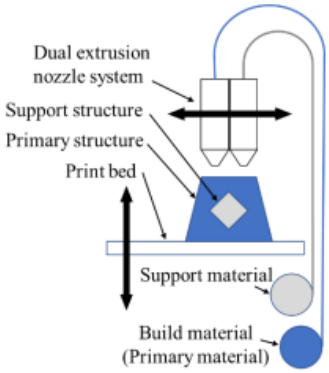


Figure 9. A system for printing with support material using a fused filament fabrication (FFF) dual nozzle (Tay et al., 2019)

The current literature lacks detailed documentation on setups for 3D concrete printing that involve the use of multiple materials. However, Zhang et al. (2018) illustrated in Figure 10 that it is feasible to employ two robotic printers to collaboratively print a single-piece structure. Each robotic printer is equipped with its own pump, allowing for synchronized printing operations. In their study, primary materials are utilized alongside support materials, such as clay, which can be integrated into one of the robots to form the necessary support structure. To prevent collisions between the robotic printers and ensure precise placement of both primary and support materials, meticulous calibration of the system is essential. The introduction of two or more nozzles significantly increases the complexity of the printing system. Nevertheless, mortar remains a cost-effective choice for the primary material in concrete printing applications. However, if the support material proves to be more expensive than the primary material, it could lead to increased overall manufacturing costs for the component. This economic consideration highlights the importance of balancing material choices to optimize both functionality and cost-efficiency in multi-material 3D concrete printing setups.

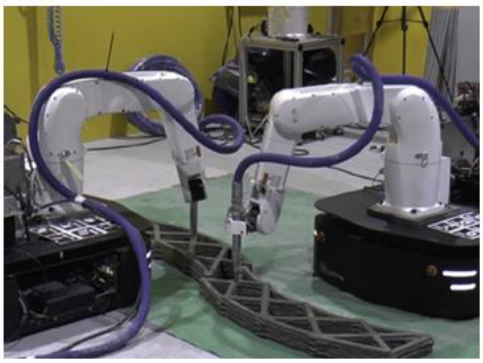


Figure 10. Two robot printers provide continuous printing (Zhang et al., 2018)

3. The Development of Three-Dimensional Printing Technology in the Construction Industry

The initial forays into automated construction by Japanese companies began in the 1980s, focusing primarily on two categories of work (Taylor et al., 2003). The first category involved the replacement of simple labor tasks on construction sites with single-task robots. These robots were utilized for various applications such as concrete floor finishing, spray painting, tile inspection, and material handling.
The second category encompassed fully automated systems capable of constructing tall buildings using steel and concrete. These structures are typically composed of pre-fabricated components assembled on-site, as illustrated in Figure 11. A notable example of this approach is the Big-Canopy system, which stands out as the first computerized building system designed for precise concrete construction. The Big-Canopy features four distinct masts that support an overhead crane, enabling the delivery of components directed by a joystick operator. Furthermore, a centralized information control system orchestrates and manages all operational tasks, ensuring efficiency and accuracy in the construction process (Khoshnevis et al., 2006; Wakisaka et al., 2000). This integration of technology in construction not only streamlines operations but also enhances the precision of building processes.

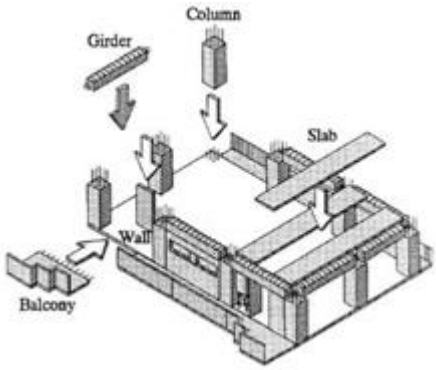


Figure 11. The use of prefabricated components in RC building (Wakisaka et al., 2000).

This text is a list of the history of 3D printing. It was written by Micallef in 2015. It talks about the most important moments in the history of 3D printing. It also talks about how 3D printing was first used to make buildings:

• The stereolithography patent was obtained by Chuck Hull in 1984. Stereolithography is the name for the process of making 3D objects using a computer-controlled laser beam that builds

the needed structure layer by layer from a liquid polymer which hardens when it touches the laser light (Kocovic, 2017).

• 1985: The technology known as selective laser sintering was first developed by two scientists, Dr Carl Deckard and Dr Joe Beaman, at the University of Texas at Austin. This is a 3D printing technique where powdered materials are heated using a strong laser (Kocovic, 2017).

• 1988: Scott Crump makes a toy frog using an old way of printing in 3D. This method was later used to make products to sell. It is called 'Fused Deposition Modelling' (FDM).

• In 1992, 3D Systems made the first 3D printer.

• 2005: The RepRap project has started. RepRap means 'Replicating Rapid Prototyper' and is a project that anyone can get involved in. It was started by Dr Adrian Bowyer, who teaches mechanical engineering at the University of Bath (UK). The objective is to develop a 3D printer that is capable of manufacturing the majority of its own components and replicating itself to a significant degree.

• 2006: Objet has engineered a machine that is capable of printing with a variety of materials.

• 8 March 2010: The initial full-scale model of a 3D-printed structure was created.

• March 2013: The first 3D-printed canal house was the brainchild of Dutch architects.

• January 2014: The building of the world's first 3D-printed home, 'Canal House', got underway.

• January 2015: WinSun has constructed an apartment complex in China employing 3D-printed panels.

Another important point to consider alongside the innovations that 3D printing technology will bring to the construction system is its potential impact on building culture and design. 3D printing technology has the potential to transform building production, and this is an area that requires comprehensive research. In general, people use three main categories of material in 3D printing: liquid, solid and powder-based. These categories include various types of materials, such as polymers, metals, ceramics and composites (Noorani, 2017). As in other fields, companies have developed different printing techniques, tools, and materials that are used on an architectural scale. Table 1 shows the 3D printing techniques that can be used in architectural construction, the materials used in production, the maximum dimensions of the produced elements, the finishing processes that can be applied afterwards, the layer height that can be produced per unit of time and the areas where 3D concrete printing technology can be used (Artuğ & Altun, 2019).

Additive manufacturing is part of the Fourth Industrial Revolution. 3D printing has the potential to transform science and technology by enabling the production of items that previously required specialised facilities using low-cost tools. While additive manufacturing will certainly not replace existing production processes entirely, it will be applied where practical and will fill gaps. For a period of time, it will be necessary to combine human labour and craftsmanship with high-tech tools (Strauss, 2016).

Table 1. Key features of different 3D printing techniques used in the architectural construction industry (Hauschid, 2011)

Technology	CNC precast concrete parts	Multi-jet modelling (MJM)	3D Printing (3DP)	Fused Deposition Modelling (FDM)	Selective Laser Sintering (SLS)	Stereo-lithography (STL)	Contour Crafting (CC) D shape	Robot-based layering
Construction material	Polymers Thermoplastics Acrylonitrile butadiene styrene (ABS) Wax	Polymers Thermoplastics Acrylonitrile butadiene styrene (ABS) Wax	Silicone Ceramics Aluminum Plastics Cement Concrete	Polymers Acrylonitrile butadiene styrene (ABS) Wax	Polymers Polyamides Polycarbonates Polystyrene plastic-covered sand	Polymers Epoxy resin Vinyl ether resin Acrylic resin	Artificial sandstone	Bricks Wood
Maximum construction size (mm)	10,000 3,000 500	298 185 203	600 500 400	600 500 600	720 500 450	1000 800 500	6,000 3,000 3,000	3,000 3,000 3,000
Precision	± 5 mm	± 0.5 mm	± 0.2 mm	± 0.2 mm	From ± 0.1 mm to ± 0.02 mm	± 0.05 mm	± 20 mm	± 10 mm
Options for finishing processes	Glazing Polishing	Sandblasting Polishing	Infiltration Sintering	Heat treatment Epoxy resin or painting Grinding	Infiltration with epoxy resin or metals which melt down	Sandblasting Grinding	Plastering Grinding Insulating	Plastering Grinding
Geometry data input	.dxf .dwg	.stl .iges .step	.stl .iges .step	.stl .iges .step	.stl .iges .step	.stl .iges .step	.stl .iges .step	.stl .iges .step
Manufacturer	3D Systems	3D Systems	3D Systems	Stratasys	3D Systems	3D Systems	Monolite UK	KUKA Prototype-Development ETH ZÜRICH
Time/mm Construction height/m²	10 s	45 s	20 s	90 s	120 s	150 s	60 s	10 s
Application	Construction industry	Automotive industry Porcelain industry Design	Model construction Design industry Architecture	Model construction	Electronics industry Office machines Automotive industry	Model construction Electronics industry Medical technology Jewellery industry	Construction industry Large prototypes	Construction industry

4. Production of Structural Elements Using Three-Dimensional Techniques

Building materials are the most basic natural components used to construct a building's structure, including bricks and glass. These components are then brought together or cast into moulds to form building elements such as stairs, walls, flooring and foundations. The structural elements of a building can be listed as follows: walls, floors, the roof, stairs, and joinery. A system can be defined as a more complex, integrated whole formed by interrelated or interdependent parts that serve a common purpose. A structure can be considered the physical assembly of numerous systems and subsystems that must be coordinated and integrated with each other, as well as with the three-dimensional form and spatial organisation of the structure as a whole (Ching and Adams, 2008). The systems that make up the structure are: Structural system; substructure (foundation system); superstructure (load-bearing wall, column, beam and slab system); enclosure system (roof, walls and joinery); mechanical systems (water supply system, wastewater drainage system, heating, ventilation and air conditioning systems, electrical system, vertical transport systems, fire extinguishing systems and waste control system).

Reinforcement in 3D printing of concrete (3DPC) is essential for enhancing structural performance and reliability. Prior studies have demonstrated the extrusion of strain-hardening cementitious composites (SHCC) integrated with steel bars, as depicted in Figure 11 (Van Zijl et al., 2016). Specifically, in the case of reinforced SHCC (R/SHCC), two steel bars were

extruded simultaneously with the SHCC, as illustrated in the figure. In this process, the steel bars were inserted horizontally through specially designed apertures located at the rear of the extruder. Once the bars were positioned, they were automatically drawn in and guided by a vertical piston extruder through a 90° bend. This innovative method allows for seamless integration of reinforcement into the 3D printed concrete, thereby improving the structural integrity and load-bearing capacity of the fabricated components. The use of R/SHCC signifies a significant advancement in the capabilities of 3DPC technologies, enabling the construction of more robust and reliable structures.

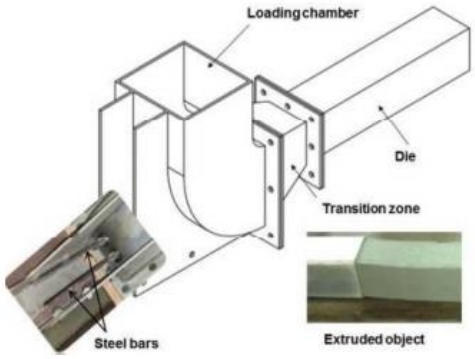


Figure 11. The process of manufacturing steel bar reinforcement in SHCC by means of extrusion. (Van Zijl et al., 2016)

The integration of reinforcement in the automated layer-by-layer 3D printing of concrete (3DPC) presents notable challenges, particularly when it comes to vertical reinforcement and its connections, largely due to the constraints of current printing technologies. To enhance the structural integrity of 3DPC structures, alternative reinforcement methods must be explored. Options such as composite fibers mixed into concrete, carbon fiber, or fiber-reinforced polymer (FRP) have potential; however, their effectiveness necessitates thorough investigation and innovative adaptations to existing 3DPC technologies. Research by Kim et al. (2003) highlights that the structural capacity and ductility of 3DPC columns and beams can be significantly improved by incorporating FRP into the design. This suggests that exploring these alternative reinforcement methods could lead to marked enhancements in structural performance. A promising solution lies in developing hybrid printing systems capable of simultaneously printing concrete and various reinforcement types in diverse configurations. Manual placement of reinforcement has already been employed in practice, as demonstrated in Figure 12 (Continuum, n.d.). This includes techniques for inserting reinforcement in intermediate layers (Figure 12.a), positioning it between filament layers (Figures 12.b & 12.c), or using extrusion through the sides of pre-tied reinforcement cages (Figure 12.d). Despite these manual methods, achieving full automation in the reinforcement process could revolutionize 3DPC. Automating the incorporation of reinforcement would enhance precision, reduce manufacturing time, lower labor costs, and minimize material waste, ultimately contributing to more efficient construction practices. Moving forward, the development of automated systems for reinforcement integration will be crucial for advancing the capabilities and applications of 3DPC.



Figure 12. Reinforcement application in 3D-printed concrete objects (Continuum, n.d.1), (Continuum, n.d.2), (3ders, n.d.), (Continuum, n.d.3).

In addition to the previously discussed methods for integrating reinforcement in 3D concrete printing (3DCP), researchers at the Singapore Centre for 3D Printing (SC3DP) are actively developing two innovative techniques, illustrated in Figure 13. The first method involves creating a new nozzle system that allows for the simultaneous extrusion of steel wire along with the concrete material, as shown in Figure 13.a. This approach requires the steel wire to possess adequate flexibility, enabling it to accommodate the dynamic movements of the printing nozzle, especially when navigating geometrical curves or transitioning between different layers of the structure. The second method introduces a robotic system tasked with automating the injection of steel fibers into an existing layer of 3DPC prior to the deposition of the subsequent layer, as depicted in Figure 13.b. This technique aims to enhance the bonding and structural integrity between layers by strategically placing reinforcement where it is most needed. Both methods are still in the preliminary stages of development, highlighting the need for further research and experimentation before they can be fully integrated into existing 3DPC processes (Paul et al., 2018). These advancements hold promise for improving the performance and durability of 3D printed structures, yet detailed investigations into their effectiveness and applicability are essential for successful implementation.

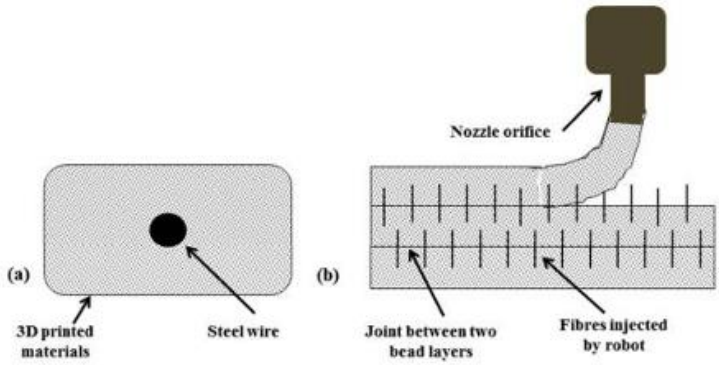


Figure 13. The following prototypes were created to show how reinforcement can be used in 3 DPPC: a) Steel wire extrusion, b) Fibre injection (Paul et al., 2018)

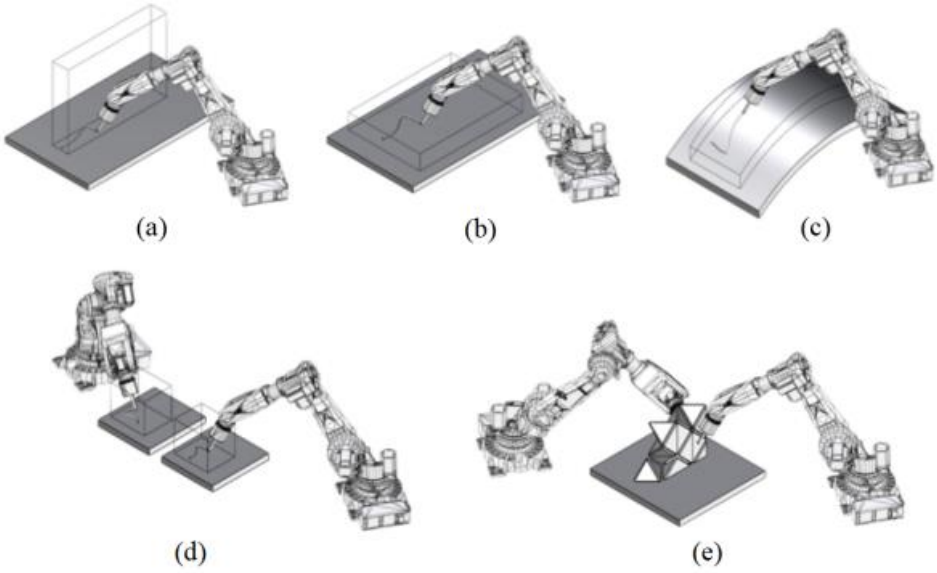


Figure 14. There are different types of external support: **a)** No support, **b)** Flat support, **c)** Curved support, **d)** Multiple supports, **e)** Assembled supports (Duballet, 2019)

External supports for 3D printing construction elements are illustrated in Figure 14, showcasing various approaches that utilize mortar extrusion controlled by a 6-axis robot. While the printing process remains consistent, the variation in external support types leads to significantly different systems and a wide range of possible forms for the printed structures. This review underscores the importance of further discussions, particularly concerning the assembly aspects of 3D printing in construction. When direct printing can occur without the need for external components or assembly elements, it simplifies the process. However, scenarios involving multiple printing instances inherently introduce an assembly step. Similarly, collaborative printing processes often necessitate an assembly phase, whereby external supports are integrated during the extrusion process. Understanding the complexities, technological challenges, and costs associated with various building systems is crucial for successful project planning. Highlighting the distinctions between these systems can enhance the anticipation of potential complications. Moreover, innovative solutions can often circumvent obstacles when the focus is on the entire building system rather than on creating overly complex processes that may hinder industrial adoption. By addressing these considerations, stakeholders can streamline the development and application of 3D printing technologies in construction, facilitating broader acceptance and implementation in the industry.

Sub-structure Production

Contour Crafting nozzle assembly and motion control system and a special method of cementitious material delivery system are employed by the method (Contourcrafting, n.d.). The substantial metal components of the tower need to be conveyed from the manufacturing facility to the wind farm for assembly (see Figure 15). They are often called "wide loads". This means that they need to be transported in a special way. Moreover, there is currently a strong impetus to construct taller towers that can reach stronger wind elevations. But the way towers are built now is limited because it costs a lot of money to build cranes that can reach higher than the current maximum height (85 to 100 metres). In addition, the construction of taller towers necessitates the use of larger base segments, which pose challenges in terms of transportation

due to limitations in road width and height restrictions imposed by overpasses. Moreover, the deployment of large cranes at wind farms requires wider roads.



Figure 15. Infrastructure work with 3D printers (Contourcrafting, n.d.)

Wall Production

a) A Block Production

In Craveiro et al., a curved external wall with a special material mix was chosen as an example. (2020) (Figure 16.a). Presently, material extrusion represents the most pervasive technology for the fabrication of homogeneous concrete structures by AM. An AM system capable of extruding functionally graded concrete was developed in this study (see Figure 16.b-c). The solitary curved block unit exhibited in Figure 17.a-b-c was printed at a deposition velocity of 25 mm/s employing cork material. A first geometrical study of the curved block unit was done after the curing period, using a 3D Systems Sense 3D scanner (resolution ~1 mm).

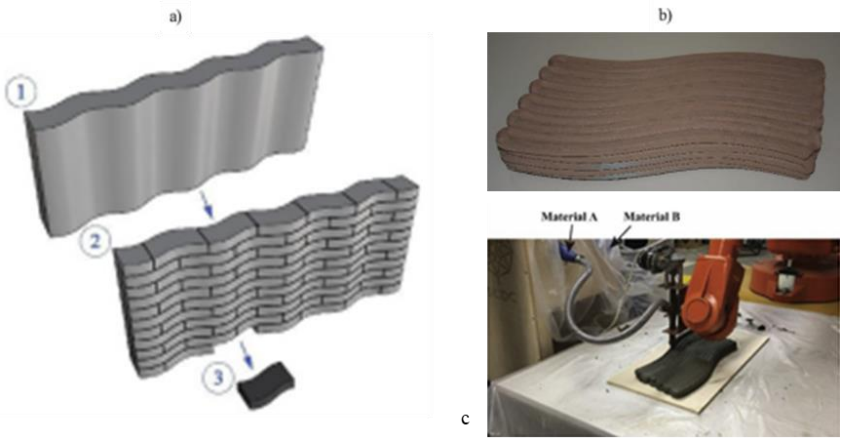


Figure 16.a) The image below shows a visual output in Rhinoceros. It includes the initial shape (1), the wall subdivided into discrete blocks (2), and one block unit extracted (3), **b)** A curved block unit produced by AM, **c)** 3D printing process (Craveiro et all., 2020)

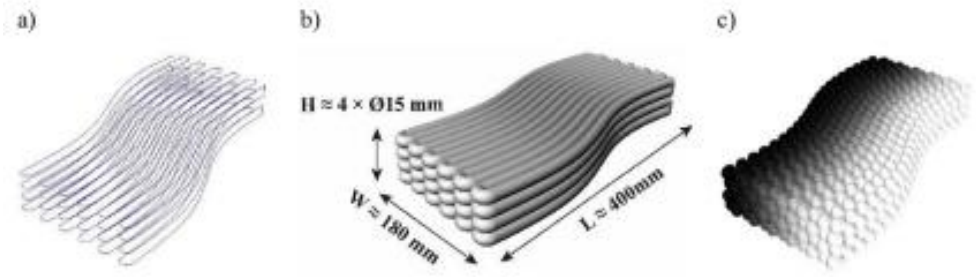


Figure 17. Curved block unit: **a)** path for the tool, **b)** computer design showing how big it is and how the filament is layered (4 layers), **c)** computer design showing the change in colour (Craveiro et all., 2020)

A block unit (Figure 16.b) made of two different concretes was produced. In this scenario, each pump reservoir contains a single material, one comprising a sand-based concrete mixture (cork) and the other a mixture in which cork granules replace 10vol% of sand (Figure 17.c). The materials were extruded through the dynamic nozzle based on the material composition and printing instructions. Each filament was 15 mm thick, and the printing speed was 25 mm/s. These values were chosen after running several tests, in an iterative process that took material flowability and hardware limitations (e.g. pump pressure) into account.

b) A Straight Wall Production

The prototype of a 'flat' wall is shown in Figure 18. Horizontal printing on the floor was the first step, followed by movement to its vertical position. A strategy like this gives you a lot of freedom when it comes to the geometry of thin 2.5 D structures. It uses the smallest dimension of the object and gets rid of the main difficulty of direct printing: height. Nevertheless, from a structural design standpoint, the loading that corresponds to the handling of the object is likely to be the worst-case scenario, and therefore to ruin the attainable lightness of the wall (Duballet et al., 2017).

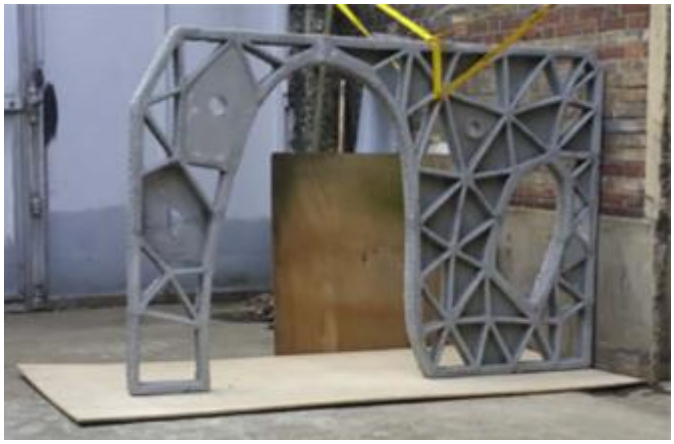


Figure 18. Flat wall (Duballet et al., 2017)

c) A Curved Wall Production

The construction of a load-bearing, steel-reinforced concrete wall using an in-situ fabrication process was carried out by Buchli et al. (2018). It is believed that one of the most comprehensive IF (in situ fabrication) processes in the building construction domain is reflected in the development and the final system. The NEST building in Dübendorf, Switzerland, was the site of the first use of robotics to build a fully load-bearing steel-reinforced concrete wall in situ (Buchli et al., 2018). The mesh mould metal (M3) process is a new way of making strong structures using steel and concrete. It is based on new ideas in materials science, structural engineering, and mechatronics (Hack, 2018). A robotic fabrication process enables the complexity of the denser mesh. This process involves a mobile robot (the in situ fabricator, or IF) guiding a special purpose tool head, which is mounted on a robotic arm, through 3D space (see Figure 19.a). The development and testing of the M3 process was a highly collaborative endeavour, involving experts from multiple disciplines working in close tandem. The subjects

involved are architectural design, structural engineering, materials science and robotics. The fundamental notion in M3 revolves around the utilisation of the reinforcement mesh as a lost formwork. The mesh is constructed with greater density than conventional steel-reinforced concrete rebar cages, thereby ensuring the concrete mix's yield stress (cohesion) prevents the concrete from flowing through the mesh (Hack et al., 2014).

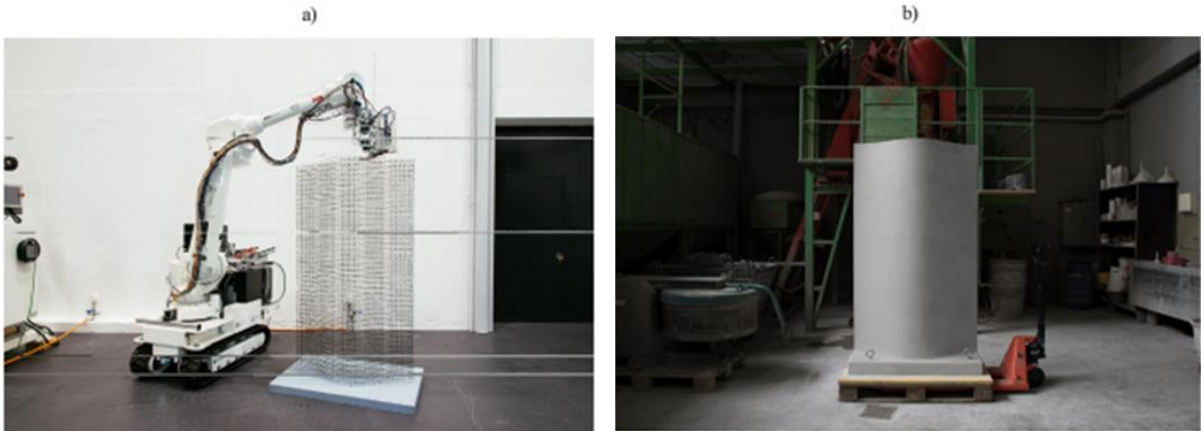


Figure 19. a) The construction of a mesh prototype, **b)** involves the creation of a filled steel-reinforced wall prototype (Buchli et al., 2018)

The M3 process is dependent on a specific concrete mixture (Hack, 2018) and the yield stress (Yahia et al., 2015) of the concrete mix to ensure it remains contained within the metal mesh. The assembly of the mesh and the filling with concrete occurs directly on the construction site, i.e. in the final position of the wall. The exterior surfaces of the meshes are subsequently overlaid with concrete, which is customarily applied by means of a spray application, followed by a manual trowelling of the surface finish (see Figure 19.b). The composition and thickness of this layer should be selected according to the expected durability and exposure conditions. The IF is equipped with additional sensors to support the building process, in addition to the process-specific M3 tooling, to facilitate the construction of the mesh. The IF must sense its position within the construction site. It must also be able to measure the mesh's contour during construction. This is in order to build the mesh accurately on-site. Using the M3 process, workers built an undulated steel-reinforced concrete wall for the DFAB house on the NEST building at EMPA in Switzerland. The wall's dimensions are 12 metres in length and 2.8 metres in height. The necessary mesh comprised over 20,000 welding points, which were constructed with an average discrepancy of 9.5 mm and a maximum discrepancy of 38 mm from the intended blueprint (see Figure 20.a, b). When finished, the wall will carry a structural live load of more than 100 t. (Buchli et al., 2018).

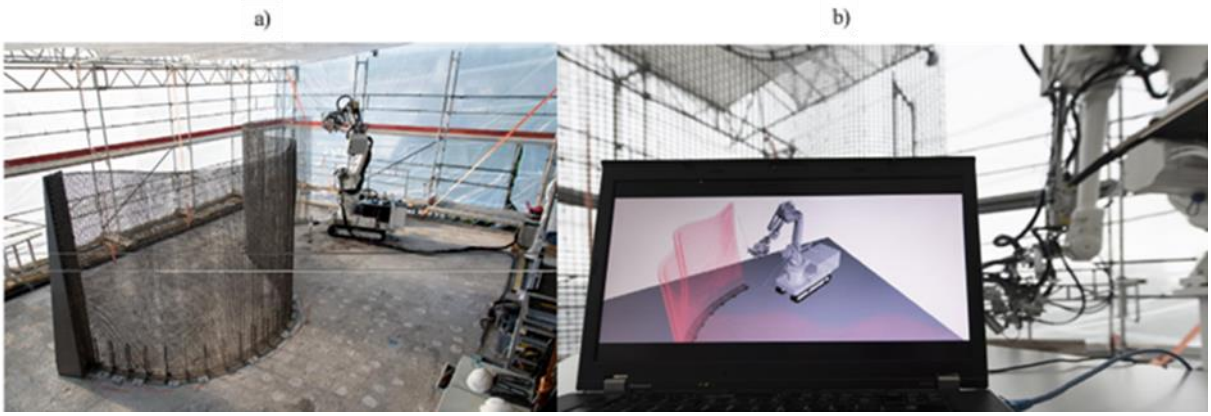


Figure 20. a) The IF assembling the metal-reinforced reinforcement mesh at the NEST building site, **b)** Screen grab of the CAD incorporation of the M3/IF manufacturing system (Buchli et al., 2018)

d) Hybrid 3D Printing & Milling for Acoustic Façades

The acoustic performance and surface precision of façade panels could be enhanced by integrating 3D concrete printing (3DCP) and robotic milling. This was the focus of the Master's thesis that Jarry Pérez López wrote at RWTH Aachen University. The design and manufacture of all prototypes was carried out at Vertico's studio in Eindhoven, using a robotic arm from ABB (model IRB 6640) and a 2K MAI-Vertico printhead (Vertico, n.d.). The study's objectives were to:

- Enhance the surface quality and geometric precision of three-dimensional printed panels.
- Find out how the speed of the printer, how thick the layers are, and the settings for milling affect how well sound is scattered.
- Establish principles for the creation of eco-friendly, sonically enhanced structural components.

Sixteen 700 mm × 700 mm concrete panels were printed in four groups, with different patterns on the surface (one-dimensional, two-dimensional, and different levels of depth) and wave height (25 mm and 50 mm). The testing of panels was undertaken within an anechoic chamber, the purpose of which was to facilitate the measurement of scattering coefficients (Figure 21) (Vertico, n.d.).

Two extra milled panels (M1 and M2) were made to compare hybrid fabrication with pure 3D printing:

- M1: 8 repetitions across two axes, changing depth, based on the top-performing B-series examples.
- M2: 12 times, with small changes in two directions, based on the C-series designs.

The highest acoustic scattering performance was achieved by two-dimensional periodic surfaces with a depth of 50 mm, especially in the case of omnidirectional noise diffusion. Milling made a big difference to geometric precision, getting rid of the staircase effect, and allowed for sharper edges and complex geometries that printing alone couldn't achieve (Vertico, n.d.). The best way to balance surface refinement with material integrity is to use green-state milling (this is a process that happens after printing and before curing). Strong potential for

urban noise mitigation was demonstrated by this hybrid manufacturing workflow, while aesthetic versatility was also offered. A seamless transition from digital concept to precisely manufactured, high-performance façade components was enabled by the combination of parametric design tools and robotic fabrication.



Figure 21. Examples of manufactured acoustic panels **(**Vertico, n.d.)

e) Masonary Wall

In 2021, an office space privacy wall was constructed by a Waterloo University team in Toronto, Canada. The structure's distinctiveness lies not only in its aesthetic appeal, but also in its remarkable method of construction. Utilising an advanced 3D printer, the structure was assembled "like a honeycomb, where the interlocking of hexagonal units forms a robust and efficient material framework" (Figure 22.a) (Prieto, 2022). The art and craft of building in clay is being reshaped by HIVE Project, which combines traditional ceramics, smart geometry and robotic precision to construct a masonry wall made up of one hundred seventy-five unique 3D-printed clay bricks. The way the wall is built plays with the opening and closing of the clay bricks, which creates a special atmosphere (see Figure 22.b). The configuration facilitates both seclusion and the diffusion of light through the partition, engendering a remarkable ambiance that compartmentalises whilst concomitantly preserving the ambience of the entire space (Figure 22.c).

Canada's first 3D-printed masonry wall was created after a complicated process of development where the team tested different materials, designs, and ways of making it before they could make it. According to the team, the project's approach aims "the spirit of traditional ceramic craft with robotic precision". This offers new avenues for material expression and geometric complexity within this field. (Prieto, 2022). One of their goals was to acknowledge the natural properties of clay. Clay is a stable and long-lasting traditional material. They assembled diverse clay mixtures. These were adaptable for an innovative 3D-printing process. The concept of 'digital craftsmanship' is introduced by HIVE as a new construction process, combining digital and analogue models.

The creation of the masonry wall involves three main steps. First, the design and best pattern for forming the wall are selected. Next, a handmade clay mixture is produced to achieve the malleability and fluidity required to shape the clay units. Finally, a robot 3D-prints the digital pattern, which has already been designed, through sliced layers of clay. The result of this work was a 2.3 m x 5.4 m 3D-printed masonry wall for a reception area (Prieto, 2022). Following extensive research and testing of various prototypes, the team developed a computer-generated design for a unit geometry that ensures the wall's feasibility. Using the association of triangular bricks composed of four hexagonal shapes, the 3D printer creates not only a stable and permeable wall, but also an artistic object with a unique pattern, texture and colour (Prieto, 2022).

A six-member research team from the University of Waterloo designed HIVE in partnership with the Investment Management Corporation of Ontario (IMCO) and the Masonry Works Council of Ontario. The project was commissioned by SDI Interior Design (Prieto, 2022), (Archdaily, n.d.).

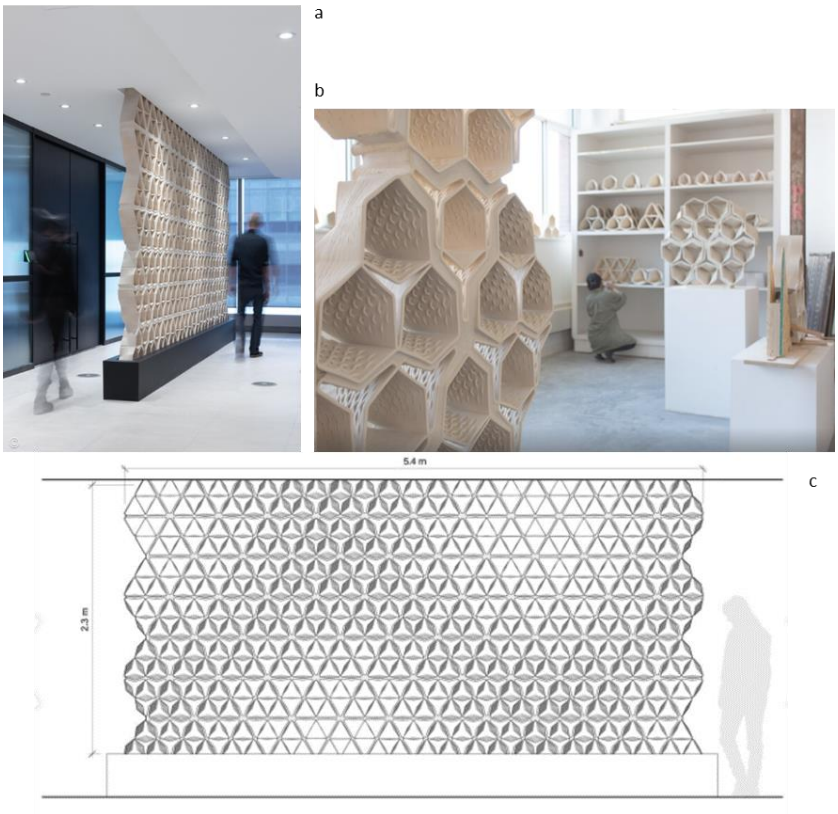


Figure 22. a) A brickwork partition for the reception area; Image © Shabaan Khokhar (Archdaily, n.d.), **b)** Joining triangular bricks made up of four hexagonal components; Image © Fred Hunsberger (Archdaily, n.d.), **c)** Wall Elevation; Image © David Correa (Archdaily, n.d.)

Beam Production

a) Truss Beam

An Italian Institute of excellence, which specialises in the study of concrete mortars, received a WASP printer. A 4-metre BIGDELTA WASP was used by Domenico Asprone and some friends of the University Federico II of Naples. Figure 23 depicts an idea proposed by the WASP Project1 of using steel bars with adequately designed components for making a lightweight composite beam. The University of Naples' Stress Consortium and University of Pavia are collaborating on the research. "3D printing allows you to create curved, hollow elements or with special features that would normally require complicated wooden shapes (moulds) for fresh concrete, which is more expensive" explained Stress Consortium's Marco Iuorio. Tests on a 3-metre long test beam are planned to check the mechanical performance of the reinforced concrete elements in the Department of Engineering Structures and Architecture's laboratories (3dwasp, n.d.).



Figure 23. a) Beam, **b)** Team members: University of Naples Federico II (3dwasp, n.d.)

b) Sloped Truss Beam

A 3D-printed beam has been produced, consisting of an irregular arc (the longitudinal profile of Vesuvius volcano) measuring approximately 4.00 m in length and 0.25 m in width. The entire shape is characterised by a double-path line of printed concrete, with the exception of the hole edges (Figure 24). The connection system for the rebar is the same as the one used for the straight RC beam. Such an unconventional form has been selected to capitalise on the possibilities afforded by AM, namely the 3D printing of unconstrained concrete elements in contrast to conventional manufacturing methodologies. As you can see in Figure 24.a, each 3D-printed concrete segment is different from the others. This is because it is not necessary to produce pieces with the same shape (Asprone et al., 2018).

The final shape of the printed beam is shown in Figure 24.b. At this early stage of the work, the shape of each beam part has been made as good as possible. This has been done by using a computer to estimate the internal stress distribution for a similar arch-shaped solid concrete beam. This makes it possible to remove the concrete material from the solid beam configuration in the "ideal" way. This also makes sure that the segments are still strong and stiff enough.

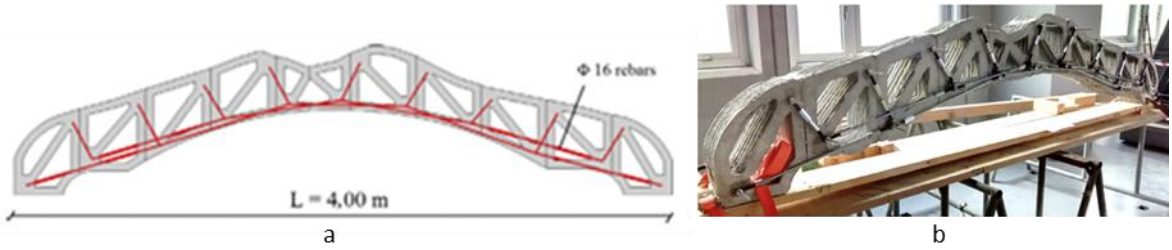


Figure 24. a) The cad design of the curved shaped truss beam, **b)** The view of the beam after printing process (Asprone et al., 2018)

c) Space Frame Production

Figure 25 shows a good way to print a concrete mould to be filled with UHPFC2, a special type of concrete. The parts between the tubes that are not used are removed afterwards, leaving only a very light, tubular, space-truss structure — in this case, a load-bearing pillar. This is called 'indirect' printing, and it shows how well concrete printing works. Although removable concrete parts can be considered printed support, Figure 25 makes no use of external support. Utilising

the same printing method (i.e. mortar extrusion directed by a 6-axis robot) and changing only the kind of outside support creates extremely divergent construction systems and achievable forms. Although direct printing does not necessitate the use of external components or assembly, multiple printing invariably involves an assembly step. In the same way, we can think of collaborative printing as including an assembly step. This is a process where external supports are added during extrusion. It is critical to point out these differences between building systems to correctly anticipate the associated complexity and technological barriers, and estimate the cost of a project. Also, you can get a good result by getting past a problem by working on the whole building system instead of making processes that are too complicated and will be hard to use on a large scale. For slipforming, the extrusion scale is usually around 1/10 of the object's size, but lower for layered extrusion (e.g. around 1/1000, as in Figures 25.a, 25.b and 25.c (R. Duballet et al., 2017). Fig. 25.c shows the structure made of two parts: the 3D-printed envelope and the core, made of conventional cast concrete. Total printing time: 15h 30m (Dirrenberger, 2019).



Figure 25. a) This is the mould for the fabrication of a space truss (XtreeE, 2016), **b)** Printed pillar location: Aix-en-Provence (XtreeE, 2016), **c)** View of school canoopy (XtreeE, 2016)

Slab Production

- **Smart Slab Formwork**

Voxeljet 3D-printed large-format formwork for the concrete casting of a smart ceiling. This was part of a research project at ETH Zurich. The project was part of the Digital Fabrication Swiss National Centre of Competence in Research (NCCR DFAB). This shows how we can create more sustainable buildings in the future. The highly complex formwork for the DFAB House research project in the NEST (Next Evolution in Sustainable Building Technologies) project of the EMPA (Swiss Federal Laboratories for Materials Science and Technology) was created by Voxeljet AG using 3D printing. This involved a 78 m² lightweight concrete slab that serves as a ceiling with a clever design. For the project, the creation of 136 formwork elements was achieved using Powder-Binder-Jetting, a 3D printing technology in which layers of silica sand are bound together with an organic binder (furan resin) through polymerisation (Voxeljet, n.d.). The VX4000 from Voxeljet is the world's largest 3D printing system for sand moulds and can print formwork elements measuring 4.00 x 2.00 x 1.00 m, with the 3D-printed elements being prefabricated by Voxeljet and infiltrated with polyester resin by ETH Zurich. These elements were then assembled into seven-metre-long formwork for the slab elements and coated with a release agent. Prior to concrete casting, application of a thin layer of fibre-

reinforced shotcrete was carried out. The struts were formed using laser-cut timber formwork, and concrete casting was used to create the structure. Consequently, the completed components were conveyed directly to the construction site and assembled there expeditiously post-stripping (Figure 26.b).

The intelligent slab constitutes a pivotal element of the DFAB House, which was conceptualised and designed by the Digital Building Technologies (DBT) research group at ETH Zurich under the direction of Prof. Dr. Benjamin Dillenburger. It shows how 3D printing can reduce construction site consumption (Figure 27.a,b). Slabs use much more concrete – up to 80% of a building's weight (Voxeljet, n.d.), so the saving potential is huge. The slab is the right weight at each point at the DFAB House. Over 60% of concrete is saved compared to conventional construction methods. 3D printing with Powder-Binder-Jetting is the ideal way to produce complex, curved formwork elements. The "Smart Slab" will help the construction industry build more compact and material-efficient structures in the future. Additional features such as lamp sockets, drill holes, and sprinkler systems can be added to the 3D printing data set.

About the project, Prof. Benjamin Dillenburger said: "There are more and more buildings being built all over the world, but we don't have enough materials to do it. We can combine the advantages of additive manufacturing in creating highly complex geometries with concrete's excellent structural capacity by 3D-printing the formwork for concrete casting. This allows us to improve the design of concrete elements and use the material more efficiently." (Voxeljet, n.d.).



a b

Figure 26. a) Highly complex, 3D printed formwork from Voxeljet (Voxeljet, n.d.), **b)** Installation of the slab elements (Voxeljet, n.d.)



a b

Figure 27. a) Top view of the flooring system of the Project, (Voxeljet, n.d.) **b)** The underside appearance of the flooring (Voxeljet, n.d.).

Staircase Production

In 2015, the Bouwbeurs 2016 trade fair in Rotterdam, the Netherlands, featured a design workshop for architects. The TU/e 3DCP production team's redesign efforts were key to the success of the workshop (see Figures 29.a and 29.b) (Bos et al., 2016). The pattern on the railing had to be changed, and a special curved print surface had to be made to get the right design. The path that the printer head follows during printing is the guiding principle in generating 3DCP geometries. Any conceivable tool path through 3D space can generally be followed by modern gantry and articulated robots, whether defined by Euclidean geometrical shapes or more complex definitions such as splines. What this also lets you do is print on any non-planar surface, as Bos and his team found out in 2016.

The reason for highlighting this issue is to set the stage for automatically generating print job files from CAD geometries, removing the need for the involvement of production and product specialists. It'd be like when you open a text processing application to print a document on paper. This is not yet a possibility in the present circumstances. Initiatives in which AMoC has been implemented have been conceived with the distinct characteristics of the production technique in mind.

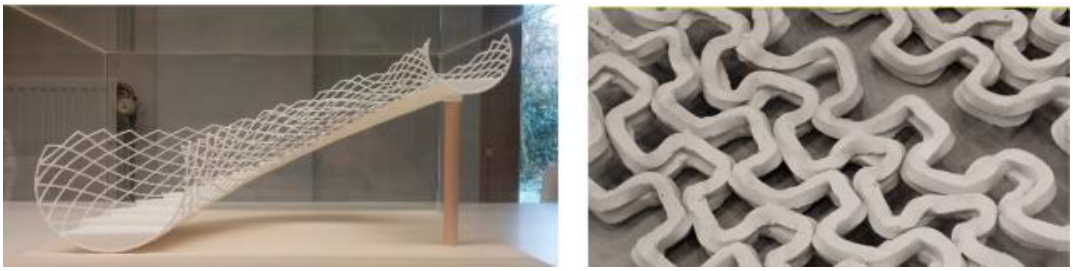


Figure 29. This is the one of the designs that was submitted to workshop, it was a staircase by BiermanHenket Architects, **a)** It is a 3D-printed scale model for this design challenge for architects back in 2015 about 3D printing concrete, **b)** A printed part of the railing (Bos et al., 2016).

Urban Furniture

İSTON has become the first company in Turkey to start producing urban furniture, such as seating, litter bins and planters, using 3D concrete printing technology. The robotic system uses mortar with a C50 concrete strength level. Products developed using ultra-high-performance

fibre-reinforced concrete offer significant material savings and greater efficiency in transportation and installation. In the garden of the Feshane Cultural Centre overlooking the sea; modern, thin-section 3D-printed white concrete seating elements and waste station boxes have been used on the grey concrete paving slabs arranged in a linear pattern, including grass-covered surfaces, creating a contrast to the building's stone masonry system (Figure 30.a). Medipol University has completed the garden landscaping design on the 4th floor with garden furniture created using 3D technology. The seating surfaces of the seating elements, which have a white concrete supporting structure, are finished with polished long wooden elements (Figure 30.b).



Figure 30. Different types of 3D printed urban elements; a) Photo from Istanbul International Feshane Exhibition and Cultural Centre (Feshane-i Amire) (Photos taken by the Author), b) Photos from the garden of İstanbul Medipol University (Photos taken by the Author)

5. Conclusion and Discussion

This study examined the production of structural elements using 3D concrete technology. The research revealed that companies and universities from various countries have collaborated to create inspiring structural elements. While some of these remain at the research and production stage, others have been used in physical buildings. Clearly, conducting 3D concrete casting studies without the support of a company is challenging. Therefore, to conduct further studies on this technology in our country, we need to set up research companies specialising in 3D concrete casting or other materials, and support these studies. The widespread sale of robots and cranes capable of large-scale production is also necessary for the development of 3D printing technology. The significant reduction in required labour and construction time, minimal material loss and advantages such as mass customisation and design flexibility for users make this construction technology attractive (Artuğ and Altun, 2019).

Considering the instances cited earlier, it's evident that 3BCP technology facilitates the creation of intricate forms (e.g. arched beams of diverse elevations), optimisation of shapes in terms of topology, minimisation of concrete volume and weight, removal of sophisticated formwork arrangements, and straightforward conveyance and assembly. 3D printing methods have reduced concrete material waste, enabled construction with fewer teams and workers in a shorter time, made it possible to produce walls and buildings in more flexible forms, and

provided concrete elements with higher tensile and flexural strength (Şahin Diri and Yıldız, 2024). Time, materials and money are all saved by 3D printing using powder-binder jetting. Ultimately, 3D-printed formwork will change the way concrete is used in construction across many different areas, including formwork, formwork skins and facades. This'll give companies a big competitive edge by letting them create unique designs.

The use of 3D printers in construction production is increasing rapidly today. The capabilities of the concrete and devices used in this technology have improved. Consequently, 3D printers are being used in an increasing number of areas, including the production of bridges, infrastructure and buildings. Interest in NASA's project tenders, private companies' designs, and researchers' work indicates that many structures and structural elements will be produced using 3D printers in the future. It is thought that the use of 3D printers in construction will increase rapidly due to the labour, moulding and material savings compared to traditional techniques.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

3ders. (n.d.). Exquisite 400 m2 villa 3D printed on-site in Beijing in just 45 days. Acceseed on: 14.06.2016 (https://www.3ders.org/articles/20160614-exquisite-400-m2-villa-3d-printed-on-site-in-beijing-in-just-45-days.html)

3dwasp. (n.d.). Concrete Beam Created Wıth 3d Prıntıng. Accessed on; 24.09.2025 (https://www.3dwasp.com/en/concrete-beam-created-with-3d-printing/)

Archdaily. (n.d.). 3D-Printed Masonry Wall: The Introduction of Digital Craftsmanship. Accessed date: 04.10.2025, https://www.archdaily.com/985574/3d-printed-masonry-wall-the-introduction-of-digital-craftsmanship

Artuğ, S., Altun, C. (2019). *3 Boyutlu Baskı Teknolojisinin Bina Üretiminde Kullanım Olanaklarının Güncel Örnekler Üzerinden İncelenmesi*, 4th International Congress On 3D Printing (Additive Manufacturing) Technologies And Digital Industry, 11-14 April, Antalya, Türkiye.

Asprone, D., Auricchio, F., Menna, C., Mercuri, V. (2018). 3D printing of reinforced concrete elements: Technology and design approach. Construction and Building Materials Journal 165, 218-231, https://doi.org/10.1016/j.conbuildmat.2018.01.018

Bak, D. (2003). "Rapid prototyping or rapid production? 3D printing processes move industry towards the latter," *Rapid Prototyping Journal*, Vol. 23, No. 4, pp. 340-345.

Bos, F., Wolfs, R., Ahmed, Z., Salet, T. (2016). Additive manufacturing of concrete in construction: potentials and challenges of 3D concrete printing. *Virtual and Physical Prototyping Journal,* Vol. 11, No. 3, 209–225, http://dx.doi.org/10.1080/17452759.2016.1209867

Buchli, J., Giftthaler, M., Kumar, N., Lussi, M., Sandy, T., Dörfler, K. & Hack, N. (2018). Digital in situ fabrication - Challenges and opportunities for robotic in situ fabrication in

architecture, construction, and beyond. *Cement and Concrete Research;* Volume 112 October 2018, Pages 66-75, https://doi.org/10.1016/j.cemconres.2018.05.013

Ching, F.D.K. and Adams, C. (2008). Çizimlerle Bina Yapım Rehberi. İstanbul; Yapı Endüstri Merkezi.

Chua, C. and Leong, K. (2014). "3D Printing and Additive Manufacturing: Principles and Applications," Fourth ed, World Scientific, Singapore.

Continuum. (n.d.1). Shanghai-based WinSun 3D Prints 6-Story Apartment Building and an Incredible Home. Acceseed on: 03.05.2016 (https://3dprint.com/38144/3d-printed-apartment-building/)

Continuum. (n.d.2). Architect Plans to 3D Print a 2-story Home in Minnesota Using a Homemade Cement Printer. Acceseed on: 03.05.2016 (https://3dprint.com/2471/3d-printed-home-in-minnesota/)

Continuum. (n.d.3). WASP Makes Progress on House 3D Printing With Modular Printed Reinforced Concrete Beams. Acceseed on: 14.06.2016 (https://3dprint.com/88467/wasp-makes-progress-on-house-3d-printing-with-modular-printed-reinforced-concrete-beams/)

Contourcrafting. (n.d.). The D-Crafter; Infrastructure Development. Accessed on: 10.09.2025, (https://www.contourcrafting.com/)

Craveiro, F., Nazarian, S., Bartolo, H., Bartolo, P.J., Duarte, J.P. (2020). An automated system for 3D printing functionally graded concrete-based materials. *Additive Manufacturing,* Volume 33, May 2020, 101146, https://doi.org/10.1016/j.addma.2020.101146

Çerçevik, A.E., Toklu, Y.C., Kandemir, S.Y. & Yaylı, M.Ö. (2018). 3B Baskı Teknolojisi Kullanarak Yapı Üretiminde Son Dönem Yenilikler. *International Journal Of 3d Printing Technologies and Digital Industry* 2:2 (2018) 116-122

Dahmen, J.F.D. and Ochsendorfs, J.A. (2012). Earth masonry structures: arches, vaults and domes. In: Hall, M.R., Lindsay, R. (Eds.), *Woodhead Publishing Series in Energy.* Woodhead Publishing, pp. 427–460 M.B.T.-M.E.B. Krayenhoff.

Dirrenberger, J. (2019). From Architectured Materials to Large-Scale Additive Manufacturing. H. Bier (ed.), Robotic Building, Springer Series in Adaptive Environments, Chapter 4, https://doi.org/10.1007/978-3-319-70866-9_4

Duballet, R., Baverela, O., & Dirrenbergerb, J. (2017). Classification of building systems for concrete 3D printing. *Journal of Automation in Construction;* 83, 247-258, https://doi.org/10.1016/j.autcon.2017.08.018

Duballet, R. (2019). Building systems in robotic extrusion of cementitious materials. Laboratoire Navier Ecole Nationale des Ponts et Chaussees CNRS, IFSTTAR; Master Thesis, Supervisors: Olivier Baverel, Justin Dirrenberger

Fahad, M., Dickens, P. and Gilbert, M. (2013). 'Novel polymeric support materials for jetting based additive manufacturing processes', *Rapid Prototyping Journal,* 19(4), pp. 230–239.

Futurist Speaker. (n.d.). Disposable Houses. Accessed on: 24.02.2018, (http://www.futuristspeaker.com/business-trends/disposable-houses/)

Gardiner, J.B. (2011). "Exploring the Emerging Design Territory of Construction 3D Printing – Project Led Architectural Research," PhD thesis, RMIT University, Australia.

Gibson, I., Rosen, D.W. and Stucker, B. (2015). "Additive manufacturing technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing," DOI 10.1007/978-1-4939-2113-3-1.

Gosselin, C., Duballet, R., Roux, P., Gaudillière, N., Dirrenberger, J., Morel, P. (2016). Large-scale 3D printing of ultra-high performance concrete–a new processing route for architects and builders. *Mater. Des.* 2016, 100, 102–109.

Hack, N., Lauer, W.V., Gramazio, F. & Kohler, M. (2014). Mesh mould: differentiation for en hanced performance. Rethinking comprehensive design: speculative counter culture, Proceedings of the 19th International Conference on Computer-Aided Architectural Design Research in Asia, CAADRIA, Kyoto, pp. 139–148 14–16 May 2014.

Hack, N. (2018). Ph.D. Thesis ETH Zurich, 2018. (In print).

Hauschid, M. (2011). "Digital processes: planning, design, production", Birkhauser, Basel.

Hull, C.W. (1986) "Apparatus for production of three-dimensional objects by stereolithography," US Patent 4575330.

Jha, K.N. (2012). "Formwork for Concrete Structures," Tata McGraw Hill Education Private Limited, New Dilhi, India. ISBN (13): 978-1-25-900733-0.

Kazemian, A., Yuan, X., Cochran, E., & Khoshnevis, B. (2017). Cementitious materials for construction-scale 3D printing: Laboratory testing of fresh printing mixture. *Constr. Build. Mater.,* 145, 639–647.

Khoshnevis, B. (2004). "Automated construction by contour crafting - related robotics and information technologies," *Automation in Construction,* Vol. 13, pp. 5–19.

Khoshnevis, B., Hwang, D., Yao, K.T. and Yeh, Z. (2006). "Mega-scale fabrication by contour crafting," *International Journal of Industrial and Systems Engineering*, Vol. 1, No. 3, pp. 301-320.

Kim, Y.Y., Kong, H.J. and Li, V.C. (2003). "Design of engineered cementitious composite suitable for wet-mixture shotcreting," *ACI Materials Journal,* Vol.100, No. 6, pp. 511-518.

Kocovic, P. (2017). "3D printing and its impact on the production of fully functional components: emerging research and opportunities", IGI Global, Hershey, Pennsylvania.

Liang, F. and Liang, Y. (2014). Study on the status quo and problems of 3D printed buildings in China. *Global Journal of Human-Social Science, 1*4 (5), 7–10.

Liu, K., Meng, Q., Kong, Q., Zhang, X. (2022). Review on the Developments of Structure, Construction Automation, and Monitoring of Intelligent Construction. *Buildings* 2022, 12, 1890.

Micallef, J. (2015). "Beginning design for 3D printing", Apress, Berkeley, CA.

Noorani, R. (2017). "3D printing : technology, applications, and selection", CRC Press, Taylor and Francis Group, Boca Raton, FL.

Paul, S.C., van Zijl, G. P.A.G., Tan, M.J., Gibson, I. (2018). A review of 3D concrete printing systems and materials properties: current status and future research prospects, *Rapid Prototyping Journal*; https://doi.org/10.1108/ RPJ-09-2016-0154

Perrot, A., Rangeard, D., Pierre, A. (2016). Structural built-up of cement-based materials used for 3D-printing extrusion techniques. *Mater. Struct.,* 49, 1213–1220.

Prieto, C. (2022). 3D-Printed Masonry Wall: The Introduction of Digital Craftsmanship

Relefors, J., Momeni, M., Pettersson, L., Hellström, E., Thunell, A., Papadopoulos, A.V., Nolte, T. (2019). Towards Automated Instal lation of Reinforcement Using Industrial Robots. In Proceedings of the 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), Zaragoza, Spain, 10–13 September 2019; pp. 1595–1598.

Stansbury, J. W. and Idacavage, M. J. (2016). '3D printing with polymers: Challenges among expanding options and opportunities', *Dental Materials,* 32(1), pp. 54–64.

Strano, G., Hao, L., Everson, R. M. and Evans, K. E. (2013). 'A new approach to the design and optimisation of support structures in additive manufacturing', *The International Journal of Advanced Manufacturing Technology*, 66(9–12), pp. 1247–1254.

Strauss, H. (2016). "Am envelope: the potential of additive manufacturing for facade constructions", Doktora Tezi, Delft University of Technology, Delft.

Şahin Diri, B. & Yıldız, S. (2024). 3 boyutlu yazıcılarla yapı üretimi; betonarme duvarlı bina örnekleri ve öneri geliştirilmesi. *Journal of International Architectural Sciences.* 1 (1): 12-36.

Tay, Y.W.D., Panda, B., Paul, S.C., Noor Mohamed, N.A., Tan, M.J., Leong, K.F. (2017). 3D printing trends in building and construction industry: *A Review.* Virtual Phys. Prototyp. 2017, 12, 261–276.

Tay, Y.W.D., Li, M.Y., Tan, M.J. (2019). Effect of printing parameters in 3D concrete printing: printing region and support structures. *Journal of Materials Processing Tech*. (2019), https://doi.org/10.1016/j.jmatprotec.2019.04.007

Taylor, M. Wamuziri, S. and Smith, I. (2003). "Automated construction in Japan," Proceedings of the Institution of Civil - *Civil Engineering,* Vol 156, Iss 1, pp. 34-41.

Van Zijl, G.P.A.G., Paul, S.C. and Tan, M.J. (2016) "Properties of 3D printable concrete," In Proceeding for 2nd International Conference on Progress in Additive Manufacturing (Pro-AM), Singapore, pp. 421-426. 54. Shanghai-based WinSun 3D Prints 6-Story Apartment Building and an Incredible Home, access on 3rd May 2016.

Vertico. (n.d.). Hybrid 3D Printing & Milling for Acoustic Façades. Accessed date: (04.10.2025), https://www.vertico.com/projects/acoustic-facades

Voxeljet. (n.d.). The advantages of 3Dprinting of formworkare proven once again. Acces: (02.10.ş2025) https://www.voxeljet.com/additive-manufacturing/case-studies/architecture/intelligent-3d-printed-concrete-formwork/

Wakisaka, T., Furuya, N., Inoue, Y. and Shiokawa, T. (2000). "Automated construction system for high rise reinforced concrete buildings," *Automation in Construction,* Vol. 9, pp. 229-250.

Yahia, A., Mantellato, S., Flatt, R.J. (2015). Concrete rheology: a basis for understanding chemical admixtures, *Science and Technology of Concrete Admixture*s, Elsevier.

Zhang, X., Li, M., Lim, J. H., Weng, Y., Tay, Y. W. D., Pham, H. and Pham, Q.-C. (2018). 'Large-scale 3D printing by a team of mobile robots', *Automation in Construction*, 95, pp. 98–106.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Comparison of Survey Results on the Use of External Wall Filling Materials and the Usage Trends of These Materials in the Construction Sector in Turkey

Berrin ŞAHİN DİRİ [1*]

ORCID: 0009-0009-6436-2549
[1]Assist. Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, İstanbul-Türkiye
berrinsahindiri@outlook.com **(**Responsible Author)

Ahmet Cüneyd DİRİ [2]

ORCID 1: 0000-0001-8122-9568
[2] Assoc. Prof. Dr., Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, İstanbul-Türkiye
acdiri@gmail.com

Abstract

Building designers and builders face material selection challenges at every stage of construction, and there's often no single, definitive criterion for selecting materials. Therefore, professionals often have to consider numerous factors when selecting materials. One of the key stages of material selection in construction is the selection of the wall system and materials. Today, curtain wall systems, panel systems, or infill wall systems constructed using adhesive mortar are used for the exterior walls of buildings. This study compared the most commonly used wall infill materials, such as brick, aerated concrete, and briquette, according to the performance criteria expected from exterior walls. For this purpose, a survey was conducted with the participation of building designers, building manufacturers, and academics. The survey evaluated and scored exterior wall performance criteria. Next, a comparison of brick, aerated concrete, and briquette was conducted using the AHP (Analytical Hierarchical Process) method. The six exterior wall performance criteria receiving the highest importance in the survey were considered in the comparison. Finally, the production and sales volumes of these materials in the construction industry were examined and compared with the selection preferences obtained from the AHP.

Keywords: Wall infill materials, material selection criteria, AHP method, material production volumes

1. Introduction

Today, sandwich wall systems, prefabricated lightweight panel systems, ightweight concrete infill or insulated precast panels, lightweight steel or aluminum curtain wall systems, or infill walls constructed using the masonry method are used on the exterior facades of builAings with reinforced concrete frame load-bearing systems.

This study examined non-load-bearing infill walls constructed using the masonry method using adhesive mortar. In the first phase, the most commonly used infill materials in these types of walls, such as brick, aerated concrete, and briquette, were compared using a survey and AHP (*Analytical Hierarchical Process*). This comparison was based on the expected properties of exterior walls and the extent to which the materials considered met these properties. Finally, the participants' preferences were compared with the production and sales volumes of these materials in Turkey.

Materials Considered, Definition, and Properties

Brick

Brick is produced by firing clay. It is a more natural material than aerated concrete and briquettes. Types include blended brick, factory brick, solid brick, and perforated brick. It is a Class A fireproof material. Its properties and types are defined in the TS EN 771-1 standard.

Bricks produced in Turkey are classified as A-quality, B-quality, and regular bricks. Class A and B bricks are produced by firing at controlled high temperatures. Class A and B bricks are more homogeneous and lighter, have lower thermal conductivity, tighter tolerances, and higher dimensional stability. Class A bricks can also be used in load-bearing wall construction. According to data from the Turkish Statistical Institute, as of 2024, there were 162 brick companies operating in Turkey (TUIK, 2024).

Aerated Concrete

Aerated concrete is a new material compared to brick. Production in Turkey began in 1965 at a facility established in Istanbul under the name Türk Ytong Sanayi A.Ş. (*Turkish Ytong Sanayi A.Ş.*). Since the 1980s, new factories have been established in various provinces, and its production has expanded. It is produced from a mixture of materials such as siliceous sand, lime, and cement. It is a Class A fireproof material. It has a porous internal structure and is notable for its low thermal conductivity and light weight. It is a breathable material, but it is also water-absorbent. It is easy to cut Easy to cut. Aerated concrete allows for a smooth wall surface, eliminating the need for a thick layer of plaster. Its compressive strength is relatively low. Because its surface strength is also low, special dowels are required for anchored connections applied to facades. According to data from the Turkish Statistical Institute, as of 2024, there were eight aerated concrete companies operating in Turkey. (TUIK, 2024)

Briquette

Briquettes are concrete-based structural elements produced from a mixture of cement, sand, and lightweight aggregate. They cure in the open air. They are a Class A fireproof material. They are also known internationally as prefabricated concrete blocks or pumice blocks. Natural pumice, a type of volcanic rock, is used as lightweight aggregate in their production, and slag, a waste product of metal separation, is used in metal separation. Because they can be recycled, they are a sustainable material. They have various uses beyond wall construction. Today, mass production can be achieved at low cost with automated machinery. According to data from the Turkish Statistical Institute, as of 2024, there were 112 briquette companies operating in Turkey. (TUIK, 2024)

Survey and AHP

The survey and AHP study were conducted based on material selection criteria for brick, aerated concrete, and briquette. Criteria affecting wall material selection include building physics, building biology, and building statics, material and labor costs, ease of access to materials, ease of construction, dimensional properties, aesthetics, environmental impacts, and sustainability.

2. Findings and Discussion

In this phase of the study, a survey was conducted with the participation of a group of building designers, building manufacturers, and academics. The survey included 140 participants, with an average age of approximately 50. Participants were given the following criteria and asked to rate them based on their importance in selecting exterior wall infill materials.

Thermal conductivity	Lightness
Vapor permeability	Cost
Water permeability/water absorbency	Environmental impacts
Sound transmission loss	Building biology/health

Earthquake resistance	Dimensional stability/surface smoothness
Fire resistance	Ease of construction
Specific heat/heat capacity	Ease of access/transportation

The criteria's resulting scores were converted to percentage weights and ranked from largest to smallest. The resulting percentage values and their columnar graph are shown in Table 1 and Figure 1, respectively.

Table 1. Percentage values obtained from the survey results (Created by authors)

Thermal conductivity	% 16.3
Cost	% 14.2
Earthquake resistance	% 12.6
Fire resistance	% 12.4
Sound transmission loss	% 10.9
Environmental impacts	% 09.8
Water permeability/water absorbency	% 05.7
Vapor permeability	% 04.8
Lightness	% 04.0
Ease of construction	% 03.2
Specific heat/heat capacity	% 02.1
Ease of access/transportation	% 01.6
Building biology/health	% 01.2
Dimensional stability/surface smoothness	% 01.2

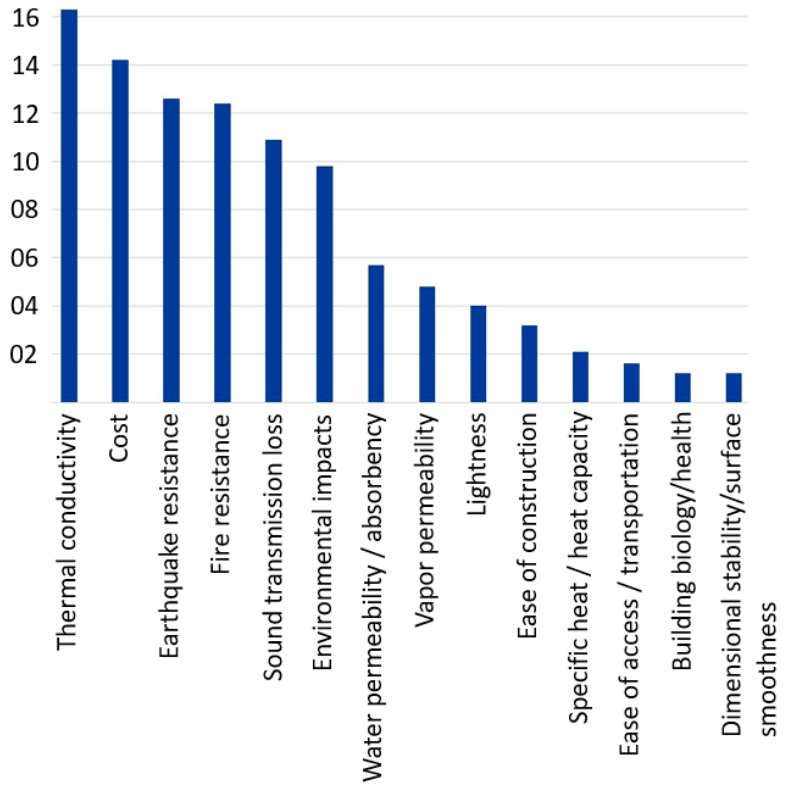


Figure 1. Columnar graph of percentage values of criteria (created by authors)

Looking at Figure 1, it can be seen that among the 14 criteria, the total weight of the first six criteria exceeds 75%, and the gap widens after the 6th criterion. These six criteria were taken into account in the AHP. These criteria are as follows, respectively:

1- Thermal conductivity	3- Earthquake resistance	5- Sound transmission loss
2- Cost	4- Fire resistance	6- Environmental impacts

Application of the AHP Method

The AHP (analytical hierarchical process) method, which began to be used in the late 20th century, facilitates choosing among multiple alternatives in multi-criteria and multi-objective decision-making situations.

This method can be used to compare and scale alternatives in complex decision-making processes involving multiple criteria. The method allows for the combined evaluation of qualitative and quantitative data.

In this method, complex decision-making processes are broken down into simpler components and evaluated through pairwise comparisons within a hierarchical structure. During the evaluations, criteria and alternatives are quantified using importance weights, and the most suitable alternative is determined through matrix calculations. Table 2 shows the AHP evaluation scale.

In summary, the process proceeds as follows: establishing the hierarchy, performing pairwise comparisons, calculating weights, finding the most suitable alternative, and conducting consistency analysis.

Table 2. AHP rating scale (created by authors)

Level of importance	Definition
1	Equally important
3	Moderately important
5	Highly important
7	Extremely important
2,4,6	İntermediate values

Firstly, the numerical values of brick, aerated concrete, and briquette corresponding to the six criteria mentioned above were determined for comparison using the AHP method.

According to TS 825 Annex E / 7.1.3.1, the numerical values, in accordance with the relevant criteria, exhibited by walls constructed with class A and B bricks compliant with the TS EN 771-1 “Masonry Units – Specifications – Part 1: Clay masonry units (*bricks*)” standard, using normal mortar, are given in Table 3. (TS 825, 2025), (TS EN 771-1, 2015)

According to TS 825 Annex E / 7.3.2, the numerical values, in accordance with the relevant criteria, exhibited by walls constructed with blocks compliant with the TS EN 771-4 “Masonry Units — Part 4: Aerated concrete masonry units (*AAC blocks*)” standard, laid with normal joint thickness and normal mortar, are given in Table 4. (TS 825, 2025), (TS EN 771-4, 2015)

According to TS 825 Annex E / 7.5.1.1, the numerical values, in accordance with the relevant criteria, exhibited by walls constructed with lightweight concrete blocks with holes compliant

with the TS EN 771-3 "Masonry Units – Specifications – Part 3: Concrete masonry units (*dense and lightweight aggregates*)" standard, are given in Table 5. (TS 825, 2025), (TS EN 771-3, 2015)

Carbon dioxide equivalent release per m^3 was used as the numerical value for environmental impact, and specific strength was used as the numerical value for earthquake resistance. The comparison of the numerical values of the materials according to the criteria is given in Table 6.

Table 3. Numerical values of walls built with A, B class bricks according to the criteria (TS 825, 2025; TS EN 771-1, 2015; Greenhouse, 2024; TUIK)

Thermal conductivity	:	$\lambda = 0.38 – 0.39$ W/mK
Unit volume weight	:	$\Delta = 750 – 800$ kg/m^3
Compressive strength	:	$\sigma = 8 – 10$ MPa => [N/mm^2]
Specific strength	:	$\sigma_s = 10.7 – 12.5$ kJ/kg
Fire resistance	:	T = 3 – 4 hours (*20 cm thickness*)
Sound transmission loss	:	$R_w \approx 51$ dB (*20 cm thickness*)
Carbon footprint	:	$W_c \approx 180$ kgCO_2eq/m^3
Current price	:	F ≈ 560 TL/m^2 (*20 cm thickness*)

Table 4. Numerical values of walls made of aerated concrete blocks according to the criteria (TS 825, 2025; TS EN 771-1, 2015; Greenhouse, 2024; TUIK)

Thermal conductivity	:	$\lambda = 0.23 – 0.24$ W/mK
Unit volume weight	:	$\Delta = 550 – 600$ kg/m^3
Compressive strength	:	$\sigma = 3 – 4$ MPa => [N/mm^2]
Specific strength	:	$\sigma_s = 6.5 – 7.2$ kJ/kg
Fire resistance	:	T = 3 – 4 hours (*20 cm thickness*)
Sound transmission loss	:	$R_w \approx 48$ dB (*20 cm thickness*)
Carbon footprint	:	$W_c \approx 250$ kgCO_2e/m^3
Current price	:	F ≈ 1050 TL/m^2 (*20 cm thickness*)

Table 5. Numerical values of walls made of lightweight concrete blocks with holes according to the criteria (TS 825, 2025; TS EN 771-1, 2015; Greenhouse, 2024; TUIK)

Thermal conductivity	:	$\lambda = 0.36 – 0.41$ W/mK
Unit volume weight	:	$\Delta = 700 – 800$ kg/m^3
Compressive strength	:	$\sigma = 6.5 – 7.5$ MPa => [N/mm^2]
Specific strength	:	$\sigma_s = 9.3 – 9.4$ kJ/kg
Fire resistance	:	T = 2 – 3 hours (*20 cm thickness*)
Sound transmission loss	:	$R_w \approx 50$ dB (*20 cm thickness*)
Carbon footprint	:	$W_c \approx 200$ kgCO_2e/m^3
Current price	:	F ≈ 300 TL/m^2 (*20 cm thickness*)

Table 6. Comparison of numerical values of materials according to criteria (Created by authors)

	Brick	Aerated concrete	Briquette
Thermal conductivity	Moderate ●●●○○ 0.38 – 0.39 W/mK	High ●●●●● 0.23 – 0.24 W/mK	Moderate ●●●○○ 0.36 – 0.41 W/mK
Cost (*20 cm thickness*)	Moderate-low ●●●●○ ≈ 560 TL/m^2	Moderate-high ●●○○○ ≈ 1050 TL/m^2	Low ●●●●● ≈ 300 TL/m^2
Specific strength	High ●●●●● 10.7 – 12.5 kJ/kg	Moderate ●●●○○ 6.5 – 7.2 kJ/kg	Moderate-high ●●●●○ 9.3 – 9.4 kJ/kg
Fire resistance (*20 cm thickness*)	High ●●●●● 3-4 hours	High ●●●●● 2-4 hours	Moderate-high ●●●●○ 2-3 hours
Sound transmission loss (*20 cm thickness*)	High ●●●●● ≈ 51 dB	Moderate-low ●●○○○ ≈ 48 dB	Moderate-high ●●●●○ ≈ 50 dB
Carbon footprint	Moderate-low ●●●●○ ≈ 180 $kgCO_2eq/m^3$	Moderate-high ●●○○○ ≈ 250 $kgCO_2e/m^3$	Moderate ●●●○○ ≈ 200 $kgCO_2e/m^3$

Then, pairwise comparison matrices were created. The pairwise comparison matrix of the criteria is given in Table 7, and the pairwise comparison matrices of the materials according to the criteria are given in Table 8.

Table 7. Pairwise comparison matrix of criteria (Created by authors)

Criteria	Thermal cond.	Cost	Spec. strength	Fire resistance	Sound tr. loss	C. footprint
Thermal conductivity	1	2	3	4	4	5
Cost	1/2	1	2	3	3	4
Specific strength	1/3	1/2	1	2	2	3
Fire resistance	1/4	1/3	1/2	1	1	2
Sound transmission loss	1/4	1/3	1/2	1	1	2
Carbon footprint	1/5	1/4	1/3	1/2	1/2	1

Table 8. Pairwise comparison matrices of materials according to criteria (Created by authors)

Thermal cond.	Brick	Aer. conc.	Briquette
Brick	1	1/3	1
Aerated concrete	3	1	3
Briquette	1	1/3	1

Cost	Brick	Aer. conc.	Briquette
Brick	1	3	1/2
Aerated concrete	1/3	1	1/4
Briquette	2	4	1

Spesifik dayanım	Brick	Aer. conc.	Briquette
Tuğla	1	3	2
Aerated concrete	1/3	1	1/2
Briquette	1/2	2	1

Fire resistance	Brick	Aer. conc.	Briquette
Brick	1	1	2
Aerated concrete	1	1	2
Briquette	1/2	1/2	1

Sound trans. loss	Brick	Aer. conc.	Briquette
Brick	1	4	2
Aerated concrete	1/4	1	1/3
Briquette	1/2	3	1

Carbon footprint	Brick	Aer. conc.	Briquette
Brick	1	3	2
Aerated concrete	1/3	1	1/2
Briquette	1/2	2	1

The normalized eigenvectors of the matrices given in Table – 7 and Table – 8 were found and from here the weight matrix of the criteria and the weight matrix of the materials according to the criteria were created (*Table 9 and Table 10*).

Table 9. Weight matrix of criteria (Created by authors)

Criteria	Weights
Thermal conductivity	0.3657
Cost	0.2311
Specific strength	0.1357
Fire resistance	0.1357
Sound transmission loss	0.0803
Carbon footprint	0.0515

Table 10. Weight matrix of materials according to criteria (Created by authors)

Criteria	Materials =>	Brick	Aer. Concrete	Briquette
Thermal conductivity		0.2000	0.6000	0.2000
Cost		0.3196	0.1220	0.5584
Specific strength		0.5278	0.1396	0.3325
Fire resistance		0.4000	0.4000	0.2000
Sound transmission loss		0.5584	0.1220	0.3196
Carbon footprint		0.5396	0.1634	0.2970

The general weight matrix of the materials was found by multiplying these two matrices (*Table 11*).

Table 11. Percentage weight matrix of materials (Created by authors)

Material	Percentage weight
Brick	% 34.55
Aerated concrete	% 33.90
Briquette	% 31.54

Consistency analysis

In the consistency analysis, the consistency rate was determined and checked to see if it was below 10%. The consistency rate is the ratio of the consistency index to the random consistency index (*CR = CI / RI*).

To find the consistency index, the maximum eigenvalue (λ_{max}) was first calculated using the formula λ_{max} = avg (*C.w/w*). (*C => comparison matrix, w => weight vector*). Then, the consistency index (*CI*) was calculated using the formula CI = (λ_{max} - n) / (n-1). The random consistency index (*RI*) was taken from Saaty's table.

$$C = \begin{vmatrix} 1 & 2 & 3 & 3 & 4 & 5 \\ 1/2 & 1 & 2 & 2 & 3 & 4 \\ 1/2 & 1 & 2 & 2 & 3 & 4 \\ 1/3 & 1/2 & 1 & 1 & 2 & 3 \\ 1/4 & 1/3 & 1/2 & 1/2 & 1 & 2 \\ 1/5 & 1/4 & 1/3 & 1/3 & 1/2 & 1 \end{vmatrix} \quad w = \begin{vmatrix} 0.3657 \\ 0.2311 \\ 0.1357 \\ 0.1357 \\ 0.0803 \\ 0.0515 \end{vmatrix}$$

$$C.w = \begin{vmatrix} 2.2208 \\ 1.4037 \\ 0.8240 \\ 0.8240 \\ 0.4875 \\ 0.3130 \end{vmatrix} \quad C.w/w = \begin{vmatrix} 2.2208 / 0.3657 \\ 1.4037 / 0.2311 \\ 0.8240 / 0.1357 \\ 0.8240 / 0.1357 \\ 0.4875 / 0.0803 \\ 0.3130 / 0.0515 \end{vmatrix}$$

Maximum eigenvalue => λ_{max} = avg (C.w/w) = 6.0732

Consistency index => CI = (λ_{max} - n) / (n-1) = 0.0146

Random consistency index => RI = 1.24 (*6x6 matris için*)

Consistency rate => CR = 0.0146 / 1.24 ≈ 0.012 => % 1.2 (*is within the acceptable range*)

Production volumes of materials in Turkey

According to data from the Turkish Statistical Institute, brick, aerated concrete, and briquette are ahead of brick in Turkey in terms of number of companies and production volume. Based on data obtained from the material production indicators in the 2024 Construction Materials Sector Report of the İMSAD (*Construction Materials Industrialists' Association*), the annual production quantities of brick, aerated concrete, and briquette in tonnes are presented in Table 12, and the production quantities in m^3 are presented in Table 13. Graphical representations of these tables are also provided in Figure 2 and Figure 3.

Table 12. Production quantities of bricks, aerated concrete and briquettes in Türkiye in tonnes by year (İMSAD 2024 report)

	Brick	Aer. Concrete	Briquette
2019	18.367.500	1.259.446	5.026.711
2020	16.281.975	1.732.294	6.690.690
2021	15.492.250	2.205.141	7.125.327
2022	13.507.475	2.270.424	6.742.349
2023	15.965.000	1.911.698	8.594.352
2024	16.444.725	2.002.649	9.449.724

Table 13. Production quantities of bricks, aerated concrete and briquettes in Türkiye in m^3 by year (İMSAD 2024 report)

	Brick	Aer. Concrete	Briquette
2019	23700000	2190341	6702281
2020	21009000	3012685	8920920
2021	19990000	3835028	9500436
2022	17429000	3978563	8989799
2023	20600000	3324692	11459136
2024	21219000	3482868	12599632

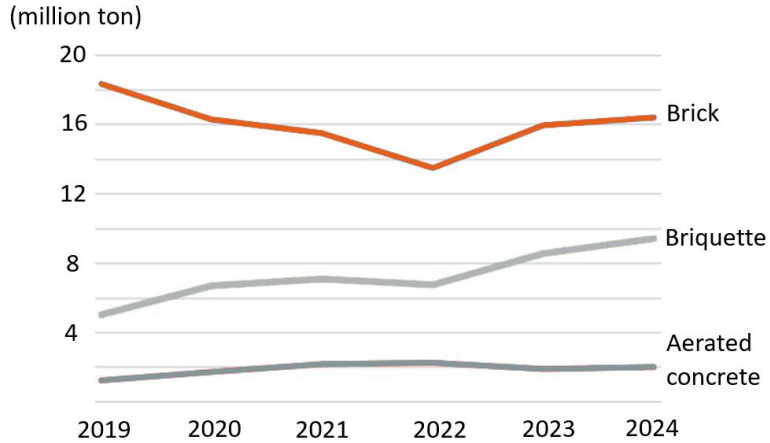


Figure 2. Production quantities of bricks, aer. concrete and briquettes in Türkiye in tonnes by year (İMSAD 2024 report)

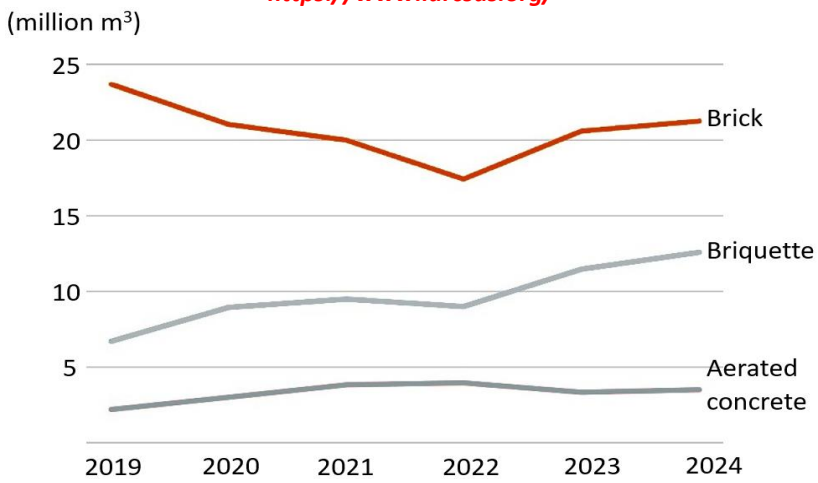


Figure 3. Production quantities of bricks, aerated concrete and briquettes in Turkey in m^3 by year (İMSAD 2024 report)

According to Table 12 and Table 13, between 2019 and 2024, the most produced material was brick, with a total of approximately 96 million tons (*124 million m^3*). Briquettes came in second with approximately 44 million tons (*58 million m^3*), and aerated concrete came in third with approximately 11 million tons (*20 million m^3*).

3. Conclusion and Recommendations

In this study, a survey was conducted with professionals and academics in the Turkish construction sector. The survey identified the criteria that participants considered important regarding exterior walls and ranked them by significance. Using the AHP method, brick, autoclaved aerated concrete (AAC), and briquettes were compared based on these criteria. In this comparison, brick's advantages were its environmental friendliness, strength, and sound attenuation. Aerated concrete's advantages were its low thermal conductivity and light weight. Cost, while an advantage for bricks, was a disadvantage for aerated concrete.

In the AHP, the relative importance of materials in pairwise comparisons was determined based on the numerical values of the materials according to the criteria. The AHP result was determined by the importance ranking of the criteria based on the scoring in the survey, and the numerical values of the materials according to the criteria. The fact that the thermal insulation criterion ranked first in the ranking of importance among the criteria gave a significant advantage to aerated concrete. However, brick ranked first among the alternatives, albeit by a small margin, due to the positive impact of the other criteria. The fact that the cost criterion surpassed all other criteria except thermal insulation also gave the brick a significant advantage. However, the brick ranked last among the alternatives, due to the negative impact of the other criteria.

When examining the annual production volumes of materials in Turkey, two differences emerge from the rankings resulting from the survey and AHP.

1 – Brick production volume far exceeds the production volumes of the other two materials.

2 – While aerated concrete (AAC) ranks second and brick last in the rankings resulting from the AHP, between 2019 and 2024, bricks ranked second and aerated concrete last in terms of production volumes in Turkey.

Tables 12 and 13 show that brick production per ton and m^3 between 2019 and 2024 exceeded the combined production of aerated concrete and briquettes. This indicates that, in the eyes of buyers, brick, as a traditional material, continues to maintain its priority as a wall material.

The reasons for the higher production of bricks compared to aerated concrete include the fact that, in addition to wall construction, they also have applications such as industrial and infrastructure applications, landscaping and environmental planning applications, agricultural and rural applications, and the higher costs of materials, energy, fuel, and labor in the production of aerated concrete. Consequently, this is reflected in the sales price, leading buyers to prefer lower-cost bricks on construction sites where cost is a priority.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Greenhouse Gas Emission Statistics, 2024

İMSAD 2024 report, 2024

TS 825. "Thermal Insulation Rules in Buildings", 2025

TS EN 771 1. (2015). "Masonry Units – Properties – Part 1: Clay masonry units (*bricks*)", 2015

TS EN 771-3. (2015). "Masonry Units – Properties – Part 3: Concrete masonry units (*dense and lightweight aggregate*)", 2015

TS EN 771 4 (2015). "Masonry Units — Part 4: Aerated concrete masonry units (*AAC blocks*)", 2015

TUIK. (2024). Turkish Statistical Institute data portal.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Eye Tracking Technology into the Urban Green Space Planning

Murat YEŞİL [1]

ORCID 1: 0000-0002-3643-5626
[1]Prof. Dr., Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
muratyesil@odu.edu.tr

Mesut GÜZEL [2*]

ORCID 2: 0000-0001-6172-5812
[2]Asst. Prof. Dr., Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
* mesutguzel@odu.edu.tr (Responsible Author)

Rabia Nurefşan AÇIKGÖZ [3]

ORCID 3: 0009-0002-1722-023X
[2]Research Assistant, Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
rabiakarabork9@gmail.com

Eda ŞENTÜRK [4]

ORCID 4: 0009-0002-4888-7037
[2]Graduate Student, Ordu University, Institute of Science, Department of Landscape Architecture, Ordu-Türkiye
edasenturk653@gmail.com

Abstract

Urban green spaces are essential urban components for sustainable and livable environments. These areas, which are important recreational spots in cities, are known to provide numerous ecosystem services. The visual quality of the natural and cultural landscape elements within urban green spaces shapes people's aesthetic evaluations of the landscape and determines their spatial usage preferences. Analyzing user preferences and expectations using scientific methods is a crucial input for urban green space planning processes. At this point, eye tracking technology comes to the fore as an alternative to traditional data collection methods. This study examines the integration of eye-tracking technology into the urban planning using the case of Tayfun Gürsoy Park in Ordu. Data were collected using a visual questionnaire and an eye-tracking application. The Green View Index values of 20 photographs were evaluated, along with the responses of questionnaire participants to seven landscape assessment variables and the relationship between the variables obtained through the eye-tracking application. The findings showed that as the proportion of greenery increases, people describe the view as more beautiful, their desire to stay in the space increases, and they tend to perceive the variety of colors and plant presence as sufficient. There were significant differences between landscape architecture students and other participants in terms of the number of fixations, total fixation time, average fixation time, and time to first fixation. This study demonstrates the importance of supporting a participatory approach with up-to-date technological tools in establishing urban green spaces with high visual quality.

Keywords: Eye tracking technology, urban green space, urban planning, green view index, visual quality

1. Introduction

The impact of urbanization is increasing worldwide. This impact is expected to grow exponentially in the future. According to the United Nations (2018), 55% of the global population currently lives in urban areas, and this percentage is expected to reach 68% by 2050. Although cities are centers of economic growth and innovation, this rapid development often leads to numerous problems, ranging from social injustices and limited access to services to air and water pollution, the urban heat island effect, and threats to public health and quality of life

(Knox & McCarthy, 2012; Kumakoshi, 2020; Yu et al., 2020). At this point, urban green spaces, which are important components of urban ecosystems, play a role in carbon sequestration and oxygen release into the atmosphere (Escobedo & Nowak, 2009; Shadman et al., 2022), the absorption of air, water, and soil pollutants (Baycan et al., 2012; Dadvand et al., 2015), absorbing noise, regulating climate (Nowak & Crane, 2002), and supporting urban biodiversity (Kong et al., 2010). Additionally, according to the World Health Organization, urban green spaces and nature-based solutions contribute to sustainable urban development, increase resilience, promote healthy lifestyles, and improve physical and mental well-being.

Urban green spaces, which are located outside the city's built structures and allow nature and greenery to be incorporated into the city, provide inviting and relaxing areas where city dwellers can experience nature (Tyrväinen & Miettinen, 2000; Li et al., 2020). These areas significantly shape perceptions of the urban environment, and the qualified and holistic planning of other structural elements that make up the landscape, such as lighting elements, seating elements, canopy elements, plastic elements, and water surfaces, contributes to urban aesthetics, visual perception, and urban identity. Visually high-quality and holistically designed urban green spaces create an environment conducive to active and passive recreational activities and provide an infrastructure that supports social and cultural events (Haase, 2022; Jabbar et al., 2022). These areas not only encourage physical interaction or provide places to relax, but also strengthen residents' sense of belonging and attachment to their city (Peschardt & Stigsdotter, 2013; Jennings et al., 2016). Recent studies show that residents tend to prefer natural landscapes such as parks, river and sea belts, and other vegetated areas over built environments (Franěk, 2023; Visintin et al., 2025).

In urban areas where land competition threatens the existence of green spaces, it is important to determine the quality of the existing landscape and improve it to meet the needs of residents (Zhang & Zeng, 2024). Regulating and planning the visual and functional quality and quantity of urban green spaces involves a collaborative process involving design and implementation professionals, such as local governments, landscape architects, architects, and urban planners, as well as citizens who use these spaces (Casprini et al., 2023; Romero-Muñoz et al., 2024; Li et al., 2025). Traditional approaches such as suggestions, complaints, and satisfaction surveys exist to ensure citizen participation in these areas. However, these practices can yield misleading results that are susceptible to manipulation, largely due to people's momentary emotional changes, anxiety and pressure in answering questions, etc. Therefore, it is crucial to adopt an objective, quantitative, repeatable, and transparent methodology through technology to effectively evaluate urban green spaces and integrate citizens' demands and expectations into planning processes (Kiss et al., 2022; Beriguete et al., 2024).

Eye tracking technologies have emerged as powerful tools that complement traditional survey applications in aesthetic perception studies. Eye movements are a direct means by which individuals acquire and process information from their surroundings. Various eye tracking technologies provide objective ways to record and analyze these movements, revealing the relationships between visual attention, scene perception, and environmental cognition. Research has shown that eye fixations and eye movements such as pupil index are related to attention and relaxation (Li et al., 2022; Sankar et al., 2025). Additionally, studies using eye-tracking technologies have investigated spatial familiarity, landscape preferences, differences in visual attention and engagement between natural and urban scenes, and viewing patterns in response to landscape complexity (Wu et al., 2021; Sugano et al., 2022; Evans & Chamberlain, 2024; Fleming et al., 2024).

This study is based on the initial findings of the project titled "An Innovative Approach to Urban Green Space Planning: Eye Tracking Technology," conducted under the TÜBİTAK 3005 Innovative Solutions in Social Sciences and Humanities Research Projects Funding Program. The study was conducted at Tayfun Gürsoy Park, one of the coastal parks located in the city center of Ordu, which features various landscape elements and attracts a high volume of visitors. Essentially, the study aims to integrate the visual perceptions of city residents into the urban green space planning process through eye-tracking technology, in addition to the traditional survey method. It seeks to determine the visual quality of urban green spaces, encourage the spread of features that enhance visual quality to other arrangements in the city, and develop recommendations for improving areas perceived as having poor visual quality.

2. Materials and Methods

The study area, Tayfun Gürsoy Park, is located in the Bahçelievler Neighborhood in the center of Altınordu District, Ordu Province, on the Black Sea coast (Figure 1). The total area of the park is approximately 8.5 ha, and its linear length along the coast is approximately 1.290 m. The park, which is one of the important recreational center for the residents of Ordu, offers various recreational facilities such as bicycle and running ways, playgrounds, cafes, car parking areas, and sports facilities (Civelek & Yeşil, 2024).

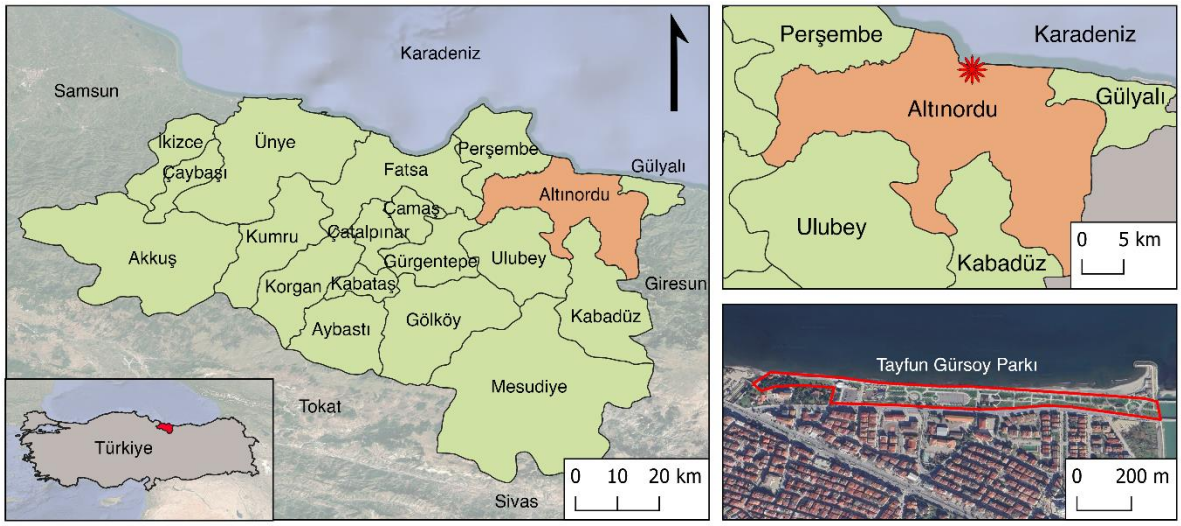


Figure 1. Location of the study area

A seven-stage method was followed in the study (Figure 2). First, photographs to be used in the eye-tracking and survey applications were taken. The Green View Index (GVI) values of all photographs were then calculated, and the photographs to be evaluated were selected. These photographs were then segmented according to landscape elements, and the proportions of these elements in the photographs were calculated. Participant characteristics were determined for the eye-tracking and survey applications, and the eye-tracking and survey applications were conducted. Finally, all data obtained in the study were analyzed using statistical methods, and the findings were evaluated.

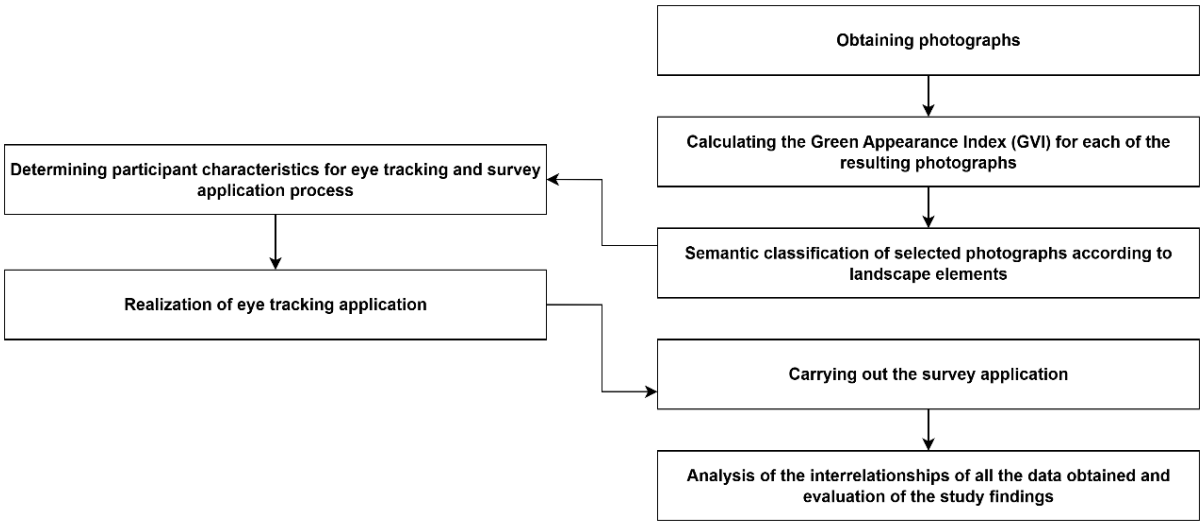


Figure 2. Methodology of the study

The photographs shown to participants in the eye-tracking and survey applications were taken at Tayfun Gürsoy Park between 8:00 and 10:00 a.m. on August 12, 2024, using a Nikon D5300 digital camera and a 67 mm lens. A tripod, set at 1.7 m, was used to stabilize the camera to ensure a standard viewing height for all photographs. All photographs were taken at a resolution of 6000x4000 pixels. A total of 616 photographs were obtained from the park, each containing at least one landscape element such as urban amenities, recreational areas, or water surfaces.

Then, the GVI values of all photographs were calculated. GVI is a parameter that measures the perceived greenness of landscapes from a human perspective. The index is obtained by multiplying the ratio of the number of green pixels corresponding to vegetation in an image to the total number of pixels in the image by 100. This method, first developed by Yang et al. (2009), was later used in many studies at the scale of urban green spaces (Wu et al., 2020; Ki and Lee, 2021).

$$GVI = \frac{Number\ of\ green\ pixels}{Total\ number\ of\ pixels} \times 100$$

After obtaining the GVI values for the photographs, the photographs were divided into four categories (0-25%, 26-50%, 51-75%, and 76-100%) based on their GVI values. Five photographs were selected from each categories using stratified random sampling, reducing the total of 616 photographs to 20. Using the smart selection tools in Adobe Photoshop CC 2014, the photographs were divided into six categories: trees, shrubs, herbaceous plants, hardscape, water surface, and other elements (urban fixtures, signs/panels/banners, fountains, etc.), and the proportions of these landscape elements in the photographs were calculated.

Certain criteria were sought in the selection of volunteers to participate in eye tracking and survey applications. The basic conditions were determined as the participants not wearing glasses, not having color blindness, normal blinking frequency, and not having excessive watery eyes. Additionally, attention was paid to the fact that the participants were healthy individuals between the ages of 18-40 and had lived in the city of Ordu for at least five years. For the applications, an environment isolated from distracting sounds and images was created at the Department of Landscape Architecture, Faculty of Agriculture, Ordu University. Gazepoint GP3 device was used for the eye-tracking application. The device was placed below

the 23.7 inch monitor, and the participants' eye calibrations were provided simultaneously with the monitor using the Gazepoint Analysis UX Edition software on the laptop (Figure 3). During the application, 20 selected photographs were projected on the monitor in random order for 10 seconds and data for a total of 4 variables were collected for each photograph through the software: the number of fixations, total fixation duration, average fixation duration, and time to first fixation. After the eye-tracking application, the participants were asked to look at the same photographs; An online survey, designed on a 5-point Likert scale, was administered to measure variables such as landscape beauty (LB), harmony of landscape elements (HL), plant presence (PP), color variety (CV), maintenance and cleaning (MC), meeting recreational needs (MR), and desire to be in the place (DP). After eliminating data that did not meet the criteria and were deemed incorrect, data from a total of 26 participants were evaluated to assess the preliminary results of the study. The GVI values obtained in the study, the proportions of landscape elements in the photograph, eye-tracking variables, and the scores assigned to the landscape evaluation variables were combined and statistically evaluated.



Figure 3. Eye tracking application

3. Findings and Discussion

3.1. Findings on Landscape Assessment Variables Using the Green View Index (GVI)

According to the results obtained, five of the landscape assessment variables show a positive correlation with GVI (Table 1). In particular, the relationship between the Plant Presence (PP) variable and GVI is quite strong ($r = 0.365$, $p < .001$). This finding means that as the proportion of green space in the scenes shown to participants increases, participants perceive greater plant richness. In addition, significant and positive relationships were also found between GVI and the variables of Landscape Beauty (LB), Harmony of Landscape Element (HL), and Color Variety (CV). This situation shows that the perception of green appearance may be related not only to the perceived presence of plant material but also to the aesthetic integrity of the

composition and color diversity. On the other hand, no significant relationship was observed between GVI and the variables of Maintenance and Cleaning (MC) and Meeting Recreational Needs (MR). Accordingly, it is understood that a landscape with a high green appearance ratio does not, on its own, give participants the impression of a well-maintained or functional area.

Table 1. Correlation between GVI and landscape assessment variables

		Landscape Assessment Variables						
		LB	HL	PP	CV	MC	MR	DP
GVI	Pearson's r	**0.213*** **	**0.192*** **	**0.365*** **	**0.211*** **	–0.051	0.072	**0.100*** **
	p-value	< .001	< .001	< .001	< .001	0.241	0.100	< .001
	N	520	520	520	520	520	520	520

LB: Landscape beauty, HL: Harmony of landscape elements, PP: Plant presence, CV: Color variety, MC: Maintenance and Cleaning, MR: Meeting Recreational Needs, DP: Desire to be in the space

The differences in the average scores of the landscape assessment variable between the four GVI categories (0-25%, 26-50%, 51-75%, 76-100%) were tested using a one-way ANOVA (Table 2). Accordingly, it was observed that the mean scores of the questionnaire participants for MC and MR did not differ significantly across GVI categories. The averages of all other variables were lowest in photos with the least green cover, while evaluations made when GVI exceeded 25% did not show a significant difference (Figure 4). This suggests that 25% may be a psychological threshold for the proportion of green cover in the landscapes visible to participants. In photographs below this threshold, participants tended to give low scores to landscape evaluation variables. In other words, weak green texture negatively affected landscape perception and satisfaction levels.

Table 2. Results of the One-Way ANOVA test

	One-Way ANOVA			
	F	**df1**	**df2**	**p**
LB	8.38	3	285	< .001
HL	8.18	3	286	< .001
PP	34.31	3	285	< .001
CV	10.59	3	285	< .001
MC	1.16	3	287	0.325
MR	1.40	3	285	0.243
DP	7.01	3	286	< .001

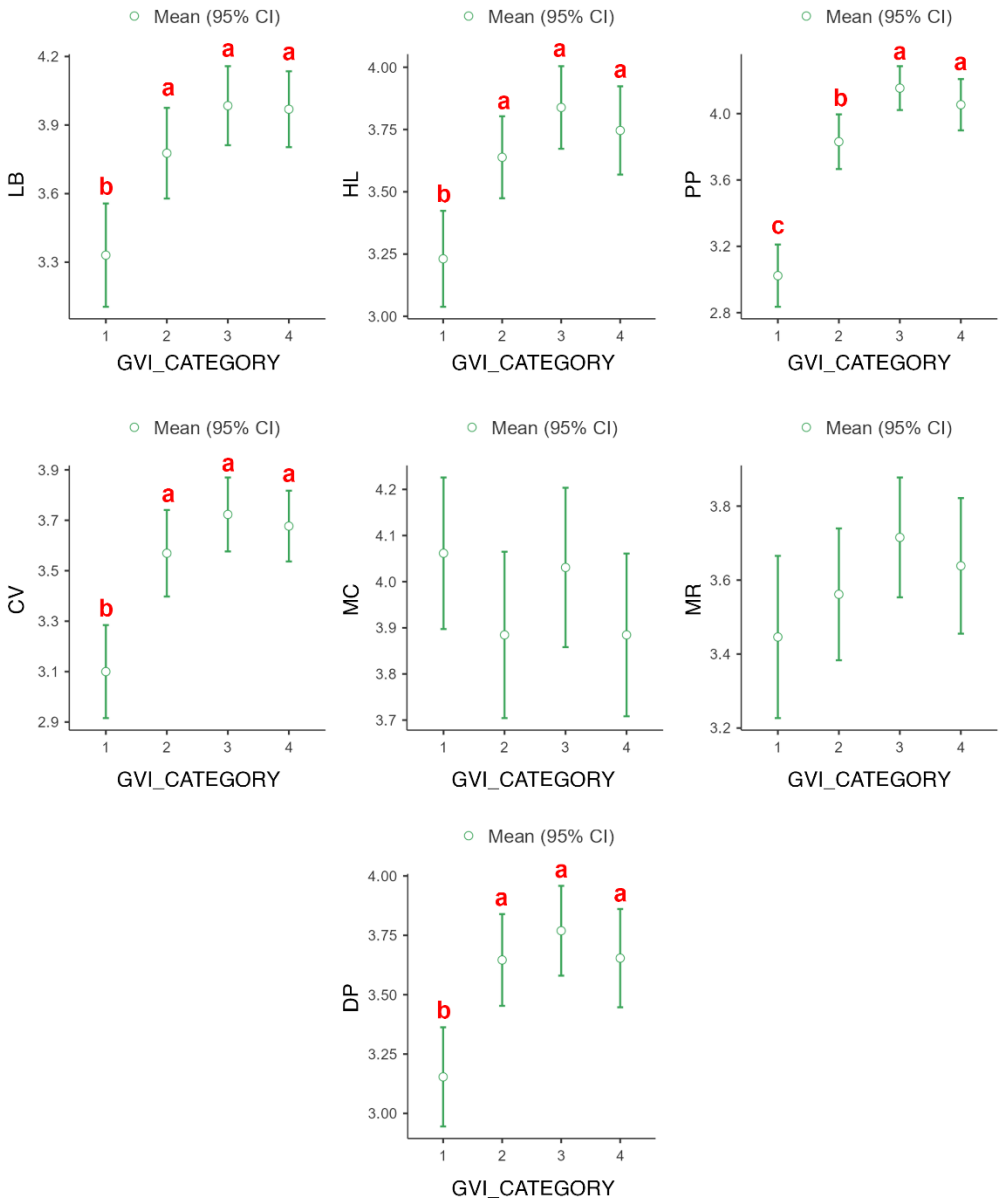


Figure 4. Differences in average scores for landscape assessment variables between GVI categories

3.2. Relationship Between Landscape Assessment Variables and the Proportion of Landscape Elements

Table 3 shows the correlation between the landscape evaluation scores of questionnaire participants regarding the photographs and the proportions of landscape elements in the photographs. The relationships between landscape elements and landscape evaluation variables are important in revealing the nature of the elements that shape participants' visual and functional perceptions.

The Landscape Beauty (LB) variable shows a significant positive correlation with the proportions of trees (r=0.094) and shrubs (r=0.104) in the photographs, and a negative correlation with hardscape (r=–0.090) and especially other elements (r=–0.169). This indicates

that questionnaire participants rated landscapes with dense vegetation as more beautiful and aesthetically pleasing. However, an increase in man-made elements such as benches, trash cans, or lighting fixtures reduced the perception of landscape beauty. The PP variable has a strong positive relationship with trees (r=0.270) and shrubs (r=0.170) and a negative relationship with hardscapes (r=–0.213) and water surfaces (r=–0.111). Participants evaluate landscapes with high tree and shrub density as rich in plant material. Hardscapes and structural elements, on the other hand, reduce the perception of plant presence. Desire to be in the space (DP) is positively correlated with shrub texture in photographs (r=0.103) and negatively correlated with other elements (r=–0.115). Participants' desire to be in a space or spend time there may increase with the continuity of the plant composition. At this point, shrubs may have served as a visual layer connecting all elements in the landscape. However, the increase in elements such as billboards or urban furniture in scenes of the park disrupted the sense of spatial integrity, reducing people's desire to be there. The Maintenance and Cleaning (MC) score showed a weak negative correlation with the tree ratio in the photographs (r=–0.096). The dense tree structure in the views seen may have created a perception of neglect by lowering the perception of visual cleanliness in people due to fallen leaves, the shading effect, or low visibility.

Generally, positive relationships are found between landscape evaluation variables and plant elements such as trees and shrubs, while negative relationships are generally observed with hardscapes or other elements. Accordingly, it is understood that participants evaluated landscapes with a plant-material emphasis and a natural character more positively in terms of aesthetics and functionality. Conversely, scenes dominated by structural landscapes were perceived with lower scores.

Table 3. Correlation between landscape assessment variables and the proportion of landscape elements in photographs

Landscape assessment variable	Tree	Shrub	Herbaceous plants	Hardscape	Water surface	Other elements
LB	**0.094***	**0.104***	0.019	**–0.090***	0.024	**–0.169*****
HL	**0.100***	**0.107***	0.025	–0.078	–0.034	**–0.089***
PP	**0.270*****	**0.170*****	0.075	**–0.213*****	**–0.111***	–0.031
CV	**0.121*****	**0.147*****	0.036	**–0.112***	–0.078	–0.047
MC	**–0.096***	0.003	–0.078	0.070	0.079	–0.002
MR	–0.001	0.056	0.050	–0.010	–0.036	**–0.105***
DP	0.070	**0.103***	0.014	–0.049	–0.049	**–0.115****

* p < .05, ** p < .01, *** p < .001

3.3. Relationship Between Eye Tracking Variables and Participant Profile

The means of eye tracking variables were analyzed using the nonparametric Mann-Whitney U test to determine whether they differed statistically based on whether participants had received landscape architecture education. The means of the four eye tracking variables differed significantly between the two groups (Table 4). The number of fixations among participants who have received or are receiving landscape architecture education is significantly higher than among participants without education in this field (Table 5). However, the total fixation duration, average fixation duration, and time to first fixation variables were lower in the group receiving landscape architecture education. These findings reveal that the visual perception process can vary depending on the education received or the level of expertise. A high number of fixations means that individuals with landscape architecture education examined the landscape elements in the photographs shown to them in a more detailed and systematic manner. It is thought that the spatial reading skills acquired as a result of the courses taken and the practical work carried out during the education process may have increased these participants' visual scanning skills regarding environmental elements. This situation means that individuals educated in landscape architecture evaluated a greater number of landscape components in the scenes shown to them with shorter fixations. On the other hand, the relatively low total and average fixation time in these participants means that individuals who have received landscape architecture education can process the visual details in the scenery shown to them more quickly and effectively. In addition, the low duration until the first fixation indicates that these individuals can experientially identify spatial patterns in visual scenes more quickly.

Table 4. Results of the mean comparison test for eye tracking variables

Eye tracking variable (LA education)	Test	Statistics	p-value
Number of fixations	Mann-Whitney U	29129	0.006
Total fixation time (seconds)	Mann-Whitney U	28194	0.001
Average fixation duration (seconds)	Mann-Whitney U	21737	< .001
Time until first fixation (seconds)	Mann-Whitney U	30383	0.046

Table 5. Mean and standard error values of eye-tracking variables at the level of groups with and without landscape architecture education

Eye tracking variable	Group	N	Mean	Std. error
Number of fixations	Has not received LA education	260	21.86	0.241
	Has received/is receiving LA education	260	22.55	0.259
Total fixation time (seconds)	Has not received LA education	260	7.83	0.075
	Has received/is receiving LA education	260	7.37	0.091

Average fixation duration (seconds)	Has not received LA education	260	0.37	0.005
	Has received/is receiving LA education	260	0.33	0.003
Time until first fixation (seconds)	Has not received LA education	260	0.54	0.018
	Has received/is receiving LA education	260	0.51	0.021

4. Conclusion and Recommendations

In studies measuring visual perception in urban green space planning, data is typically collected using traditional methods such as questionnaires, interviews, or observation. However, these methods can be limited in terms of achieving objective results. In this context, eye-tracking technology is an important complementary tool in urban green space planning in terms of revealing how individuals perceive landscapes or which elements they pay more attention to. The results of this study show that when eye-tracking is used in conjunction with traditional approaches, it enables a more comprehensive analysis of visual quality perception in both quantitative and qualitative terms.

The difference in landscape evaluation scores between GVI categories has shown that a 25% green fabric ratio may be a psychological threshold in landscape perception. It was observed that the evaluation scores given by participants dropped significantly in photographs below this ratio. Therefore, maintaining green texture above a certain ratio is important for increasing visual satisfaction in urban green spaces. Correlations between GVI and landscape evaluation variables reveal that green appearance is linked not only to ratio but also to qualities such as visual integrity and color balance.

When examining the relationships between the proportions of landscape elements in the photographs and landscape evaluation variables, it was observed that the presence of trees and shrubs created a positive perception, while hardscape or other structural elements created a negative perception. It is understood that participants found spaces with a natural character, balanced with plant material, and where structural landscaping was not dominant to be more aesthetically pleasing from a visual perspective. The results of the eye-tracking analysis revealed that individuals who had received or were receiving landscape architecture education examined the scenes with a greater number of fixations, but for relatively shorter periods of time. This situation shows that participants, who have gained visual and aesthetic skills through their landscape architecture education, scan the environmental elements in the photographs more systematically. Considering the preliminary results of the study, it is understood that the use of eye-tracking technology in conjunction with traditional data collection methods can provide a physiological basis for urban green space planning and design decisions.

Thanks and Information Note

This conference paper utilizes data and findings obtained from project number 124K606, supported by TÜBİTAK under the 3005 program. The paper complies with national and international research and publication ethics. Ethics committee approval for this study was obtained from the Ordu University Social and Human Sciences Research Ethics Committee,

dated October 30, 2024, with decision number 2024-157. All authors contributed equally to the paper.

References

Baycan, T., Girard, L. F., & Nijkamp, P. (2012). Chapter 1: Creative and sustainable cities: A new perspective. In Sustainable City and Creativity. Ashgate: Surrey, UK.

Beriguete, F. E., Santos, J. S., & Rodriguez Cantalapiedra, I. (2024). Digital revolution: Emerging technologies for enhancing citizen engagement in urban and environmental management. *Land,* 13(11), 1921.

Birleşmiş Milletler. (2018). M. World Urbanization Prospects - The 2018 Revision; Technical Report; Department of Economic and Social Affairs, United Nations: New York, NY, USA, 2018.

Casprini, D., Oppio, A., Rossi, G., & Bengo, I. (2023). Managing urban green areas: The benefits of collaborative governance for green spaces. *Land,* 12(10), 1872.

Civelek, P., & Yeşil, M. (2024). Park Equipment Information System the Case of Tayfun Gürsoy Park in Altınordu District, Ordu Province in Türkiye. *Turkish Journal of Agriculture - Food Science and Technology,* 12(8), 1417-1426.

Dadvand, P., Rivas, I., Basagaña, X., Alvarez-Pedrerol, M., Su, J., Pascual, M. D. C., Amato, F., Jerret, M., Querol, X., & Sunyer, J. (2015). The association between greenness and traffic-related air pollution at schools. *Science of the Total Environment,* 523, 59-63.

Escobedo, F. J., & Nowak, D. J. (2009). Spatial heterogeneity and air pollution removal by an urban forest. *Landscape and urban planning,* 90(3-4), 102-110.

Evans, D., & Chamberlain, B. (2024). In Pursuit of Eye Tracking for Visual Landscape Assessments. *Land*, 13(8), 1184.

Franěk, M. (2023). Landscape preference: The role of attractiveness and spatial openness of the environment. *Behavioral Sciences,* 13(8), 666.

Fleming, W., Rizowy, B., & Shwartz, A. (2024). The nature gaze: Eye-tracking experiment reveals well-being benefits derived from directing visual attention towards elements of nature. *People and Nature,* 6, 1469-1485.

Haase, A. (2022). Green Spaces and Their Social Functions: Specific Challenges in Urban Spaces of Arrival. Ieva Misiune Daniel Depellegrin, 273.

Jabbar, M., Yusoff, M. M., & Shafie, A. (2022). Assessing the role of urban green spaces for human well-being: A systematic review. *GeoJournal,* 87(5), 4405-4423.

Jennings, V., Larson, L., & Yun, J. (2016). Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. *International Journal of environmental research and public health,* 13(2), 196.

Ki, D., & Lee, S. (2021). "Analyzing The Effects of Green View Index of Neighborhood Streets on Walking Time Using Google Street View and Deep Learning", *Landscape and Urban Planning*, 205, (103920).

Kiss, B., Sekulova, F., Hörschelmann, K., Salk, C. F., Takahashi, W., & Wamsler, C. (2022). Citizen participation in the governance of nature-based solutions. *Environmental Policy and Governance,* 32(3), 247-272.

Knox, P. L., & McCarthy, L. M. (2012). Urbanization: An Introduction to Urban Geography. Boston: Pearson.

Kumakoshi, Y., Chan, S. Y., Koizumi, H., Li, X., & Yoshimura, Y. (2020). Standardized green view index and quantification of different metrics of urban green vegetation. *Sustainability,* 12(18), 7434.

Kong, F., Yin, H., Nakagoshi, N., & Zong, Y. (2010). Urban green space network development for biodiversity conservation: Identification based on graph theory and gravity modeling. *Landscape and Urban Planning,* 95(1-2), 16-27.

Li, J., Zhang, Z., Jing, F., Gao, J., Ma, J., Shao, G., & Noel, S. (2020). An evaluation of urban green space in Shanghai, China, using eye tracking. *Urban Forestry & Urban Greening,* 56, 126903.

Li, C., Yuan, Y., Sun, C., & Sun, M. (2022). The Perceived Restorative Quality of Viewing Various Types of Urban and Rural Scenes: Based on Psychological and Physiological Responses. *Sustainability,* 14(7), 3799.

Li, X., Dai, D., Dong, J., & Hu, K. (2025). Research on the collaborative mechanism between site selection optimization model and control of green space planning under the background of urban renewal. *Discover Sustainability*, 6(1), 230.

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental pollution,* 116(3), 381-389.

Peschardt, K. K., & Stigsdotter, U. K. (2013). Associations between park characteristics and perceived restorativeness of small public urban green spaces. *Landscape and Urban Planning,* 112, 26-39.

Romero-Muñoz, S., Sánchez-Chaparro, T., Muñoz Sanz, V., & Tillie, N. (2024). Urban Greening Management Arrangements between Municipalities and Citizens for Effective Climate Adaptation Pathways: Four Case Studies from The Netherlands. *Land,* 13(9), 1414.

Sankar, G., Djamasbi, S., Tulu, B., & Muehlschlegel, S. (2025, May.). Measuring Cognitive Engagement with Eye-Tracking: An Exploratory Study. In International Conference on Human-Computer Interaction (pp. 69-78). Cham: Springer Nature Switzerland.

Shadman, S., Khalid, P. A., Hanafiah, M. M., Koyande, A. K., Islam, M. A., Bhuiyan, S. A., ... & Show, P. L. (2022). The carbon sequestration potential of urban public parks of densely populated cities to improve environmental sustainability. *Sustainable Energy Technologies and Assessments,* 52, 102064.

Sugano, S., Tazaki, M., Arai, H., Matsuo, K., & Tanabe, S. I. (2022). Characteristics of eye movements while viewing indoor plants and improvements in occupants' cognitive functions. *Japan Architectural Review,* 5(4), 621-632.

Tyrväinen, L., & Miettinen, A. (2000). Property prices and urban forest amenities. *Journal of Environmental Economics and Management,* 39(2), 205-223.

Visintin, C., Garrard, G. E., Weisser, W. W., Baracco, M., Hobbs, R. J., & Bekessy, S. A. (2025). Designing cities for everyday nature. *Conservation Biology,* 39(1), e14328.

Wu, Y., Zhuo, Z., Liu, Q., Yu, K., Huang, Q., & Liu, J. (2021). The Relationships between Perceived Design Intensity, Preference, Restorativeness and Eye Movements in Designed Urban Green Space. *International Journal of Environmental Research and Public Health*, 18(20), 10944.

Yang, J., Zhao, L., McBride, J., & Gong, P. (2009). "Can You See Green? Assessing The Visibility of Urban Forests İn Cities", *Landscape and Urban Planning*, 91(2), 97-104.

Yu, X., Ma, S., Cheng, K., & Kyriakopoulos, G. L. (2020). An Evaluation System for Sustainable Urban Space Development Based in Green Urbanism Principles - A Case Study Based on the Qin-Ba Mountain Area in China. *Sustainability*, 12(14), 5703.

Zhang, W., & Zeng, H. (2024). Spatial differentiation characteristics and influencing factors of the green view index in urban areas based on street view images: A case study of Futian District, Shenzhen, China. *Urban Forestry & Urban Greening,* 93, 128219.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Effects and Limitations of Safety Standards on Creative Designs in Children's Playgrounds

Elif SAĞLIK [1*]

ORCID 1: 0000-0002-5230-3869
[1]Assoc. Prof. Dr., Çanakkale Onsekiz Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale- Türkiye
elifysaglik@gmail.com (Responsible Author)

Efe Arda HASANOĞLU [2]

ORCID 2: 0009-0000-6117-2103
[2]Graduate Student, Çanakkale Onsekiz Mart University, Graduate Education Institute, Department of Landscape Architecture, Çanakkale-Türkiye
hasanogluefearda@gmail.com

Abstract

Children's Playgrounds are among the most significant environments where physical and cognitive development takes shape, and the foundations of freedom are established. These playgrounds provide experiential spaces that support imagination, develop motor skills, and strengthen the sense of security. Children who merge their games with imagination may become the captain of a ship or an inseparable part of nature. Within this process, the feeling of safety is their most fundamental right. To ensure that playgrounds are designed with safety in mind, specific criteria must be established. At this point, safety standards serve as guiding frameworks. Safety standards aim to prevent possible accidents by defining measurement ranges and limitations for playgrounds and equipment. While national standards demonstrate similarities, they also present significant differences in content. This study seeks to reveal the effects of different safety standards on design and functionality. Two of the most widely applied global standards, TS EN and ASTM, were selected for comparison. Based on these standards, the design outcomes of playgrounds and equipment were evaluated through both visual and conceptual analysis. The findings obtained from this process were directly associated with design practice, and two distinct models were developed. The research highlights how playground design is directed by safety norms. At the scale of equipment, the overall site, and design criteria, the balance between safety and creativity was critically discussed. Differences between standards were found to play a decisive role in shaping playground design in terms of aesthetics, functional diversity, and experiential richness.

Keywords: Children's playground, safety, safety standards, creativity balance, design process

1. Introduction

Play nurtures children's imagination and enables them to develop their creativity. At the same time, it offers children the opportunity to gradually build self-confidence and a sense of independence by making their own decisions and interacting with their surroundings (Polat, Doğan & Şahin, 2022). In order for children to grow into healthy individuals, it is of great importance for the future of society to create physical environments that ensure their fundamental needs and rights, support play opportunities, and prioritize safety (Onay & Kuş Şahin, 2019).

Throughout history, in line with social transformations and technological advancements, play—having a fundamental place in child development—has constantly evolved, renewing its spatial organization, formal structure, tools and materials, as well as its expressive language (Kahya Canlı & Demirarslan, 2020). Whether play takes place indoors or outdoors leads to differences in the types of materials and equipment used. These spaces, which play a key role in children's processes of experiencing their environment—particularly outdoor playgrounds—gain importance as environments that support these developmental processes in a more natural and

interactive way (Kaya & Alıncak, 2024). In contrast, traditional playgrounds dominated by elements such as swings, slides, and sandpits tend to promote more individual play behaviors and mainly contribute to the development of children's gross and fine motor skills (Başaran Uysal, 2013). In addition to improving gross and fine motor skills, playgrounds that are associated with specific and/or different themes through developing technology also contribute to children's mental development (such as imagination, empathy, and social/communication skills). Furthermore, ensuring a safe play experience within the play–child relationship established in playgrounds is of great importance.

Due to deficiencies in design and supervision in children's playgrounds, risks such as falling, entrapment, and collision may occur; therefore, safety principles have become an integral part of the design process in organizing playgrounds (Sarıaslan Senyen & Erdoğan, 2019). The play equipment that supports children's physical development must be diverse and sufficient to meet the developmental needs of different age groups and must be designed and implemented in accordance with relevant safety standards (Aklıbaşında, Tırnakçı & Özhancı, 2018).

When the standards related to playground elements are examined, it is understood that—regardless of the type or nature of the equipment—the primary consideration in the design, installation, and use processes of a playground should be safety (Sarıaslan Senyen & Erdoğan, 2019). The standards used in children's playgrounds in Turkey have been shaped by adapting the regulations valid in Europe. Accordingly, the previously applied TS 5219 and EN 71 standards have been replaced by TS EN 1176 and TS EN 1177, which have entered into force (Ulaş & Ayan, 2016). The TS EN 1176 standard, which contains comprehensive provisions regarding the safety of equipment used in children's playgrounds, consists of a total of eleven sections covering different types of equipment as well as installation and maintenance processes (TS EN 1176-1, 2023).

While TS EN 1176 is valid in Europe and Turkey, ASTM F1487 is applied in the United States (USA) as the primary reference standard concerning playground safety. The ASTM F1487 standard defines nationally recognized safety requirements for equipment used in public playgrounds, based on the injury risk criteria determined by the U.S. Consumer Product Safety Commission (CPSC) (ASTM International, 2025).

The fundamental approaches and safety priorities on which these two standards are based shape the formal design of playground equipment, material selection, fall height criteria, and risk management parameters through different methodologies. Therefore, in the design of children's playgrounds, not only the level of safety but also the quality of play experience, spatial diversity, and the degree of creativity are directly influenced by these standards.

This research aims to examine the effects and limiting aspects of the TS EN 1176 and ASTM F1487 safety standards—used in playground design—on creative design processes, within the scope of two separate playground models designed according to the respective values of these standards. By comparing the effects of standards on design decisions, it seeks to reveal the balance between safety and design freedom. The designs are constructed with a simplified approach, free from excessive detail, to clearly and visibly present the differences between the two standards.

2. Materials and Methods

This research consists of five main sections: determination of the research purpose, examination of the relevant materials identified in line with this purpose, determination of the research limitations, formation of the findings, product design, and visualization.

The aim of the research is to examine the effects and limiting aspects of the standards **TS EN 1176 – Playground Equipment and Surfacing: Safety Requirements and Test Methods** (Turkish Standard European Norm 1176) and **ASTM F1487 – Standard Consumer Safety Performance Specification for Playground Equipment for Public Use** (American Society for Testing and Materials F1487), which are used in playground design, on creative design processes within the scope of two separate playground models designed according to the respective values of these standards. The playground design was constructed with a simplified approach—free from excessive detail—to clearly and visibly reveal the differences between the standards. Accordingly, by comparing the effects of the standards on design decisions, the study aims to reveal the balance between safety and design freedom.

The main materials of the research, **TS EN 1176** and **ASTM F1487,** were obtained from the official websites of the relevant institutions. For a comparative analysis between the two standards, a detailed review was conducted; and based on the initial assessments, it was observed that the diversity of product groups and the broad scope and content addressed by the standards were extensive. Therefore, in order to define the scope and limitations of the study, basic design elements included in a complex playground structure—where the differences between the two standards can be most clearly observed—were selected. These include **tube slides, stepped ladders, inter-platform transition elements, railings, and barriers.** These selected design components were comparatively analyzed between the two standards, and the findings obtained were evaluated through comparative tables supported by visual materials.

The design was developed based on the **"Puzzle" concept**. The reason for selecting this concept lies in the fact that although both standards adopt the same ultimate goal of ensuring safety in children's playgrounds, they present different approaches to achieving this objective. Much like the differently shaped pieces of a puzzle, both standards share similar principles but diverge in terms of their methods of application and design orientations. To represent this situation, a **common platform symbolizing the intersection point of the two standards** was designed and named the **"Standard Platform."**

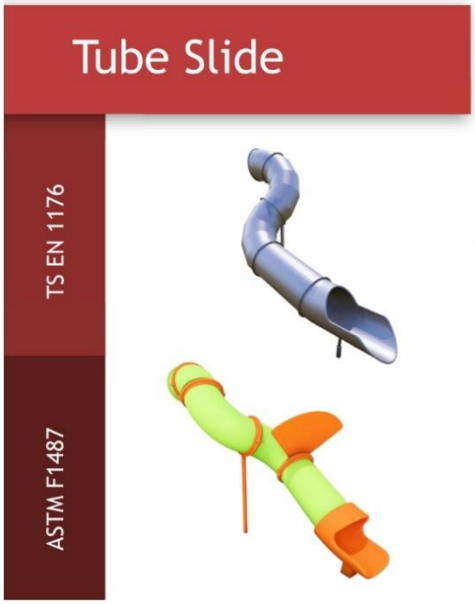
Based on the findings obtained from the analysis and the determined design concept, two separate playground groups were designed according to the respective standards. The designs were modeled using **SketchUp**, and **product and component renderings** were produced using **Lumion**. Additionally, in order to support site layout and visualization, **Google's artificial intelligence software Gemini** was utilized for generating visual representations.

3. Findings and Discussion

The TS EN 1176 and ASTM F1487 standards aimed at ensuring safety in children's playgrounds were compared, and similarities and differences between the two standards were revealed through their design principles, risk prevention approaches, and component criteria. The examinations conducted within the scope of the research showed that the standards are quite extensive in terms of scope and content; therefore, it was not possible to include all articles in the design process. For this reason, the study focused on four fundamental design elements—tube slides, stepped ladders, inter-platform transition elements, and railings and barriers—

where the differences between the standards could be most clearly observed. The designs were prepared with a simplified approach to demonstrate how these differences emerge both visually and functionally.

In the tube slide design, according to the two standards, a total of eight design criteria were identified: transition platform, sliding slope, entry section, sliding channel width, exit section length, fall height, slide protection, and supporting structure. The application details of these criteria as specified in the standards are presented in Figure 1. The design criteria in which differences were observed between the two standards are indicated in different colors on the table.



Criteria	TS EN 1176	ASTM F1487
Transition Platform	A transition platform must be provided. The depth is generally ≥ 350 mm.	The depth of slide transition platforms shall be at least 360 mm.
Sliding Slope	The angle of the sliding section relative to the horizontal should not exceed approximately 40°.	No part of the sliding surface shall be steeper than 50° relative to the horizontal.
Entry Region	A handrail or guiding element must be provided to assist the user in moving into the sitting position.	A handhold, head piece, or protective guiding element is required to direct the user into the correct sitting position.
Slide Bedway / Internal Width	For tunnel slides, the minimum internal height and width of the sliding surface must be at least 750 mm.	For tube slides, the internal diameter must be 580 mm or greater.
Exit Region Length & Slope	The exit section must have a slope between 5° and -10°, with a minimum length of 300 mm.	The exit section must have a slope between 0° and -10°, with a minimum length of 280 mm.
Fall Height Measurement	The fall height is measured from the protective surfacing to the start of the sliding section.	The reference fall height for a fully enclosed slide tube is taken as 2130 mm.
Slide Protection (Upper Guarding)	No guard is required on the slide body itself; protection must comply at the platform level (guardrail/barrier criteria).	A protective guard must extend 970 mm above the slide surface, covering a 645° arc around the entry.
Support Structure	Support posts may remain accessible in the free space.	Support structures of tube slides must be designed to minimize opportunities for climbing.

Figure 1. Differences between the two standards in tube slide design (Adapted from TS EN 1176 and ASTM F1487)

In the comparison of safety standards applied in tube slide design, the design criteria of sliding channel width, fall height, and slide protection stand out. According to the TS EN standard, the inner height and inner width of the sliding surface must be at least 750 mm (TS EN 1176-3, 2010). In the ASTM standard, the internal diameter is required to be 580 mm or more. Regarding fall height, in the TS EN standard, the distance from the protective surface to the starting point of the slide is taken as reference, while in the ASTM standard, the tube protection height of 2,130 mm is taken as reference. For slide protection, the TS EN standard does not require any protection on the upper part of the slide; it only stipulates that the barrier and railing criteria of the starting platform must be met. In contrast, the ASTM standard requires protection extending 970 mm above the upper surface of the slide, covering an arc of 645°.

In the design of stepped ladders, according to the two standards, there are six design criteria: step height and depth, ladder width, slope, handrail and railing, step spacing, and fall prevention measures. The application details of these criteria as specified in the standards are presented in Figure 2.

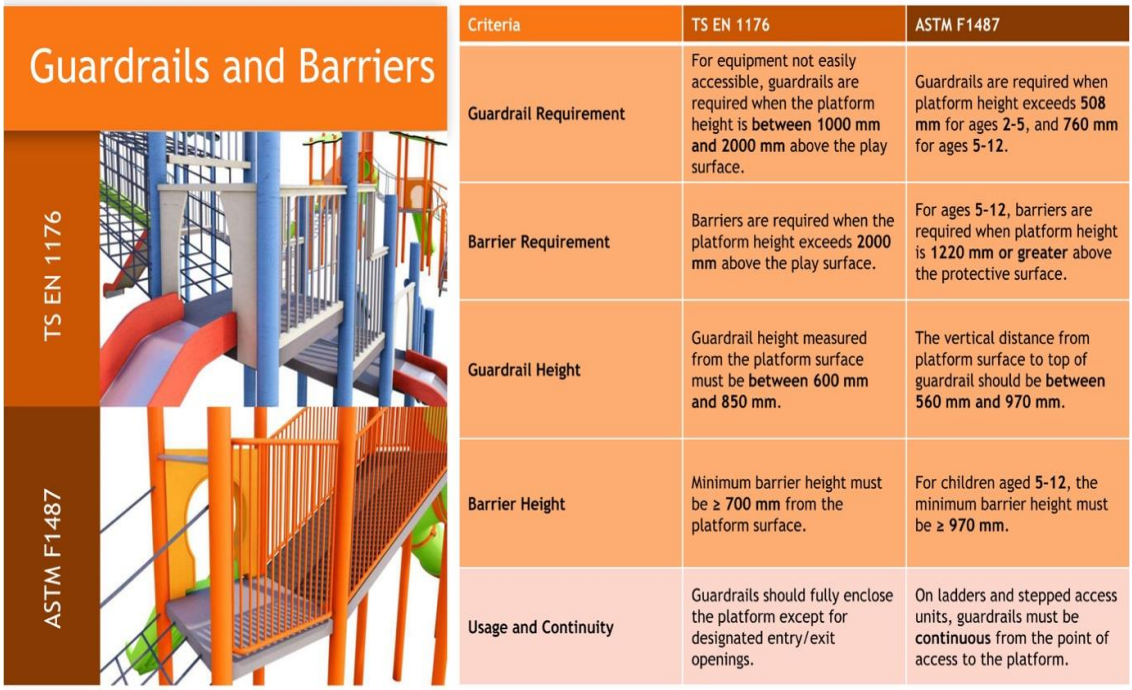


Criteria	TS EN 1176	ASTM F1487
Step Height & Depth	Minimum tread depth should be ≥ **110 mm** to provide sufficient standing area.	Vertical rise between steps must be < **229 mm**; minimum tread depth ≥ **178 mm**.
Ladder Width	No fixed dimension, but the ladder is generally recommended to match the width of the access platform.	If double-sided access is provided, the total ladder width must be > **910 mm**.
Slope	Ladder inclination should remain consistent.	A series of steps used for ascent or descent should have a slope ≤ **50°** relative to horizontal.
Handrails & Guardrails	The height of the guardrail measured from the stepping or platform surface must be **between 600 mm and 850 mm**.	Continuous handrails shall be provided on **both sides** of ladders, ramps, and stepped access systems with multiple steps.
Step Openings / Risers	Open risers are permitted; however, openings should be < **30 mm**.	Vertical openings between steps shall not exceed **230 mm**.
Fall Protection Measures	Barriers are required if the accessible platform height exceeds **600 mm** above the play surface.	Any step located **1220 mm** above the protective surface requires a protective barrier.

Figure 2. Differences between the two standards in stepped ladder design (adapted from TS EN 1176 and ASTM F1487)

In the comparison of safety standards applied in the design of stepped ladders, the design criteria of slope, step spacing, and fall prevention measures are prominent. According to the TS EN standard, it is stated that the slope of the ladders must have a fixed value, although no numerical value is specified. In the ASTM standard, however, it is defined as a series of steps used for ascent and descent, having a slope of 50° or greater relative to the horizontal plane. Regarding step spacing, the TS EN standard does not require the risers of the steps to be closed; however, if the risers are closed, the gap must be less than 30 mm. In the ASTM standard, the vertical spacing between steps must not exceed 230 mm. For the fall prevention criterion, according to TS EN, when the platform is more than 600 mm above the play surface, access must be provided through barriers. In the ASTM standard, all steps with a height of 1,220 mm above the protective surface must include a protective barrier.

When the requirements and dimensional ranges of guardrails and barriers are examined, they are analyzed according to design criteria such as the necessity of guardrails, the necessity of barriers, guardrail height, barrier height, and usage. The application details of these criteria as specified in the standards are presented in Figure 3.



Criteria	TS EN 1176	ASTM F1487
Guardrail Requirement	For equipment not easily accessible, guardrails are required when the platform height is **between 1000 mm and 2000 mm** above the play surface.	Guardrails are required when platform height exceeds **508 mm** for ages **2-5**, and **760 mm** for ages **5-12**.
Barrier Requirement	Barriers are required when the platform height exceeds **2000 mm** above the play surface.	For ages **5-12**, barriers are required when platform height is **1220 mm or greater** above the protective surface.
Guardrail Height	Guardrail height measured from the platform surface must be **between 600 mm and 850 mm.**	The vertical distance from platform surface to top of guardrail should be **between 560 mm and 970 mm.**
Barrier Height	Minimum barrier height must be ≥ **700 mm** from the platform surface.	For children aged **5-12**, the minimum barrier height must be ≥ **970 mm.**
Usage and Continuity	Guardrails should fully enclose the platform except for designated entry/exit openings.	On ladders and stepped access units, guardrails must be **continuous** from the point of access to the platform.

Figure 3. Differences between the two standards in guardrail and barrier design (adapted from TS EN 1176 and ASTM F1487)

In the comparison of safety standards applied in guardrail and barrier design, the criteria of usage requirement and application height stand out for both components. According to the TS EN standard, the use of guardrails is required for equipment that is not easily accessible, with a platform surface height between 1000 mm and 2000 mm, whereas in the ASTM standard, the requirement is defined based on age groups: for the 2–5 age group, when the platform height exceeds 508 mm, and for the 5–12 age group, when it reaches 760 mm. When this criterion is considered for barriers, according to the TS EN standard, a barrier must be provided when the equipment that is not easily accessible exceeds 2000 mm from the play surface, while in the ASTM standard, this value corresponds to a height of 1220 mm or more above the protective surface for the 5–12 age group.

In terms of application height, the TS EN standard specifies that the height to the upper part of the guardrail, measured from the platform and from the surface of the ladder or ramp, must be no less than 600 mm and no more than 850 mm. In the ASTM standard, the vertical distance to the top surface of the guardrail is between 560 mm and 970 mm. Regarding barrier application height, the TS EN standard states that the height to the top of the barrier, measured from the surface of the platform, ladder, or ramp, must be at least 700 mm; according to the ASTM standard, this value must be at least 970 mm for surfaces used by children aged 5 to 12 years.

When flexible and non-flexible platform transition elements are examined within the scope of the two standards, it has been observed that they are brought together with different structural components and are classified under general criteria but not defined as separate topics. Platform transition elements, within the context of general design criteria, have been analyzed through parameters such as surface slope in horizontal net crossings, side protection height, mesh spacing, barrier requirement, passage width, guardrail system, surface characteristics, and bridge classification. The application details of these criteria as specified in the standards are presented in Figure 4.



Criteria	TS EN 1176	ASTM F1487
Surface Slope (Angle of the Net Surface)	Horizontal net transitions are permitted when the surface slope is ≤ 45°.	Net transitions may be used instead of climbing elements when the slope does not exceed 50°.
Side Protection Height	The vertical height from the transition surface to the top of the guardrail or barrier must be ≥ 700 mm.	The vertical distance from the foot support surface to the top of the protective barrier must be ≥ 970 mm.
Net Mesh Opening Size	Maximum mesh opening: ≤ 230 mm.	Maximum mesh opening: ≤ 230 mm (same requirement).
Barrier Requirement	Barriers are required when the transition height exceeds 1000 mm, with minimum barrier height ≥ 700 mm.	Barriers required when fall height exceeds 1200 mm, with protective height determined by child age group (commonly ≥ 970 mm for ages 5-12).
Transition Width	Recommended minimum clear width: ≈ 700 mm.	Minimum clear width: ≥ 910 mm (may be reduced to 810 mm over short distances).
Guardrail Height Along Transition	Vertical height from the walking surface to the top of the guardrail should be 600-700 mm.	Vertical height from the walking surface to the guardrail top should be 560-970 mm.
Barrier Requirement Based on Height	Barriers are required when the transition height exceeds 1000 mm, with barrier height ≥ 700 mm.	Barriers are required when fall height exceeds 1200 mm, with barrier height determined by age group (≥ 970 mm for ages 5-12).
Surface Characteristics	Non-slip, water-draining surface with foot support projections recommended.	Non-slip, water-draining surface required.
Slope and Classification	Transition walking surfaces must not exceed 38°; beyond this, the surface is classified as a climbing element.	Surfaces with a slope > 30° are no longer considered a play surface, but become climbing elements.

Figure 4. Differences between the two standards in platform transition elements (adapted from TS EN 1176 and ASTM F1487)

In the comparison of flexible platform transition elements, the criteria of side protection height and barrier requirement stand out. According to the TS EN standard, the side protection height must be 700 mm or greater, measured from the tube passage surface to the top of the barrier or guardrail, whereas in the ASTM standard, this value is measured as ≥ 970 mm from the foot level. Regarding the barrier requirement, according to TS EN, barriers are mandatory for transitions exceeding 1000 mm in height. In the ASTM standard, barrier requirements are defined based on fall height when the value exceeds 1200 mm.

In the comparison of non-flexible platform transition elements, the criteria of passage width, guardrail system, and barrier requirement stand out. According to the TS EN standard, the minimum recommended passage width is 700 mm, while in the ASTM standard, the minimum clear width is 910 mm, and for short-distance transitions, it is measured as 810 mm. The

guardrail height in the TS EN standard must be between 600 mm and 700 mm, whereas in the ASTM standard, this value ranges between 560 mm and 970 mm. The barrier requirement in the TS EN standard is mandatory when the height exceeds 1000 mm, while in the ASTM standard, the use of barriers is defined according to age group when the fall height exceeds 1200 mm.

In bridge classification, according to the TS EN standard, when the slope on bridges and transition surfaces exceeds 38 degrees, the element is no longer considered a bridge but is classified as a "climbing element." Similarly, according to the ASTM standard, surfaces with a slope greater than 30 degrees are not regarded as "play surfaces" and are classified as climbing elements.

As a result of the comparative analyses conducted, it has been observed that there are significant differences between the TS EN 1176 and ASTM F1487 standards in the criteria related to the design elements addressed within the scope of the study. In order to present these differences systematically, both the quantitative and qualitative definitions of the two standards were evaluated through comparative tables (Figures 1–4). In light of the findings obtained, a subsequent design process was carried out to reveal not only the technical differences but also their potential impacts on user experience, design aesthetics, and designer creativity, and to visualize these differences more concretely. The design process was conducted by creating two separate designs based on the differences identified between the two standards (Figure 5).



Figure 5. Playground equipment design based on the differences between TS EN and ASTM standards

In the design process, how the criteria and parameters specified in the standards were reflected in the selected design elements was systematically examined. In line with these examinations, the playground design was carried out based on the results of the comparative analyses presented above. The design was modeled in the SketchUp program, and product and component renderings were produced using the Lumion program. The component render visuals of the product are presented in the comparative tables given above (Figures 1–4).

In the design, the materials used were selected in accordance with the regulations adopted and inspected by the relevant manufacturers, and the design elements included in the playground were structured and scaled appropriately for production. Additionally, since the design was carried out within the framework of a specific concept, visualization was performed using the artificial intelligence tool Gemini to simulate the perceptibility of the comparison between the two standards within a real environment (Figure 6).



Figure 6. Real-world view of playground equipment designed according to the standards

Through the visualization study, the process of the designed playground model has contributed not only to the evaluation of the design at the conceptual, plan, and model scale, but also to the assessment of potential implementation scenarios in the future.

4. Conclusion and Recommendations

Safety is one of the most defining and limiting elements in the design process of children's playgrounds. In this context, TS EN 1176-1:2023 and ASTM F1487-21 are the two primary reference documents that are recognized as valid in both Turkey and Europe as well as in the United States, containing the most comprehensive regulations on playground safety. Both standards aim to minimize risks such as falling, entrapment, impact, and access through the use of master (probe) tests developed based on child anatomy and behavioral patterns and defined by measurable dimensional values. Through these testing methods, specific spacing intervals, barrier heights, platform distances, and surface inclinations have been scientifically standardized.

However, these safety requirements also establish mandatory frameworks that can restrict creativity for playground designers. Even when a designer pursues aesthetics, functionality, and innovation, each element must remain within certain dimensional limits; platform heights, slope ratios, barrier heights, and mesh openings are required to comply with the standards. This situation particularly narrows the boundaries of design in play components that involve high fall potential or are constructed with flexible materials (such as nets, ropes, or bridges). Nevertheless, the purpose of the standards is not to inhibit creativity but to encourage innovative solutions within the boundaries of safety.

On the other hand, it is evident that neither of the two standards is detailed enough to cover all possible design variations. Especially in contemporary design approaches involving net climbing structures, flexible transitions, or themed and hybrid play constructions, there are gaps in the standard texts where direct equivalents are not provided. At this point, the evaluation of designs often depends on the interpretive judgment of supervisory bodies or experts; thus, the same design may be interpreted differently across various implementations. Consequently, the interpretive sections of the standards create uncertainties for both designers and manufacturers during the processes of technical compliance and safety certification.

In conclusion, TS EN 1176 and ASTM F1487 standards constitute the fundamental framework that defines the balance between creativity and safety in children's playgrounds. While these standards ensure safe play environments, they also allow designers to pursue originality and aesthetic value within certain boundaries. However, this measurement-based system grounded in test methods needs to be continuously updated to support the development of flexible and innovative designs aligned with contemporary play concepts. The evolution of these standards to consider not only mechanical safety but also the quality of play experience and the design freedom that supports children's physical, social, and cognitive development is of great significance for the future of playground design.

Thanks and Information Note

We would like to express our gratitude to ASLIPARK ÇEVRE TASARIM MÜH. SAN. VE DIŞ TİC. LTD. ŞTİ. for their support in providing the main materials of the study, namely the TS EN 1176 and ASTM F1487 standards. The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Aklıbaşında, M., Tırnakçı, A., & Özhancı, E. (2018). Çocuk oyun alanlarının önemi ve tasarım kriterlerinin Nevşehir kenti örneğinde irdelenmesi. *İnönü Üniversitesi Sanat ve Tasarım Dergisi,* 8(17), 59-71. Doi: https://doi.org/10.16950/iujad.412099

ASTM International. (2025). ASTM F1487 – 25: Standard consumer safety performance specification for playground equipment for public use. West Conshohocken, PA: ASTM International.

Başaran Uysal, A. (2013). Bir kamusal alan olarak çocuk oyun alanları (Çanakkale). *Academia*. Access Address (10.10.2025): https://www.academia.edu/27267606/Bir_kamusal_alan_olarak_%C3%A7ocuk_oyun_alanlar%C4%B1_%C3%87anakkale_

Kahya Canli, S., & Demirarslan, D. (2020). Çocuk oyun alanlarının tarihi gelişimi. *Çocuk ve Gelişim Dergisi,* 3(6), 60-75.

Kaya, H., & Alıncak, F. (2024). Çocuk oyun alanlarının ebeveynler açısından değerlendirilmesi (Gaziantep ili örneği). *Eğitim ve Yeni Yaklaşımlar Dergisi, 7*(2), 67–83. Doi: https://doi.org/10.52974/jena.1499332

Onay, B., & Kuş Şahin, C. (2019). Kentsel rekreasyon kapsamında çocuk oyun alanlarında güvenlik: Isparta Ayazmana ve Gökçay Mesireliği örneği. *Kent Akademisi*, 12(3), 575-585. Doi: https://doi.org/10.35674/kent.603580

Polat, Z., Doğan, S., & Şahin, N. (2022). Çocuk oyun alanları planlamasının günümüzden geleceğe irdelenmesi: Didim (Aydın) İlçesi örneği. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi,* 19(2), 293-304. Doi: https://doi.org/10.25308/aduziraat.1174575

Sarıaslan Senyen, H. M., & Erdoğan, E. (2019). Kamusal çocuk oyun alanlarında güvenliğin Avrupa standartları üzerinden değerlendirilmesi. *Bartın Orman Fakültesi Dergisi*, 21(3), 665–684. Doi: https://doi.org/10.24011/barofd.579837

Türk Standardları Enstitüsü. (2010). *TS EN 1176-3: Oyun alanı elemanları ve zemin düzenlemeleri – Bölüm 3: Kaydıraklar için ilave güvenlik kuralları ve deney yöntemleri*. Ankara: TSE.

Türk Standardları Enstitüsü. (2014). *TS EN 1176-11: Oyun alanı elemanları ve zemin düzenlemeleri – Bölüm 11: Havada asılı ağlar için ilave güvenlik kuralları ve deney yöntemleri.* Ankara: TSE.

Türk Standardları Enstitüsü. (2023). *TS EN 1176-1+A1: Oyun alanı elemanları ve zemin düzenlemeleri – Bölüm 1: Genel güvenlik kuralları ve deney yöntemleri.* Ankara: TSE.

Ulaş, M., & Ayan, S. (2016). Çocuk oyun alanları değerlendirme ölçeği: Geçerlik-güvenirlik çalışması. *CBÜ Beden Eğitimi ve Spor Bilimleri Dergisi,* 11(2), 10–24.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Visualizing the Impacts of Modularity and Mobility on Contemporary Urban Design through AI: Inspirations from Archigram

Elif SAĞLIK [1]*

ORCID 1: 0000-0002-5230-3869
[1] Doç. Dr., Çanakkale Onsekiz Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale -Türkiye
elifsaglik@comu.edu.tr (Responsible Author)

Fatma ERDOĞAN [2]

ORCID 2: 0000-0002-4087-3960
[2] Graduate Student, Çanakkale Onsekiz Mart University, School of Graduate Studies, Çanakkale- Türkiye
fatmayetisir@hotmail.com

Abstract

Rapid technological advancements today are reshaping urban life and spatial production processes, bringing flexibility, mobility, and user-centered experiences to the forefront. In this context, the Archigram group, emerging in the 1960s, developed radical, experimental, and technology-centered architectural visions as alternatives to modernist planning paradigms. Radical architectural projects such as Plug-In City, Walking City, Instant City, Living Pod, Cushicle, and Suitaloon placed modularity, portability, and individual freedom at the core of architectural design. Archigram's utopian vision represents not only the technological imagination of its era but also a critical, creative, and innovative perspective on future urban living scenarios. This study examines the intersections between Archigram's modular and mobile spatial concepts and contemporary urban design practices that prioritize sustainability, flexibility, and user-centered approaches. Emergency housing solutions after disasters, climate-induced migration, and smart city applications are evaluated as contemporary reflections of Archigram's vision. Furthermore, AI-assisted methods were employed to visualize future-oriented urban design proposals. This approach enables a contemporary reinterpretation of Archigram's utopian vision through modern technologies and highlights the potential of AI as an experimental research and design tool in architecture and urban planning. The study also emphasizes the necessity of addressing the impact of new technologies—such as AI and augmented reality—on spatial design, promoting social participation, and developing innovative, climate-resilient urban models. In conclusion, Archigram's experimental projects serve as a powerful and transformative source of inspiration, guiding equitable, sustainable, and participatory design approaches to address today's complex urban challenges.

Keywords: Archigram, modularity and mobility, technology and urban design

1. Introduction

In contemporary society, the acceleration of technological advancements has significantly reshaped urban life and urban culture. This transformation, encompassing physical, social, cultural, and technological dimensions, transcends the traditional boundaries of the concepts of human–space–time. Within this context, questions such as how urban spaces should be configured, how individuals will experience these spaces, and how the social structure will be influenced by this transformation occupy an important place in the research and practice agendas of architecture and urban planning disciplines (Seymen Aksu & Yalçıner Ercoşkun, 2022).

It is anticipated that the cities of the future will evolve into focal points shaped by technological developments and defined through futuristic visions. Accordingly, various inquiries have been made regarding the extent to which technology can be integrated into urban design, and these inquiries have paved the way for innovative projects that push the boundaries of their time.

Integrating technology not only into buildings but also into social life, public spaces, and the processes through which individuals gain autonomy has become a fundamental approach. The objective of this understanding is not merely to produce buildings or physical environments, but to employ technology to transform individuals into participants of a more liberated, interactive, and dynamic mode of living. In this way, technology transcends being merely an instrumental component in the production of space and becomes an active element of social transformation and individual experience. This approach is particularly evident in the design vision of the Archigram group (Fernandez Rubio, n.d.).

Formed through the collaboration of Warren Chalk, Dennis Crampton, Ron Herron, Peter Cook, David Greene, and Mike Webb, the British group Archigram emerged in the 1960s as an intellectual platform where new ideas in architecture were generated, debated, and disseminated, fostering an experimental mindset that proposed radical tendencies in design (Wilkinson, 2023).

Archigram—its name derived from the combination of "architecture" and "telegram"—was initially founded as a magazine, but soon evolved into an intellectual movement that marked a significant turning point in the history of architecture (Figure 1). Rejecting conventional approaches to architecture, its founders adopted a more flexible, dynamic, and experimental design perspective. Questioning historical heritage and traditional architectural practices, Archigram sought to transform architecture by drawing inspiration from popular culture, exuberant visual narratives, and the emerging technological opportunities of the period (Gardinetti, 2024).



Figure 1. Cover images from Archigram 4 (left) and Archigram 8 (right) (Architecture & Design Community, 2025)

Radical Architectural Concepts of Archigram and Their Potential in Urban Design

Emerging in the 1960s under the strong influence of Modernism, the Archigram group adopted a radical stance in architecture by developing a dynamic, speculative, and flexible approach that challenged the rationalist and static planning paradigms of the period. The cities, social

environments, and intellectual atmospheres in which the members were raised shaped their architectural production, while the technological, social, and ideological transformations of the modern era profoundly influenced Archigram's experimental approach. The group argued that the city could not be defined by static and rigid boundaries, advocating instead for portable and transformable architectural proposals developed at the intersection of technology, individual needs, and popular culture, thereby transforming architecture into a forward-looking field of critical inquiry. In this respect, Archigram addressed unresolved issues of Modernism in creative ways, leaving a significant theoretical legacy for contemporary architectural thought. Today, rapid urbanization, mass migration, climate crises, and technological advancements necessitate the design of cities that are flexible, sustainable, and user-centered. Within this context, the principle of modularity introduced by Archigram in the 1960s has resurfaced in contemporary architecture through prefabricated structures, temporary housing solutions, and sustainable residential systems. Portable and mobile living units developed for emergency settlements following disasters and climate-induced migration closely align with Archigram's "moving city" concept. Additionally, through the widespread adoption of data-driven smart city applications, Archigram's technology-integrated urban vision is being reinterpreted in new ways, finding both theoretical and practical resonance in contemporary urban planning approaches. The group's key projects that exemplify its radical approach in architecture include Plug-In City, Walking City, Instant City, Living Pod, Cushicle, and Suitaloon (Somer, 2006). To illustrate the formal and conceptual diversity of these designs, English-language prompts were prepared and an AI-assisted design process was employed, generating spatial interpretations of these visionary architectural concepts.

2. Plug-in City

Plug-in City is an experimental urban system proposal developed by the Archigram group between 1962 and 1964, consisting of a synthesis of small-scale projects and conceptual ideas. The themes discussed in Issues 2 and 3 of the Archigram magazine during this period received positive feedback, and Peter Cook articulated this process as follows: "It was therefore inevitable that we should investigate whether the entire urban environment could be programmed and structured to adapt to change." Plug-in City was first published in 1964 in Issue 4 of the Archigram magazine. This work emerged as a speculative series of proposals designed for change, envisioning a computer-controlled urban system in which removable components would unite under a megastructure service framework. The system adopts a linear rather than circular form. However, as these linear structures expand and develop over time, their short-term accessibility to the surrounding rural settlements (villages, hobby houses, etc.) may diminish. Archigram designed Plug-in City as a connective network capable of integrating small-scale rural structures dispersed across Europe. In doing so, the proposal envisioned providing equal access not only to the urban center but to all lands and natural resources. The system's most significant characteristic is its capacity to "continuously construct and reshape itself." This dynamic structure is made operable through a monorail line that runs above the grid system (Figure 2). The monorail not only transports passengers but also carries cranes. These cranes are capable of moving modular components attached to the grid vertically, horizontally, and diagonally. In this way, spaces with various functions—from living units to parking structures—can be flexibly integrated into the system according to the "plug-and-play" principle (Tsigkouni, 2012).



Figure 2. A sectional view of Plug-in City illustrating its structural components (Tsigkouni, 2012).

Flexible and Modular Architecture

'A futuristic cityscape with flexible, modular buildings that can expand or shrink, dynamic architecture made of lightweight materials, structures that resemble plug-in capsules, minimalistic design with high-tech interfaces — vibrant colors, blue sky, utopian feel.'

Based on the information provided above, sample visualizations were generated using Lookx AI. The biomorphic and spherical structural forms depicted in these images are shaped by the radical visions of the Archigram group—particularly inspired by the flexible, modular, and ephemeral characteristics of the Plug-in City concept. These designs represent high-tech and autonomous living units independent from existing urban morphology, while simultaneously reflecting contemporary tendencies toward flexibility, adaptability, and personalization in urban planning. The capacity of AI to materialize such a vision can be regarded as a new methodological tool for exploring the potential of future sustainable and adaptive architectural solutions through an interdisciplinary approach (Figure 3).



Figure 3. AI-generated design: flexible and modular architecture.

3. Walking City

The concept of the Walking City, designed by Ron Herron, describes a structure resembling a robot capable of movement through its telescopic legs. This structure is not merely about the relocation of architectural components; rather, it signifies the capacity of the urban whole to move spatially (Figure 4). Free from attachment to a fixed location, this flexible system can reposition itself in response to needs, crises, resources, and opportunities, thereby demonstrating that the city is not dependent on a static physical setting. The character of such

a structure is boundless, and its movements are inherently unpredictable (Tutkun & Demirkan, 2023).

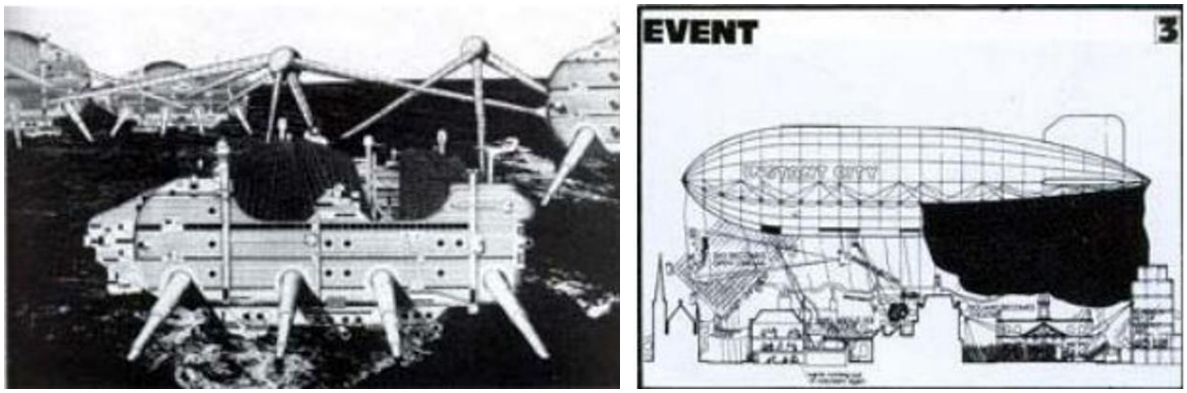


Figure 4. A sectional view of Plug-in City illustrating its structural components (Tsigkouni, 2012).

Mobile Urban Units

'A visionary mobile city with walking robotic buildings, movable housing units with wheels or legs, portable urban systems, a surreal blend of technology and architecture, inspired by Archigram's Walking City — bright, imaginative, sci-fi aesthetic.'

Based on the information provided above, sample visualizations were generated using Lookx AI. The mobile, spherical, and biomorphic units depicted in Figure 5 symbolize, in line with Archigram's vision, an autonomous, self-sufficient, and flexible mode of existence rather than a fixed and hierarchical urban structure. The wheeled and modular design emphasizes these units' capacity for spatial adaptation and relocation, challenging conventional notions of permanence in settlement. The ability of artificial intelligence to materialize this radical concept holds the potential to revive philosophical and architectural debates on limitless urbanization and life in perpetual motion. This study contributes to contemporary research examining the relationship between urban mobility and capsule architecture.



Figure 5. AI-generated design: mobile urban units

4. Instant City

Developed in 1970, the concept of Instant City was designed as a flexible organism capable of responding to the variable and immediate needs of urban inhabitants. Lacking a fixed structure,

this city can be shaped according to the desires and current conditions of its users (Figure 6). Instant City allows urban spaces to transform instantly in response to user requirements, providing flexibility and rapid adaptation. The project integrates inflatable and lightweight structural units through trailer modules, combining bridges, towers, support systems, scaffolding, audiovisual screens, projection equipment, and various electronic systems into a cohesive whole. Conceived as a temporary and dynamic urban model, the design draws inspiration from a circus structure that operates in one location for a limited time before relocating, thereby maintaining its mobility (Akgül, 2006).

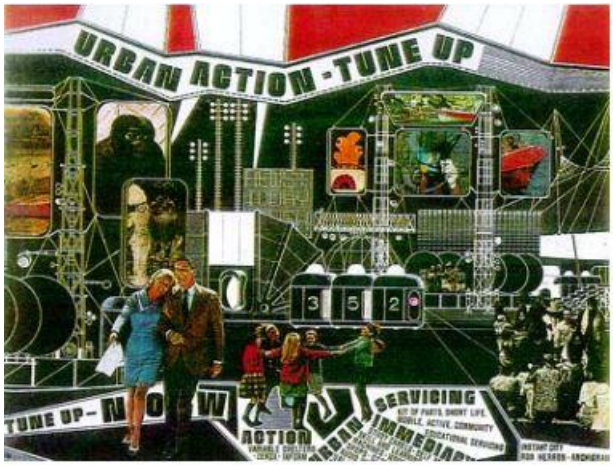


Figure 6. Instant City (Akgül, 2006)

Integration of Technology and Daily Life

'A high-tech living space where architecture is seamlessly integrated with digital technology, interactive walls, wearable smart devices, and intelligent building systems — futuristic but cozy environment, sleek design, cybernetic landscape.'

Based on the information provided above, sample visualizations were generated using Lookx AI. These images depict a public space defined not by traditional structural components, but by information, media, and temporary lighting. Large illuminated screens highlight a scenario in which the flow of information and ephemeral cultural events becomes more central than the architectural form itself. This parallels Archigram's pursuit of creating an urban environment centered on "events" or "experiences," rapidly assembled and dismantled. The space presents a hybrid landscape in which walls function not only as physical boundaries but also as dynamic communication surfaces. AI's interpretation emphasizes the transient and information-intensive nature of urban spaces, offering a significant contribution to contemporary discussions on digital public realms (Figure 7).



Figure 7. AI-generated design: Integration of Technology and Daily Life

5. Living Pod

Living Pod is a technology-integrated living unit concept developed by the Archigram group, focusing on individual life (Figure 8). The concept is expressed as a portable and modular capsule, defining the occupant's living space with maximum functionality in a minimal area. Advocating the idea that space should be mobile and transformable rather than fixed and permanent, this design radically challenges traditional notions of housing. Living Pod represents one of the early examples of user-centered, adaptive, and flexible spatial organization, proposing personalized micro-living environments that can be shaped according to an individual's lifestyle (Beşlioğlu, 2014).

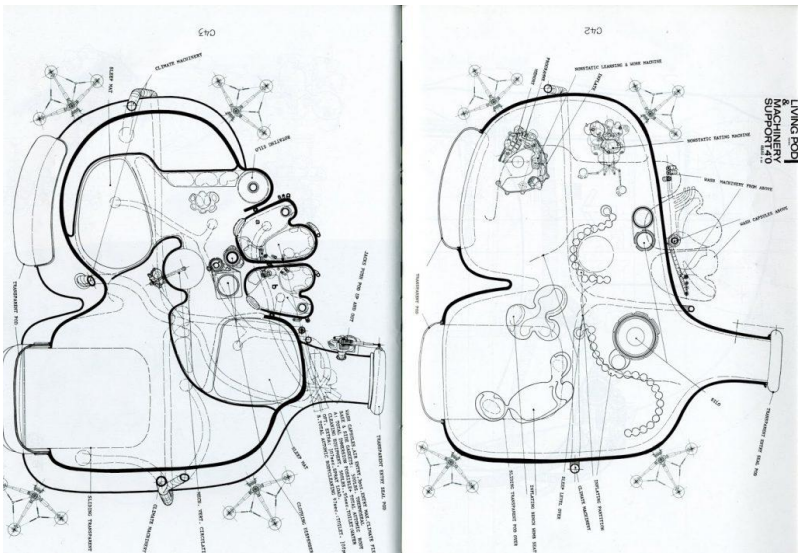


Figure 8. Living Pod (URL1)

Sustainable and Self-Sufficient Systems

'A green, futuristic neighborhood with solar panels, vertical gardens, and water recycling systems — eco-architecture with self-sufficient pods or capsules, surrounded by nature, combining organic forms with technology — clean, bright, hopeful atmosphere.'

Based on the information provided above, sample visualizations were generated using Lookx AI. The depicted vertical and curvilinear structures represent not only modular units but also

an ecological urban fabric interwoven with dense vegetation. In addition to the traditional Living Pod emphasis on technology and autonomy, these capsules incorporate biophilic design elements, reinforcing a symbiotic relationship between humans and nature. AI's interpretation merges contemporary architectural trends—such as urban farming, green façades, and vertical forestry—with the Living Pod's vision of individualized and flexible living, exploring the potential of future eco-autonomous living units. This study offers a novel solution to challenges of limited resources and high-density urban settlements through the lens of Archigram's radical philosophy (Figure 9).



Figure 9. AI-generated design: Sustainable and Self-Sufficient Systems

6. Cushicle

Cushicle is another radical living unit concept developed by Archigram member Michael Webb in 1966. Designed as a wearable living system, Cushicle is a compact structure that can be carried like a backpack and, when unfolded, transforms into a functional living space (Figure 10). It includes a sleeping area, food storage, and environmental control systems, thereby addressing concepts of individual freedom, mobility, and independence within the architectural context. This system is conceived to enable a person to live autonomously without dependence on the surrounding environment, and it serves as a significant example reflecting the impact of technological advancements on architecture during the latter half of the 20th century (Webb, 1966).

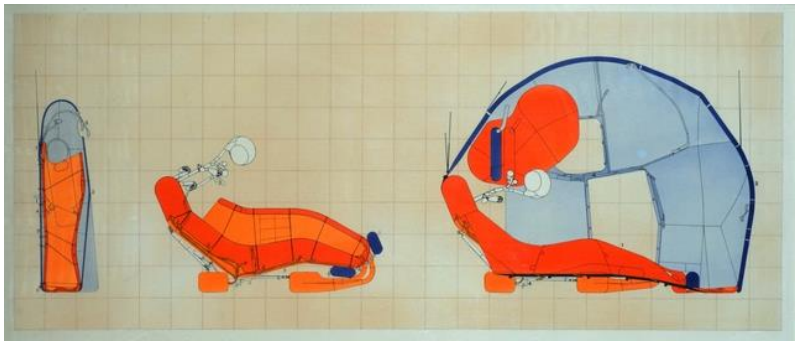


Figure 10. Cushicle (URL2)

Flexible Cities and Service Nodes

'Visualize Michael Webb's 1966 Cushicle concept as a contemporary urban design vision. The urban design features a dynamic, fluid public space filled with modular service nodes and charging stations where Cushicle users can temporarily 'plug in' and receive technological services. In this space, inflatable, transparent Cushicle units expand from their backpack form into personalized, capsule-like living environments. The ground and service nodes are covered in a futuristic, grid-like, technology-focused pattern. The atmosphere should blend the aesthetic of 1960s Futurism (Pop Art influences) with contemporary high-tech. A night or twilight setting, dominated by neon lights and pneumatic structures, emphasizing individual freedom and urban flexibility.'

Based on the information provided above, sample visualizations were generated using Lookx AI. In Figure 11, the inflatable, transparent, and individual living/rest units offer a contemporary interpretation of Cushicle's core concept: a personal habitat that meets individual needs and is portable anywhere. These designs create temporary and customized micro-spaces within public areas such as city squares, reflecting the individual's desire for autonomy from environmental conditions. The soft, illuminated, and almost ambient forms of the units emphasize the tension between digital interaction and personal space.



Figure 11. Flexible Cities and Service Nodes

7. Suitaloon

Suitaloon, also developed by Michael Webb, is another wearable living space concept that can be considered within the same thematic framework as Cushicle (Figure 12). Derived from the combination of "Suit" and "Balloon," this concept envisions a portable, inflatable dwelling unit that envelops the human body. Suitaloon is conceived as an architectural structure that directly engages with the human body and functions as its extension. In this respect, it advocates viewing space not only as a functional entity but also as an experiential and personal extension. By integrating technology with the human body, this design invites a reconsideration of architecture and living space as fluid and boundary-defying concepts (Webb, 1966).

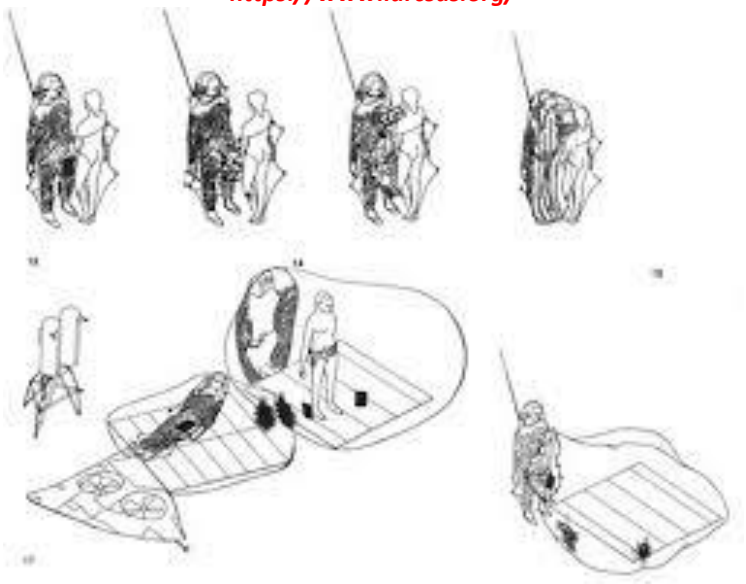


Figure 12. Suitaloon (URL3)

The Future of Urban Privacy and Fluid Spaces

'The city features a modular and lightweight infrastructure that adapts to the dynamic and fluid movements of individual Suitaloon users. People navigate urban spaces or temporarily 'settle' within their transparent or semi-transparent inflatable 'balloon' dwellings that envelop their bodies. These Suitaloons create personalized micro-environments. The city landscape is filled with high-tech, modular walking platforms, inflatable architectural elements, and light trails indicating energy flows. The atmosphere is futuristic, slightly dystopian yet emphasizing individual freedom, set at night or dusk. A strong contrast between neon colors and organic inflatable forms prevails.'

In Figure 13, the inflatable, illuminated, and spherical units evoke the concept of Suitaloon transforming from a wearable shell for individual shelter and environmental interaction into a full-scale spatial installation. Transparency and lighting convert these units into striking and temporary installations within the urban landscape, while positioning the user as a protected and autonomous presence against the backdrop of the modern metropolis. This design effectively visualizes architectural tendencies that challenge the necessity of fixed forms and blur the boundaries between personal and public space.



Figure 13. The Future of Urban Privacy and Fluid Spaces

8. Conclusion

This study examined the theoretical legacy of modularity and mobility—radical architectural concepts developed by the Archigram group in the 1960s—on contemporary urban design paradigms through AI-assisted visualization. In the context of rapidly changing urban needs, technological advancements, and global challenges such as the climate crisis, the visionary projects of Archigram—including Plug-In City, Walking City, Instant City, Living Pod, Cushicle, and Suitaloon—were materialized using AI-based design tools to explore their potential relevance to current urban planning and architectural practice.

The resulting visualizations offer a contemporary reinterpretation of Archigram's philosophy. The principle of modularity has been redefined beyond prefabrication, temporary shelter solutions, and adaptive housing systems, integrating biophilic design elements (as seen in the Living Pod interpretation) and high-tech infrastructure (as in Plug-In City) to create self-sufficient and ecological systems. The AI-generated images reinforced the notion that urban fabric need not operate within fixed, rigid boundaries but can function according to a megastructure logic, allowing detachable, plug-in, and rapidly transformable components.

The concept of mobility emphasized not only physical relocation—as exemplified by the robotic mobility of Walking City—but also the fluidity and temporality of urban experience and spatial functions. The visualization of Instant City highlighted the capacity to generate an "atmosphere" or "event" rapidly assembled and dismantled, structured more around information, media, and temporary occurrences than traditional architectural form. The interpretations of Cushicle and Suitaloon integrated architecture with the human body, demonstrating how personal freedom and urban privacy could be achieved through digital and pneumatic micro-environments. This approach presents a radical challenge to conventional notions of settlement, offering a theoretical counterpart to today's individualized and perpetually mobile lifestyles.

Methodologically, the use of tools such as Lookx AI should be regarded as a new interdisciplinary interface for materializing futuristic and speculative architectural concepts. AI demonstrates the potential for a novel research and design methodology in architecture and urban planning by synthesizing complex philosophical and architectural visions with rapidly evolving aesthetic and technological trends. This approach makes the design process more speculative, prototype-driven, and extends beyond traditional drawing techniques.

In conclusion, while Archigram's vision was nourished by the technological optimism of the 1960s, its proposed adaptive, flexible, and user-centered urban spaces exhibit strong theoretical alignment with contemporary demands for sustainability, adaptability, and personalized experiences. This study underscores that the cities of the future should be designed as dynamic systems based on continuous change and interaction rather than fixed forms, and that AI-based visualization constitutes a critical tool for understanding and disseminating such futuristic urban visions.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Architecture & Design Community. (2025, Ocak 10). *Archigram 10 – ADC.* https://ad-c.org/2025/01/10/archigram-10-adc/

Akgül, A. (2006). *Mimarlıkta mobilite kavramı: Göçebe çingeneler ve sirk yaşamı üzerine bir inceleme (Yüksek lisans tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü).*

Beşlioğlu, B. (2014). The critical approach of 'plug' in re-conceptualisation of architectural program. *VLC arquitectura*, 1(1), 59-76.

Gardinetti, M. (2024, Kasım 22). Archigram, geleceğin kalıntıları [Blog yazısı]. *Archinect*. https://archinect.com/marcelogardinetti/archigram-vestiges-of-the-future

Webb, M. (1966). The Cushicle. In Beyond Architecture (ACSA Annual Meeting Proceedings), ACSA.

Wilkinson, P. (2023). Gerçekten Bilmeniz Gereken 50 Mimarlık Fikri (8. Baskı). (V. Atmaca, Çev.). Başakşehir İstanbul: Domingo. (Orijinal çalışma basım tarihi 2010).

Fernandez Rubio, M. M. (t.y.). Architecture avant-gardes of the 60's: Archigram, Archizoom, Superstudio (22 sayfa). *Academia.edu.* https://www.academia.edu/44656371/Architecture_avant_gardes_of_the_60_s_Archigram_Archizoom_Superstudio

Seymen Aksu, N. ve Yalçıner Ercoşkun, Ö. (2022). Kentlerde dijital dönüşüm ve metaverse. *Eksen Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi,* 3(2), 108–122. https://doi.org/10.58317/eksen.1165011

Somer, P. M. (2006). *Archigram'ın modern mimarlığa getirdiği eleştirinin bilimkurgusal boyutu (Yüksek lisans tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü). Polen, İTÜ.*

Tsigkouni, S. (2012). Plug-In City – Archigram (1964). Humanities Assignment: Issues in Contemporary Architecture, Sheffield School of Architecture. https://www.academia.edu/6048928/PLUG_IN_CITY_Archigram

Tutkun, Z. ve Demirkan, Ö. (2023). Konutlarda hareketli iç mekân tasarımı. *İnsanat: Sanat Tasarım ve Mimarlık Araştırmaları Dergisi,* 3(2), 183–204.

URL1: https://hiddenarchitecture.net/living-pod/ last accessed on November 11, 2025.

URL2: https://architecturewithoutarchitecture.blogspot.com/p/cushicle-and-suitaloon-were-conceptual.html last accessed on November 11, 2025.

URL3: https://tr.pinterest.com/pin/824158800545300163/ last accessed on November 11, 2025.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Timber Decay in Gaziköy Houses and The Sustainability of The Rural Fabric

Özlem BOZKURT [1*]
ORCID 1: 0000-0002-8549-0648
[1] Assisst. Prof. Dr., Tekirdağ Namık Kemal University, Vocational College of Technical Sciences, Department of Material and Material Processing Technology, Tekirdağ-Türkiye
obozkurt@nku.edu.tr (Responsible Author)

Abstract

Gaziköy is a coastal settlement in the Şarköy district of Tekirdağ. Preserving much of its authentic architectural heritage, Gaziköy is currently protected under both urban and archaeological site status. Traditional wooden houses constitute one of the most significant components of the settlement's architectural heritage. Despite various natural and human-induced threats, the village continues to preserve authentic examples of wooden structures. The aim of this study is to evaluate the current problems of timber decay in Gaziköy houses and to discuss their effects on the sustainability of the rural fabric. The research is based on field observations, non-destructive wood material analyses, and data compiled from previous survey drawings. The analyses revealed that wooden elements such as structural frames, floors, roofs, and façades have deteriorated due to physical factors, biological decay, and human-induced problems. These issues affect not only the durability of the buildings but also the integrity of the settlement pattern and the continuity of its cultural identity. The study emphasizes that ensuring the sustainability of the rural fabric requires integrating appropriate conservation methods for wooden materials into holistic rural heritage management strategies. The continuation of traditional repair techniques, the involvement of the local community, and the implementation of sustainable tourism policies are highlighted as essential steps for the long-term preservation of Gaziköy's wooden houses and the rural environment they shape.

Keywords: Gaziköy houses, timber decay, conservation, rural heritage, sustainability

1. Introduction

Gaziköy, a coastal settlement located in the Şarköy district of Tekirdağ, stands out as one of the most significant rural heritage areas of the region with its authentic architectural fabric and multilayered cultural structure. Since the Ottoman period, the settlement has developed around economic activities such as viticulture, olive cultivation, and fishing, traces of which still characterize the local landscape and social life today.

Gaziköy is among the few settlements that have preserved a large part of their original architectural heritage. The village is protected under both *urban conservation* and *archaeological site* status, and there are forty-one registered examples of civil architecture within the settlement (Özer et al, 2023). This situation demonstrates that Gaziköy possesses values that must be preserved not only in terms of architectural heritage but also with respect to cultural continuity and rural lifestyles.

Timber plays a crucial role in shaping the civil architectural identity of the settlement. The timber-framed houses are distinguished by the use of locally sourced wooden materials in structural components such as load-bearing systems, floors, and roofs. However, the timber elements in these houses are increasingly affected by physical, biological, and human-induced factors, leading to progressive material degradation. These problems threaten not only the structural integrity and lifespan of individual buildings but also the coherence of the rural fabric and the continuity of its cultural identity.

The aim of this study is to examine the problems related to the timber material used in Gaziköy houses and to evaluate their impact on the sustainability of the rural fabric. While documenting

the deterioration processes of timber, the study also seeks to discuss appropriate conservation approaches necessary for transmitting the traditional rural environment to future generations.

2. Materials and Methods

This research was conducted in Gaziköy, a settlement located within the Şarköy district of Tekirdağ province. Within the scope of the study, timber structures that have retained their authenticity were selected based on their preservation status, material integrity, and representativeness within the overall settlement pattern. During the field survey, the current conditions of the buildings were documented through photographs, and deteriorations observed in façades, floors, roofs, and load-bearing structural elements were recorded. Previously prepared measured drawings (rölöve), registration documents, and data from the Tekirdağ Cultural Inventory were also evaluated as supplementary sources.

Non-destructive observation techniques were employed in identifying timber-related problems. On-site examinations were carried out to detect signs of moisture, cracks, deformation, and biological deterioration in wooden components. No microscopic or chemical analyses were performed; instead, assessments were based on visual observations and comparative literature data. This approach enabled the collection of reliable information without causing damage to the original material of the registered buildings.

The data obtained from the fieldwork were classified according to types of deterioration. The findings were then analyzed to discuss the conservation issues of Gaziköy houses within the broader context of rural heritage sustainability.

3. Historical and Cultural Context of Gaziköy

Gaziköy is an important coastal village located on the shores of the Marmara Sea, at the foothills of the Ganos Mountains. It has witnessed continuous settlement from antiquity to the present day. Known as *Ganos* in ancient times, the settlement demonstrates a remarkable historical continuity supported by archaeological findings and epigraphic evidence. The discovery of tomb stelae, ceramic kilns, and the remains of religious structures in the area reveal the archaeological significance of Gaziköy (Bülbül, 2019).



Figure 1. Gaziköy settlement (tr.wikipedia.org)

During the Ottoman period, Gaziköy became known for its agricultural production—particularly viticulture and olive cultivation—as well as for its rich marine resources. From the late 19th century onward, the region also drew attention for its mining potential. According to Özkan (2023), between 1876 and 1950, petroleum and coal exploration activities in and around Gaziköy directly influenced the settlement's economic and social structure. These diverse

economic activities contributed to the formation of a multilayered rural fabric where agricultural production coexisted with early industrial enterprises.

Today, Gaziköy is protected as both an urban conservation site and an archaeological site. In 2016, the Edirne Regional Council for the Conservation of Cultural Heritage designated the village as an "urban conservation area," during which forty-one examples of civil architecture were officially registered (Özer et al., 2023; Arkeolojik Haber, 2016). Furthermore, in 2021, the Tekirdağ Metropolitan Municipality approved a 1/5000-scale Conservation-Oriented Master Zoning Plan for Gaziköy (Tekirdağ Metropolitan Municipality, 2021). These decisions demonstrate that the village holds a multifaceted protection status encompassing both its archaeological and architectural heritage.

In recent years, projects initiated by local authorities have also attracted attention. Within the framework of the "Heritage Workshop" (Miras Atölyesi) initiative of the Tekirdağ Metropolitan Municipality, the restoration of numerous houses in Gaziköy and its surroundings has been planned (Anonymous, 2019). These initiatives emphasize that Gaziköy should be regarded not merely as a remnant of the past, but as a living component of sustainable rural heritage.

4. Use of Timber in Gaziköy

Gaziköy houses are timber-frame structures built upon stone ground floors, reflecting the characteristic architectural features of the coastal settlements of Tekirdağ. These houses, mostly two-storey dwellings, are adapted to the region's topography and are situated on sloping terrain (Figure 2). Their floor plans are typically organized around a central sofa, with rooms symmetrically arranged around this core. A significant portion of the building stock in Gaziköy was constructed between the late 19th and early 20th centuries, reflecting local production techniques and traditional material practices.



Figure 2. Mümin Pala House, Gaziköy

The timber-frame system, widely used in traditional Turkish architecture, also forms the principal construction technique in Gaziköy houses. In this system, the structural framework is composed of wooden posts, beams, and diagonal braces, while the spaces between them are filled with adobe, brick, or stone (Çobancaoğlu, 2003). This method was preferred in earthquake-prone regions because it provided both lightness and flexibility. Stone foundations were generally used at the junction between the frame and the ground, preventing moisture from coming into direct contact with the wooden elements (Saydamer, 2014).

In the Gaziköy examples, stone masonry is typically used on the ground floor, while timber-frame construction is applied on the upper levels (Figure 3). This stratified construction approach offers a solution that is well adapted to both the material diversity and climatic conditions of the region.



Figure 3. Stone masonry on the ground floor, timber-frame walls on the upper floor, Gaziköy

Timber floor beams play a crucial role in the structural integrity of the houses. As shown in Figure 4, the floors are formed by wooden boards placed over timber beams. The ceilings, on the other hand, are usually plain and finished with simple wooden laths (Figure 5). Similar structural systems are also common in other traditional settlements across the Thrace region (Pala Azsöz, 2022).



Figure 4. Floor beam construction detail, Gaziköy



Figure 5. Ceiling and wall details, Gaziköy

The roofs are hipped and covered with traditional alaturka clay tiles. Timber rafters and purlins carry the roof loads. On the façades, timber components are used not only as structural elements but also as aesthetic features. Wooden craftsmanship is prominently displayed in the design of bay windows, overhangs, eaves, and window frames. Similarly, in other traditional houses of Tekirdağ and its surroundings, façade surfaces are finished with either wooden cladding or lime plaster.

The types of timber used in the construction of Gaziköy houses are closely related to the region's natural vegetation. In the Thrace region, oak (*Quercus*), pine (*Pinus*), and chestnut (*Castanea*) are the most commonly used local species (Saydamer, 2015). Owing to their durability and workability, these species were preferred for both load-bearing and finishing elements.

To enhance resistance against the region's humid maritime climate, some examples show that wooden surfaces were protected with traditional oil-based paints or covered with lime-based plasters. These practices aimed to extend the material's lifespan by reducing direct exposure to air and moisture.

In Gaziköy houses, timber stands out not only as a structural component but also as an expression of craftsmanship. Handcrafted yet modest wooden details can be observed in doors, windows, and ceilings. The console brackets beneath bay windows, the carved window surrounds, and the projecting eaves are key features defining the architectural character of the region. These details are not only aesthetically motivated but also structurally functional: for instance, the wide eaves protect wooden façades from rainfall, while the brackets support the overhangs. Thus, every timber element in Gaziköy houses carries both technical and cultural significance.

5. Timber Material Problems

In Gaziköy houses, timber constitutes the main component of the structural frame as well as the flooring, roofing, and façade elements. However, by its very nature, timber is highly susceptible to both environmental and human-induced factors. This vulnerability has led to various forms of deterioration that threaten the authenticity and integrity of the buildings. Similar issues observed in traditional wooden structures across Türkiye have also been identified in the case of Gaziköy (Perker & Akıncıtürk, 2006; Kartal, 2016).

Due to its hygroscopic nature, timber is sensitive to fluctuations in environmental humidity and temperature. Changes in moisture content trigger swelling, shrinkage, and cracking behavior (Ridout, 2004). In Gaziköy, which is located in close proximity to the sea, high humidity levels and salt-laden air cause deformation and surface deterioration in timber elements. In addition, UV radiation leads to color fading and thermal degradation on sun-exposed façades (Figure 6). Although physical deterioration develops gradually, long-term neglect may result in cross-sectional loss of load-bearing elements. Deflections observed in floor beams and eaves are typical indicators of such deformation.



Figure 6. Surface greying caused by weathering and UV exposure on a timber façade in Gaziköy

As an organic material, timber is also vulnerable to biological degradation. The most common types of decay observed in Gaziköy houses are caused by fungi and insects. Wood-decay fungi (*Basidiomycetes*) decompose cellulose and lignin, leading to a weakening of the fiber structure. Brown rot, particularly prevalent in water-exposed areas, is the most common type of fungal decay. Figure 7a shows a floor element darkened and deformed due to brown rot, while Figure 7b illustrates fungal deterioration in a roof structure. The decay, exacerbated by human neglect and abandonment, has spread through ceilings and floors, eventually causing structural collapse.



(a) **(b)**

Figure 7. (a) Example of a floor deformed by brown rot fungus in Gaziköy. (b) Attic timber structure deformed due to moisture and fungal infestation

Additionally, channels formed by wood-boring insects and termites cause significant cross-sectional loss in structural members (Bozkurt, 2013). Gaziköy's humid climate supports the life cycle of these biological organisms, accelerating the overall decay process.

One of the most evident problems observed in Gaziköy's wooden buildings is the lack of maintenance. In long-abandoned or unused houses, roof leaks, broken gutters, and uncontrolled vegetation growth contribute to rapid timber decay (Pala Azsöz, 2022). Moreover, improper repair attempts—such as the use of cement-based plasters, plastic paints, or incorrectly

dimensioned timber reinforcements—block the natural breathability of the material and accelerate deterioration (Figure 8). In some cases, interventions made during the re-functionalization of buildings also damage the original fabric. Such practices pose a critical threat to the holistic sustainability of the rural identity.



Figure 8. (a) PVC window inserted into a stone wall with brick infill; (b) fiberboard covering used to conceal moisture damage on ceiling; (c) old wooden door reused as support for stairs and ceiling structure

6. Conclusion and Recommendations

Gaziköy is one of the few coastal settlements in Tekirdağ that has largely preserved its authentic wooden housing fabric. The construction techniques, craftsmanship, and spatial organization of these buildings clearly reflect the rural way of life and the material knowledge of their period. However, the analyses reveal that the timber material has suffered significant damage over time due to physical, biological, and human-induced factors. This condition threatens not only the lifespan of individual structures but also the integrity of the rural fabric. Therefore, the timber-related problems observed in Gaziköy's traditional buildings demonstrate that conservation should not be limited to physical restoration alone but should instead be approached through a holistic heritage management framework. Within this framework, multidimensional conservation principles should be developed, ranging from material-based approaches to community involvement.

Material-based conservation approaches play a fundamental role in the sustainability of Gaziköy's traditional wooden structures. Conservation interventions should be compatible with the original material and technical characteristics of the buildings. Non-destructive analytical methods should be prioritized in diagnostic and intervention processes. Moreover, studying the mechanical properties of local tree species and ensuring their sustainable use in restoration practices are crucial both ecologically and structurally.

Education and the participation of skilled artisans constitute another indispensable component of the conservation process. The expertise of local carpenters and woodworkers should be documented and integrated into academic and training programs. Establishing local workshops in collaboration with universities, municipalities, and the Regional Council for the Conservation of Cultural Heritage would sustain the transfer of traditional craftsmanship from master to apprentice. In this regard, "the Miras Atölyesi" (Heritage Workshop) initiative

represents an important step; however, its activities have not been adequately maintained to ensure long-term sustainability.

From the perspective of sustainable rural heritage management, Gaziköy's rural landscape should be regarded not only as an architectural heritage area but as a living cultural landscape. Restoration policies should be supported by economic models that allow local residents to sustain their livelihoods, such as eco-tourism, handicrafts, and small-scale accommodation initiatives. In the implementation of the Conservation-Oriented Development Plan, it is essential to strengthen local participation mechanisms alongside environmental sustainability principles.

Finally, continuous research and documentation are vital for the preservation of Gaziköy's wooden architectural heritage. Documentation studies concerning the architectural, material, and functional characteristics of the buildings should be periodically updated. The integration of photographs, drawings, measured surveys, 3D scans, and archival materials will enable the establishment of a long-term monitoring system. This will not only facilitate the tracking of material deterioration but also ensure that future conservation decisions are grounded in scientific evidence.

Ultimately, the preservation of timber in Gaziköy signifies not merely the repair of physical structures but also the safeguarding of rural lifestyles, collective memory, and local identity. Therefore, sustainable conservation strategies must place both material science and cultural continuity at their core, ensuring that the authentic identity of Gaziköy is preserved within the principles of holistic heritage management.

Thanks and Information Note

This study was enriched by the valuable contributions of many students who participated in the Surveying and Restoration Project course conducted between 2016 and 2024 in the Ganos Region. Their dedication, fieldwork, and documentation efforts have been an essential part of this research. I sincerely thank all of them for their commitment and collaboration.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Anonim. (2019). *Geçmişe ilk adım: Miras Atölyesi.* Tekirdağ Büyükşehir Belediyesi, İmar ve Şehircilik Dairesi Başkanlığı, Kültür Varlıkları Şube Müdürlüğü. Tekirdağ: Toprak Ofset Matbaacılık.

Arkeolojik Haber. (2016, Nisan 14). Gaziköy kentsel sit alanı oldu. https://www.arkeolojikhaber.com/haber-tekirdagda-gazikoy-kentsel-sit-alani-oldu-196/

Bozkurt, Ö. (2013). Anobium punctatumun biyolojisi ve mücadelesinde çeşitli yöntemler. *Yapı Dünyası Dergisi,* 42–47.

Bülbül H. A. (2019). *Tekirdağ Ganos'tan (Gaziköy) bir mezar steli: Ioukounda.* In *Mnemes Kharin: Filiz Dönmez Öztürk anısına makaleler. Anadolu arkeolojisi, epigrafisi ve eskiçağ tarihine dair güncel araştırmalar* (pp. 129–140). İstanbul: Homer Kitabevi ve Yayıncılık. ISBN 978-9944-483-86-5.

Çobancaoğlu, T. (2003). Türkiye'de geleneksel ahşap ev yapı sistemlerinin irdelenerek gruplandırılmasına yönelik bir değerlendirme. *Tasarım + Kuram,* 2(3), 27–42. https://doi.org/10.23835/tasarimkuram.240843

Kartal, S. N. (2016). Tarihi Ahşap Yapılarda Biyotik/Abiyotik Bozunmalar ve Koruma/Bakım Önlemleri. *Restorasyon ve Konservasyon Çalışmaları Dergisi,* 16, 51–58.

Özer, N., Kiper, T., Çabuk, S. (2023). Tekirdağ Ganos Bölgesi Kırsal Yerleşmelerinde Tarım ve Turizm Temelli Planlama Yaklaşımına Yönelik Strateji Geliştirme. *Journal of Humanities and Tourism Research,* 13 (1), DOI: 10.14230/johut1339, s.205-229.

Özkan, A. (2023). Osmanlı'dan Cumhuriyet'e Şarköy, Mürefte ve Gaziköy (Ganos) bölgelerinde petrol ve kömür çıkarma çalışmaları (1876-1950). *Vakanüvis – Uluslararası Tarih Araştırmaları Dergisi,* 8 (Dr. Recep Yaşa'ya Armağan), 2995-3035. https://doi.org/10.24186/vakanuvis.1351375

Pala Azsöz, G. (2022). Geleneksel konut mimarisi: Tekirdağ Ertuğrul Mahallesi incelemesi. *EKSEN Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi,* 3(2), 89–107. https://doi.org/10.58317/eksen.1142364

Perker, Z. S., & Akıncıtürk, N. (2006). Cumalıkızık'ta ahşap yapı elemanı bozulmaları. *Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi,* 11(2).

Ridout, B. (2004). *Timber Decay in Buildings* London: Spon Press, ISBN: 0-419-18820-7

Saydamer, A. (2014). Türkiye'deki geleneksel ahşap yapılarda kullanılan taşıyıcı sistemlerin irdelenmesi ve Bursa örneği. geleneksel yapım teknikleri üzerine bir inceleme (Unpublished PhD thesis). Uludağ Üniversitesi, Bursa.

T.C. Kültür ve Turizm Bakanlığı. (2022, 16 Aralık). Tekirdağ halk mimarisi. https://www.kulturportali.gov.tr/turkiye/tekirdag/kulturatlasi/tekirdag-halk-mimarisi

Tekirdağ Büyükşehir Belediyesi. (2021). Meclis Karar Özetleri: Gaziköy Mahallesi koruma amaçlı nazım imar planı. https://www.tekirdag.bel.tr/karar_metin_goruntule/1825/1748

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Adaptive Reuse of Historical Buildings as Libraries: Original Function-Based Approaches

Rümeysa AYDIN [1]*

ORCID 1: 0009-0000-3968-1155
[1]Research Assistant, Nuh Naci Yazgan University, Faculty of Fine Arts and Design, Department of Interior Architecture and Environmental Design, Kayseri-Türkiye
raydin@nny.edu.tr (Responsible Author)

Şebnem ERTAŞ BEŞİR [2]

ORCID 2: 0000-0002-0568-6529
[2] Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya-Türkiye
sertasbesir@akdeniz.edu.tr

Abstract

Adaptive reuse, also referred to as re-functionalization, is an established approach that aims to adapt existing buildings to contemporary requirements while preserving their historical and architectural values. Within this framework, the conversion of historical buildings into libraries stands out as a practice that combines social benefit with heritage conservation. This study compiles and examines cases classified according to the original functions of historical buildings (e.g., religious structures, industrial facilities, palaces and public buildings, bank buildings, and military barracks), focusing on the strategies employed in their transformation into libraries. The analysis addresses aspects such as spatial reconfiguration, structural reinforcement, accessibility, integration of technical infrastructure (climate control, acoustics, lighting, fire safety), placement of collections and user programs, as well as conservation principles including minimal intervention, reversibility, and the legibility of the relationship between new and old. The findings demonstrate that the constraints and opportunities inherent in original functions distinctly shape transformation strategies, thereby providing architects, planners, and cultural heritage experts with decision-supportive principles and comparative insights for adapting historical buildings into libraries without compromising historical integrity.

Keywords: Adaptive reuse (re-functionalization), historical buildings, library, conservation principles

1. Introduction

Any kind of architectural work built for shelter or other purposes is defined as a structure (TDK, 2022). A structure is also defined as a whole formed by many building materials that protects its contents from adverse external conditions, and structures can be classified according to many criteria. In this context, accommodation structures (hotels, etc.), healthcare structures (hospitals, pharmacies, etc.), religious structures (mosques, churches, synagogues, etc.), commercial structures (business inns, shops, etc.), social structures (theaters, coffeehouses, cinemas, etc.), transportation structures (roads, bridges, ports, airports, etc.), water structures (dams, water canals, etc.), sports structures (indoor sports halls, stadiums, etc.), educational structures (libraries, schools, etc.), monuments (Çanakkale Martyrs' Memorial, Anıtkabir, etc.), residences (houses, apartments, etc.), and industrial structures (factories, etc.) are among the main types of structures widely referenced in the literature (Güner and Yüksel, 2016).

Today, rapid changes in social, cultural, and technological fields have caused many structures to no longer fulfill their original functions. Therefore, various types of structures that have fallen out of use over time are being re-evaluated and reorganized with contemporary techniques in line with today's needs. This process is called "adaptive reuse" or "refunctionalization," which means bringing structures back into use with new functions. The adaptive reuse approach stands out as a significant method at the intersection of architecture, interior architecture, and conservation disciplines.

Adaptive reuse, or refunctionalization by another name, is a concept that dates back to ancient times. Wong cites historical examples of this approach, such as the use of a cave as a living space or animal hides as clothing. This concept is directly related to many practices such as adaptation, addition, alteration, conservation, transformation, expansion, maintenance, modernization, reconstruction, renovation, rehabilitation, relocation, repair, replication, restoration, and strengthening, and should be addressed in conjunction with and as part of these processes. Examples of adaptive reuse can be found everywhere today. Especially structures with cultural heritage value undergo remarkable transformations in line with contemporary approaches shaped by economic concerns. In this context, old schools are converted into residences, prisons into hotels, industrial facilities into art studios, and places of worship into restaurants, thus being used with new functions (Wong, 2017). The refunctionalization of historical buildings is not only a process of structural transformation but also of great importance in ensuring cultural continuity, preserving urban identity, and maintaining collective memory. Especially structures reused with public and cultural functions such as libraries bring together the architectural heritage of the past with today's understanding of information sharing.

The Turkish Language Association (TDK) defines the concept of a library as "an institution that collects, organizes, and effectively provides access to all kinds of recorded information sources such as books, films, records, etc., in accordance with its founding purpose and mission" (TDK, 2022). Although the term library often evokes spaces with books and study desks, today there are many different types of libraries shaped according to technological needs and designed with contemporary methods. The Turkish Librarians' Association (TKD) emphasizes that libraries should no longer be seen merely as places where books are stored and lent, but rather as active centers of social interaction, cultural transformation, and information sharing (TKD, 2023).

Although studying is an individual act, education has historically been a collective phenomenon. Therefore, educational structures (schools, libraries, faculties, study halls, study centers, private teaching institutions) have served and continue to serve as spaces for collective study throughout the centuries. The need for collective study continues today. For this reason, refunctioning spaces—especially as libraries that respond to a public demand—is socially and culturally beneficial.

2. Materials and Methods

This study was conducted based on the qualitative research method. Qualitative research is a term that encompasses various methods involving its own specific techniques such as narrative analysis, ethnographic study, and content analysis (Aydın, 2023). In fact, it would not be incorrect to characterize this research as a typological approach. Typological thoughts and actions assume two things: first, the recognition and discovery of basic types; second, the ability to see things in complementary relationships. The discussion of type and typology can encourage a way of looking at the built environment; while helping us to recognize and discover basic types, it also enhances our ability to perceive differences and similarities by noticing the invisible connections between architectural works (Güney, 2007). For this purpose, the original functions of some historical buildings that have been converted into libraries were first identified in the study (Figure 1).

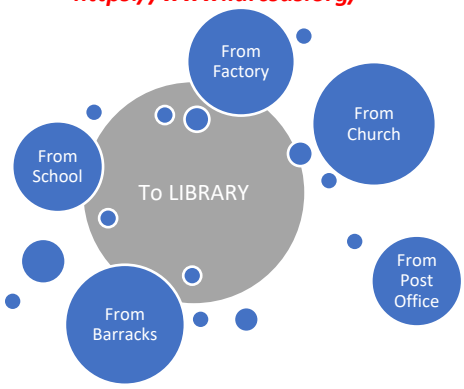


Figure 1. Original functions of some historical buildings converted into libraries (created by the author)

Subsequently, these historical buildings identified through a literature review were classified according to the building category corresponding to their original functions, based on their intended purposes at the time of construction (Figure 2).

From Industrial Building to Library	• Adams Street Library **(Brooklyn, USA)** • Afife Batur Library **(İstanbul, Türkiye)** • Cemil Meriç Library **(Antalya, Türkiye)** • İstanbul Bilgi University Library **(İstanbul,Türkiye)** • LocHal Library **(Tilburg, Netherlands)**
From Administrative or Public Building to Library	• Çorum Former Municipality Building Library **(Türkiye)** • Gürün Public Library–Women's House **(Sivas, Türkiye)** • Idea Exchange **(Ontario, Canada)** • Neude Utrecht Library **(Utrecht, Netherlands)**
From Educational Building to Library	• Historical Atatürk Primary School Library **(Balıkesir, Türkiye)** • James Baldwin Media Library **(Paris, France)** • Bibliotheek Aalst - Utopia **(Aalst, Belgium)**
From Religious Building to Library	• Athy Community Library **(Kildare, Ireland)** • Virgin Mary Church Library **(Kayseri, Türkiye)** • IGI Library **(Liberec, Czech Republic)** • House of Literature - Maison de la littérature **(Québec, Canada)** • Selexyz Dominicanen Bookstore **(Maastricht., Netherlands)**
From Commercial Building to Library	• Biblioteca Salaborsa **(Bologna, Italy)** • Kansas City Central Library **(USA)**
From Civil Building to Library	• Kressbronn Library **(Kressbronn am Bodensee, Germany)** • Heybeliada Public Library **(Islands-Istanbul, Türkiye)** • Transformation of Old House into Capsule Hotel and Library **(Zhejiang, China)**
From Military Building to Library	• Gendarmerie Station Library **(Antalya, Türkiye)** • Baby and Child Library in Döşemealtı **(Antalya, Türkiye)** • Rami Library **(İstanbul, Türkiye)**

Figure 2. Classification of historical buildings converted into libraries (Created by the author)

The classified examples were examined using a descriptive method in line with the established analysis criteria. These criteria include spatial reconfiguration, structural reinforcement, accessibility, technical infrastructure integration, and conservation principles.

The analysis results reveal how the original function guides transformation strategies across different building types, offering insights for conservation and design practice. Furthermore, the classification and inclusion of these buildings—converted into libraries—into the literature

according to their original functions will demonstrate that the information regarding what needs to be done before, during, and after the adaptive reuse process may vary depending on the original function. In this way, the data obtained can be analyzed in a more systematic and comparable manner based on the aforementioned classification.

3. Findings and Discussion

It is observed that a large number of buildings that have lost their original function in our country and around the world have been reintegrated into social life through contemporary library use. Due to its functions of providing access to information and serving as a public gathering space, the library has become a frequently preferred target function in the re-evaluation of idle buildings from different periods and typologies. Since every building is initially designed for a specific purpose of use, during the process of re-evaluating these buildings as libraries, the original function generates both limiting conditions and new spatial and symbolic possibilities for the designer at many scales, such as spatial organization, structural system, openness, and circulation layout.

Figure 3 shows the global distribution of building examples that have been converted into libraries. According to the literature review, it has been determined that in Canada, the USA, France, the Netherlands, Germany, the Czech Republic, Belgium, Italy, Turkey, and China, many buildings with different original functions—such as factories, churches, school buildings, post office buildings, and barracks—and often of historical significance, have been converted into libraries (Figure 3).



Figure 3. Countries with buildings converted into libraries through adaptive reuse around the world (Created by the author based on the literature review of buildings converted into libraries)

Most adaptively reused buildings possess cultural, historical, aesthetic, artistic, rarity, or folkloric values. Buildings that embody one or more of these values are considered architectural heritage. According to ICOMOS, architectural heritage is defined as buildings and groups of buildings of various scales and characteristics that are the common property of humanity, that must be transmitted to the future with their original qualities preserved, and that should be protected in accordance with integrated conservation principles (ICOMOS 2013). The groups

of historic buildings that possess these values, require preservation, and have been renewed through conversion into libraries are examined in this study under seven categories: industrial, administrative, educational, religious, commercial, civil, and military.

3.1. Buildings Converted from Industrial Structures into Libraries

Following the Industrial Revolution, especially during the 1930s under statism policies, many industrial buildings were constructed in various countries but gradually lost their functions over time. Urbanization, pressure from land value, and economic transformations have placed these areas at risk of disappearance. However, since the 1970s, these buildings have begun to be regarded as "industrial heritage," and the idea that they should be preserved as part of urban identity has gained importance. In this context, international organizations such as UNESCO, DOCOMOMO, ERIH, ICOMOS, and its sub-unit TICCIH have been operating to document and preserve industrial heritage (Genç, 2023).

These industrial buildings that have lost their function have begun to be used for different purposes. Due to their nature as industrial structures, their wide spans and open spatial layouts make them suitable for adaptive reuse in functions that require multi-user occupancy, such as libraries, hotels, social centers, and museums. These buildings, which represent industrial heritage with their architectural qualities, also gain value when they are designed by prominent architects. Instead of demolition and reconstruction, adaptive reuse should be adopted as a primary strategy, and cultural continuity should be considered. Today, industrial buildings can be re-evaluated through reuse by being converted into museums, art studios, offices, residences, schools, and multifunctional buildings (Cantell, 2005). Examples of industrial buildings converted into libraries are frequently encountered both in Turkey and abroad.

One such example is a historic building in Brooklyn, dating back to 1901, which has served various functions over the years, from a torpedo factory to a recycling facility. Today, the ground floor of this adaptively reused industrial building functions as a library. The building also includes residential units and commercial spaces. Designed by the WORKac team, this library preserves the dialogue between old and new along the brick perimeter walls, which contrast with a series of pixelated murals inspired by the layered history of the building. The fifteen-meter-high windows surrounding the library support a series of open spaces that connect to a porous volume and an elevated children's area. The volume, clad in MDF with a custom CNC-milled pattern, offers suitable environments for stroller parking and book storage within its wide and curved openings; the elevated section provides young visitors of the library with the opportunity to view the Manhattan skyline, East River, and Main Street Park from the main reading room (Karakoç, 2022). This design decision highlights the importance of designing spaces not only to meet physical needs but also to address users' psychological needs, demonstrating that the designer has provided emotional comfort to encourage users to spend more time in a comfortable environment.

Another example is the LocHal in Tilburg, the Netherlands, which was converted from a locomotive workshop into a library and now houses Bibliotheek Midden-Brabant (public library), Kunstloc Brabant (cultural and arts research center), and Brabant C (cultural and creative industries investment fund) units (Döğerlioğlu, 2019).

It is also known that a section of the historic Hasanpaşa Gasworks, which ceased functioning as a factory in 1993, has been converted into a library. Originally a coal gas plant, Hasanpaşa Gasworks was refunctioned with two main functions in mind: a museum and a library, and was

organized into museum and library buildings. In this context, the museum buildings were designed as an activity hub incorporating temporary exhibition spaces, a science center and workshop, a bookstore, and a museum shop, and were included in the functional scheme as "Museum Buildings"; the library was planned to operate in connection with shared workspaces and a café. The former compressor building (Building F) of the gasworks was transformed into the Afife Batur Library, serving as a library and quiet study area. The ground floor consists of a reception desk, library, and research sections. Concrete pedestals are surrounded by bookshelves, and the niches between them are used as research and reading areas. The research areas include high tables with eight computers, while the reading areas feature free seating units. Work desks have been placed in front of the façade openings to benefit from natural light. The upper floor was designed as a free study area with tables along the central axis and a stepped seating arrangement along an inner wall. User comfort was enhanced with movable side tables and storage niches (İtez, 2022).

Another example is the Cemil Meriç Library located in Antalya (Figure 4). The building was converted from the transformer building of a former yarn weaving factory into a library. The building consists of a ground floor and a basement; the lower floor is mainly equipped with book storage units and accommodates the administrative unit. On the ground floor, study areas, wet areas, and a café section were arranged, and the system room was also located on the ground floor (Aydın, 2025).



Figure 4. Cemil Meriç Library (Antalya, Türkiye)-Photo Source (Aydın, 2025- Author archive)

Another example that can be examined is the Istanbul Bilgi University Library. It was converted from the buildings of the Silahtarağa Electric Power Plant, which ceased functioning in 1983 and holds the status of industrial heritage. Since 2004, conservation and adaptive reuse efforts have been carried out by Nevzat Sayın Architectural Services. Until 2013, only dismantling and reinforcement were undertaken in two boiler rooms, after which boiler rooms 4 and 6 were transformed into the faculty of architecture. The library integrated into this educational facility serves as a good example of the adaptation of industrial buildings into spaces for education and knowledge (İtez 2015).

When all these examples are considered, a common point can be observed in the adaptive reuse of industrial buildings. Due to their large spaces and multi-building complexes, while a part of the complex is used as a library, other parts offer opportunities to be used with different functions such as museums, exhibition areas, science centers, and galleries.

3.2. Buildings Converted from Administrative or Public Structures into Libraries

Administrative buildings previously used as municipal or party headquarters, or buildings such as post offices open to public use, have also been adaptively reused and started to function as library buildings.

The 100-year-old historic post office building in Utrecht, the Netherlands, was converted into the Neude Library by Zecc Architecten and Rijnboutt. In this way, the city gained a space for reading books, studying, listening to music, drinking coffee, or simply relaxing. The Art Deco-style building bears the signature of architect Joseph Crouwel, who was influenced by the Amsterdam School. With its large parabolic ceiling, yellow glazed stones, and figures symbolizing continents, the building now serves a multifunctional public use such as reading, studying, listening to music, and socializing (Merdim, 2020).

The conversion of an old post office into a library in Canada differs from the previous example in the Netherlands in that it does not contain book storage or reading areas. Idea Exchange, instead of shelves filled with books, includes spaces for makers, sound and film studios, a children's discovery center, a café, and an event hall. For this reason, it is referred to as "Canada's first bookless library." The Canadian architecture firm RDHA added glazed volumes to the historic post office in Cambridge, Ontario, and transformed the building into a community center (Merdim, 2019).

The historic stone building in Çorum, originally built as a library in 1923 and used as a municipal building since 1960, was restored through a comprehensive restoration process and regained its original function. With this transformation, carried out in line with the principles of cultural heritage preservation and continuity of public use, the building now serves as an information access center under the name "Nation's Library," providing 24/7 service (Ceylan, 2023; Ceylan 2024).

Information about the building in Gürün, Sivas, which was used as a public library for a period, is somewhat ambiguous. It is said that the building was constructed by CHP and has definitively functioned as a party building since 1936. According to one study, it was built as a Rüştiye (Ottoman secondary school) (Zor and Bilget Fataha, 2022: 421), while another study suggests that it was built as a People's Party building in 1923 and used as a middle school for two years (Öz, 1999: 237–238). (cited in Gündoğan Baldık, 2025).

It has been inferred from documents that the building was constructed by CHP in 1935, served as a party building in 1936, and as a community center and community center library in 1939. From 1946 to 2006, the building served as the "District Public Library," and since 2006, it has been serving the public as the "Women's House." Although it functioned as a library for a period, it is no longer used as a library today (Sivas Provincial Directorate of Culture and Tourism, 2024). (cited in Gündoğan Baldık, 2025).

3.3. Buildings Converted from Educational Structures into Libraries

Education is defined by the Turkish Language Association (TDK) as "direct or indirect assistance, inside or outside of school, in helping children and young people acquire the knowledge, skills, and understanding necessary to take their place in social life and to develop their personalities; upbringing" (TDK, 2022). The buildings in which the evolving understanding of education and instruction comes to life are called educational buildings.

Schools, faculties, libraries, study centers, private teaching institutions, and various course halls can be considered educational buildings.

The transformation project carried out by Atelier Associer in the 19th district of Paris involves the conversion of a high school building from the 1970s into a media library and reception center. The existing structure of the building was preserved, decontaminated from asbestos, and subjected to a comprehensive cleaning process. Prefabricated elements such as reinforced concrete columns, beams, slabs, and façade panels were restored; components obtained through selective dismantling were reused on-site. These interventions re-established the spatial order of the building and enhanced surface quality, enabling the creation of high-quality public spaces suitable for contemporary use (Leblebiciler, 2025).

The Utopia building, designed by KAAN Architecten in the city of Aalst in the Flemish region, is a high-quality transformation project that integrates contemporary architecture with cultural functionality. Located within the fragmented fabric of the city's streets and squares, the building occupies an area of 8,000 m² within the structural shell of a former military school and serves as both a city library and an academy of arts. While the building's exterior presents a simple appearance compatible with its surroundings through its red brick cladding, the interior is shaped by an architectural narrative that promotes collective learning and cultural production. Open and permeable spatial arrangements support individual and collective learning processes, thereby strengthening the public character of the building. In this context, Utopia stands out as a contemporary cultural structure integrated into urban life on both physical and intellectual levels (URL1, 2018).

The Atatürk Primary School building, located in the district of Burhaniye in Balıkesir, Turkey, and bearing the characteristics of a historical structure, was reintegrated into public life with the function of a library following a comprehensive restoration process. Constructed in 1908 as a Military Recruitment Office under the leadership of local notables and with public contributions, the building was modified in 1916 to meet educational needs and transferred to the Ministry of National Education, hosting educational activities under various names. Throughout its historical process, the building bore the names Kutluili Mektebi (1916), Boys' School and Kuvâ-yı Milliye Hospital (1919), Numune Mektebi (1923), Şükrü School (1924), First School (1926), and finally Atatürk Primary School (1946), reflecting a multi-layered history of education and healthcare. With the construction of a new 10-classroom building in 1990 by philanthropist Faruk Kızıklı, this historic structure continued to serve as an annex to the school. As a result of the restoration work carried out under the leadership of the Balıkesir Governorship in 2022, the building's original architectural fabric was preserved and transformed into a contemporary Culture, Art, and Education Center. This transformation constitutes a significant example in terms of both the preservation of cultural heritage and the sustainability of collective memory (URL 2; URL 3).

3.4. Buildings Converted from Religious Structures into Libraries

Structures such as churches, mosques, synagogues, etc., that serve a religion and are used by people for worship in accordance with their beliefs are called religious buildings. Structures in which worship takes place are also referred to as temples or sanctuaries (TDK, 2022). The loss of function and reuse stories of buildings often emerge as a result of various migrations or conquests (Wong, 2017). Especially in the case of religious buildings, due to migration or conquest, a structure that does not align with the beliefs of the newly arrived community loses

its function and becomes idle. These idle structures can be repurposed with various functions such as restaurants, libraries, or hotels.

In the town of Athy, Ireland, the historic Dominican Church, which had been closed since 2015, was adaptively reused as the Athy Community Library following an official opening held at the beginning of March. The new library preserved the original atmosphere of the historic structure and was transformed into a creative space in terms of both aesthetics and functionality. Thus, the Dominican Church was reintegrated into urban life not only as an architectural backdrop but also as a public space that sustains collective memory and supports cultural production (URL 4; URL 5).

In the city of Liberec, Czech Republic, an idle Roman Catholic presbytery building was also adaptively reused as a new public library. The interventions, carried out while preserving the existing structure, ensured the sustainability of architectural heritage and provided an open, accessible cultural space for city residents. Thus, the building was evaluated not only as a physical transformation but also as a spatial manifestation of social and cultural revitalization (Cive, 2023).

Maison de la littérature was opened to the public in 2015 following a comprehensive renovation process. The historical origin of the building dates back to 1848, when it was initially constructed as a Methodist church named Wesley Temple serving the Anglophone community. In 1944, it was adaptively reused by the prestigious Institut Canadien du Québec, which has a 175-year history in French literature, as a flagship library and conference campus. After losing this function in 1999, the building remained idle for a long time before being reintegrated into urban life as a public library. This process represents a good example of the evolution of a historic building into a space that serves cultural production while preserving its multilayered identity (Khan, 2024; URL 6).

The Dominican Church, built approximately 700 years ago and currently home to the Selexyz Dominicanen bookstore, is a noteworthy example of the adaptive reuse of religious architectural heritage. Bearing distinct traces of the Gothic style and with its historical structure preserved during renovation, the building played a central role in urban life for centuries through its religious function; however, after the end of its sacred duties, it was transformed into a cultural and commercial space. Although the structure is not a library and should not be analyzed as such, it is considered worth mentioning as an aesthetic and functional solution in the context of its adaptive reuse into a bookstore—a function closely related to that of a library—and its opening to contemporary use. This transformation is regarded as a qualified intervention that ensures architectural continuity and contributes to cultural sustainability (Lo, 2015; Hassan, 2023).



Figure 5. Virgin Mary Church Library (Kayseri, Türkiye)- (Aydın, 2025- Author archive)

Another example of a structure converted into a library is the Church of the Virgin Mary (Figure 5). The former church building is located in Kayseri, Turkey. Having lost its original function, the building was used over time for various purposes such as a sports hall, warehouse, and gendarmerie station. Although interventions such as paint and other applications that did not align with the character and history of the building were made over time, the structure was cleaned of unnecessary additions during its conversion into a library and was adaptively reused (Aydın, 2025).

3.5. Buildings Converted from Commercial Use to Libraries

Commerce is defined as the buying and selling of products, goods, etc.; trade (TDK, 2022). The word commercial refers to anything related to commerce. Commercial buildings can simply be listed as business inns, shops, and shopping malls. Like other types of buildings, commercial buildings may lose their function over time. It is also possible to encounter commercial buildings with historical value, just like other structures.

Buildings such as banks and currency exchange offices, where there is no direct sale of products but where money transactions occur frequently, can also be considered commercial buildings. For example, Salaborsa has long been the central hub of economic life in Bologna, Italy; stock exchange transactions, market activities, and commerce took place there. After World War II and until the 1960s, Salaborsa became a modern sports facility, hosting basketball and even boxing matches. Today, the building functions as a library, and its modernist interior design of glass and iron makes it unique. The documents it offers are not limited to books and newspapers but also include comics, CDs, maps, audiobooks, and much more (Belli, 2021; URL 7).

The city library located in Kansas City, USA, is also a building that has been converted from a bank into a library. The former bank vault now houses the Stanley H. Durwood film collection, while the 11-meter-high ceilings of the old bank add grandeur to the main reading room. However, the idea of converting a bank into a library may be a more challenging adaptive reuse compared to other buildings, especially in terms of accessibility (for example, fully integrating the vault room into the transformation during renovation).

3.6. Buildings Converted from Civil Use to Libraries

Civil architecture today evokes structures that are not produced by the state and are not used for public purposes. Within a hierarchy of preservation that prioritizes significant buildings belonging to the state/public—especially religious and military ones—the possibility of civil

architecture belonging to ordinary citizens becoming an object of preservation is generally only feasible if it represents the best of its kind (VEKAM, 2014).

The transformation project carried out by Steimle Architekten in the town of Kressbronn am Bodensee, Germany, is an example of the adaptive reuse of rural civil architectural heritage. Located in the village center near the municipal building and festival hall, the former barn structure was converted into a library and community center, equipped with angled vertical shutters on the façade. During the transformation process, the original character of the building was preserved; its structural simplicity and material language were reinterpreted in harmony with the new functions. This intervention enabled the creation of a public space that supports both spatial continuity and local identity. Thus, the building evolved into a cultural hub that responds to current social needs while serving as a memory space bearing traces of the past (Merdim, 2020).

The transformation project carried out by Atelier tao + c in Zhejiang Province of the People's Republic of China involves the redesign of a 232-square-meter historic building in the village of Qinglongwu in the Tonglu region with the functions of a capsule hotel, bookstore, and library. This old structure, with a wooden frame and mud plaster, is positioned to face the mountains to the south and east, and the village road to the north. The greatest challenge in the design process was to ensure openness and spatial continuity for public functions within a limited physical space while preserving the privacy of the accommodation areas. Atelier tao + c addressed this challenge through architectural organization and spatial transitions, creating a balanced layout within the building that supports both social interaction and individual use. This approach serves as an exemplary case in terms of architectural adaptive reuse and spatial integration in a rural context (Merdim, 2020).

The historic mansion located in the Princes' Islands of Istanbul, which began serving as a public library in 1968, was kept open for over thirty years through the devoted efforts of Fevzi Yılmaz until 2001. Like many public libraries in Turkey, this structure survived with limited resources and undertook a modest public function by providing essential reference materials to island students and offering a place to study by the stove. After 2001, the library was partially kept open through volunteer support and short-term assignments, but due to the insufficiency of these efforts, it struggled to survive until 2008 and was eventually completely abandoned. During this period, the status of the library's collection became uncertain, and the space turned into a significant void in terms of preserving cultural memory (Demirhan, 2024; URL 8).

Although there are not many examples of the adaptive reuse of structures referred to as civil architecture, there are mansions and residences in our country that should be preserved. The most important issue in the adaptive reuse of these buildings is to ensure proper promotion of the repurposed structure and to resolve matters such as accessibility and transportation. Otherwise, sustainability may not be achieved with the newly assigned function.

3.7. Buildings Converted from Military Use to Libraries

ICOFORT (International Scientific Committee on Fortifications and Military Heritage) was established in 2005 under ICOMOS (International Council on Monuments and Sites) to address military heritage and fortification elements. The committee carries out activities related to the preservation, identification, restoration of military heritage and fortifications, the development of international cooperation, raising awareness, promoting scientific studies, and encouraging maintenance and repairs ("Committee", 2022). In line with the committee's initiatives, a

significant step was taken in 2021 when the guiding principles concerning fortifications and military heritage were adopted at the ICOMOS General Assembly ("ICOMOS Guidelines", 2022; cited in Armağan, 2022). Within this scope, the study examines the conversion of a gendarmerie station, a service building affiliated with the same station, and a military barracks into libraries.

The building located in Döşemealtı district of Antalya, formerly a gendarmerie station, remained idle for many years before being restored by the Ministry of Culture and Tourism and converted into a public library for young people. During the opening ceremony, photographs from the building's derelict period were exhibited, creating a visual memory of the transformation process. The renovated structure offers a contemporary space for learning and socializing for young users, contributing to the cultural infrastructure of the region (Çınar, 2025). The service building affiliated with the same station was also renovated and opened for use as a two-story Baby and Children's Library (URL 9).

Located in Eyüpsultan, Istanbul, the Rami Library offers cultural, artistic, and educational experiences to visitors of all ages through modern library services and the "living library" concept. With its 250-year history dating back to the Ottoman era, the Rami Barracks underwent comprehensive restoration in 2023 and became one of Istanbul's largest and among Europe's notable library complexes. As a result of restoration and adaptive reuse efforts carried out by the Republic of Turkey Ministry of Culture and Tourism, the Rami Barracks, which dates back to the 18th century, was redesigned as a multifunctional library complex. The structure was planned as a comprehensive public space catering to users of all age groups; in addition to baby, children, youth, and adult libraries, it includes specialized libraries, an archive unit, a café, workshop areas, a theater hall, and gallery spaces. With a total seating capacity of 4,200, the complex offers not only access to information but also a versatile platform for cultural production and social interaction (Gürbüz, 2023; URL 10).

Open to users of all ages, the structure was designed as an inclusive and holistic public space that promotes intergenerational learning. In this context, the project aims to produce a knowledge ecosystem that supports cultural continuity and keeps collective memory alive (Akgün, 2025). Additionally, Rami Library is recognized as Turkey's first library to receive a sustainability certificate. It can be confidently stated that the library underwent a successful adaptive reuse process, as the Sustainability Certificate—granted on December 30, 2022, by Biosphere, a program accredited by the Global Sustainable Tourism Council—is held by only 56 facilities worldwide (URL 11).

4. Conclusion and Recommendations

The study is fundamentally based on two concepts: adaptive reuse and the library. Adaptive reuse is seen as significant for disciplines operating in accordance with the principles of architecture, interior architecture, and conservation. While adaptive reuse contributes to economic, social, and architectural development, it also safeguards cultural and collective memory. This study demonstrates that converting historic buildings into libraries constitutes a sustainable and culturally meaningful conservation strategy.

Comparative analyses show that each building type carries its own constraints and opportunities; these characteristics guide the design and transformation process. Therefore, the balance between conservation and adaptation must be established with respect for the original character of the building. Such projects extend the life cycle of heritage structures, transforming

them into dynamic spaces that respond to the cultural and intellectual needs of contemporary society. The study offers guiding principles for architects, interior designers, cultural heritage experts, and anyone interested in the concept of adaptive reuse, focusing on processes that preserve historical integrity.

The analyses conducted reveal that the original function of each historic building significantly influences the adaptation strategies and spatial organization followed during its conversion into a library. For instance, religious buildings, due to their monumental spatial character and symbolic atmosphere, generally require minimal physical intervention; it is important that the new function remains legible within the existing sacred context. In some cases, religious buildings are adaptively reused through the addition of an annex. In this way, the historically, religiously, and spiritually significant parts of the building are preserved with minimal interference, and the space is opened for use.

In contrast, industrial buildings, with their wide spans and flexible layout plans, allow for more experimental and contemporary design interpretations. Administrative and public buildings, due to their strong representational value and rich interior details, require balanced interventions. The adaptive reuse of commercial buildings demands a careful process of structural reinforcement and accessibility adaptation due to their solid and compartmentalized layout schemes, while military buildings, often composed of repetitive modular units, are suitable for reorganization in line with library programs. Among the categories, the conversion of educational buildings into libraries is perhaps the most straightforward and easily achievable renovation.

Since libraries are educational structures by function, conversion projects from schools or faculties into libraries represent a compatible functional choice due to the similarity in building type. In the case of civil structures such as mansions, residences, and buildings constructed for individual use in agricultural and rural areas—like barns, stables, and granaries—structural reinforcement must be carried out with greater care, as aging and potential construction limitations and oversight deficiencies during the building phase, especially in our country, may have led to overlooked issues. Additionally, for these small spaces, problems such as insufficient area based on user numbers, lack of visibility, and consequently the creation of underutilized spaces may arise.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Akgün, M. M. (2025). https://www.arkitera.com/proje/rami-kutuphanesi

Armağan, M. (2022). Askeri Mimari Mirasın Korunması Bağlamında Çakmak Hattı Kıyı Koruganları (Anadolu Feneri-Riva-Şile). *Trakya Üniversitesi Sosyal Bilimler Dergisi*, 513 Aralık 2022 Cilt 24 Sayı 2 (513-538). DOI: 10.26468/trakyasobed.1163988

Aydın, N. (2023). *Nitel Araştırma Yöntemleri.* Gaziantep: Özgür Yayın-Dağıtım.

Aydın, R. (2025). *Yeniden İşlevlendirmede Mekân Adaptasyonu Cemil Meriç Kütüphanesi Örneği, Akdeniz Üniversitesi, Fen Bilimleri Enstitüsü, İç Mimarlık Anabilim Dalı, Yüksek Lisans Tezi. Antalya/Türkiye.*

Belli, A. (2021). https://www.bologna-experience.eu/the-salaborsa-library-and-its-incredible-uses-over-the-time

Cantell, S.F. (2005). The Adaptive Reuse of Historic Industrial Buildings: Regulation Barriers, Best Practices and Case Studies. Master Thesis, Virginia Polytechnic Institute and State University.

Ceylan, K. (2023). https://www.aa.com.tr/tr/kultur/corumun-asirlik-tas-binasi-yeniden-kutuphane-olarak-hizmet-verecek-/3084169

Ceylan, K. (2024). https://www.aa.com.tr/tr/kultur/corumun-asirlik-tas-binasi-millet-kutuphanesi-oldu/3166188#

Cive, O. (2023). https://www.arkitera.com/proje/igi-library

Çınar, M. (2025). https://www.dha.com.tr/foto-galeri/metruk-bina-modern-kutuphaneye-donustu-acilisi-bakan-ersoy-yapti-2630558/6

Demirhan, S. (2024). https://adalidergisi.com/tum-sayilar/2024/temmuz-sayi-229/triandafilidis-koskunden-heybeliada-halk-kutuphanesine

Döğerlioğlu, N. (2019). https://www.arkitera.com/proje/lochal-kutuphanesi

Genç, F.N. (2023). Sümerbank Fabrikaları ve Günümüzdeki "Yeni" İşlevler. T.E. Sepetcioğlu (Ed.) Cumhuriyetin 100. Yılında Geçmişten Geleceğe Nazilli içinde 213-230.

Gündoğan Baldık, E. (2025). Sivas Gürün'de Cumhuriyet'in Modern Mimarlık Örneklerinden Bir Yapı: Halkevi (Kütüphane) Binası. *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi,* (50), 532-559.

Güner, M.S. ve Yüksel, A. (2016). *Mesleki Uygulamalar Yapı Bilgisi İnşaat Mühendisliği Uygulamaları Teknolojisi 1-2* (24. Baskı) İstanbul: Favori Basım Yayın.

Güney, Y.İ. (2007). Type and typology in architectural discourse. BAÜ FBE Dergisi Cilt:9, Sayı:1, 3-18 Temmuz 2007.

Gürbüz, M. (2023). https://www.arkitera.com/haber/tarihi-rami-kislasi-rami-kutuphanesi-oldu

Hassan, M. (2023). Adaptive Reuse of Historic Buildings towards a Resilient Heritage. *Conservation of Urban and Architectural Heritage - Past, Present, Future.* DOI: http://dx.doi.org/10.5772/intechopen.110280

ICOMOS TÜRKİYE Mimari Mirası Koruma Bildirgesi. (2013). (30 Mayıs 2012 ve 17 Mart 2013 tarihleri arasında gerçekleştirilen ulusal mimari koruma uzmanları toplantıları ve ıcomos türkıye milli komitesi'nin revizyonu ile son şekli verilmiştir)

İtez, Ö. (2015). https://www.arkitera.com/proje/santral-4-ve-6-nolu-kazan-daireleri-mimarlik-fakultesi-ve-kutuphane-donusumu

İtez, Ö. (2022). https://www.arkitera.com/proje/muze-gazhane-muze-ve-kutuphane-binalari-yeniden-islevlendirme-ve-ic-mekan-tasarimlari

Karakoç, N. (2022). https://www.arkitera.com/haber/brooklynde-1901-yilindan-kalma-endustriyel-bir-binada-bulunan-kutuphane-adams-street-library

Khan, S. (2024). https://broadview.org/church-library-quebec-diverse-communities

Leblebiciler, R. S. (2025). https://www.arkitera.com/proje/james-baldwin-medya-kutuphanesi

Lo, K. (2015). https://www.atlasobscura.com/places/selexyz-dominicanen

Merdim, E. (2019). https://www.arkitera.com/haber/kanadanin-ilk-kitapsiz-kutuphanesi-idea-exchange

Merdim, E. (2020). https://www.arkitera.com/haber/hollandadaki-100-yasinda-postane-halk-kutuphanesine-donustu

Merdim, E. (2020). https://www.arkitera.com/haber/steimle-architekten-eski-bir-ahiri-kutuphaneye-donusturdu

Merdim, E. (2020). https://www.arkitera.com/haber/eski-yapinin-kapsul-otel-ve-kutuphaneye-donusumu

TDK. (2022). Güncel Türkçe Sözlük. Türk Dil Kurumu Sözlükleri: https://sozluk.gov.tr/

TKD (Türk Kütüphaneciler Derneği). (2023). Cumhuriyet'in 100. Yılında Türk Kütüphaneciliği Sempozyumu Sonuç Bildirgesi, 4-7 Ekim, Ankara.

URL1: https://www.arkitera.com/haber/askeri-okul-kutuphane-ve-performans-sanatlari-merkezine-donusturuldu

URL2: https://burhaniye.meb.gov.tr/www/eski-ataturk-ilkokulu-tarihi-binasi-kutuphaneye-donusturuldu/icerik/1557

URL3: https://balikesir.meb.gov.tr/www/eski-ataturk-ilkokulu-tarihi-binasi-kutuphaneye-donusturuldu/icerik/3329

URL4: https://www.bibliotheca.com/library-story-athy

URL5: https://www.workrestplay.net/libraries/athy-community-library-irelands-newest-modern-library

URL6: https://archello.com/project/maison-de-la-litterature-house-of-literature

URL7: https://en-wikipedia-org.translate.goog/wiki/Biblioteca_Salaborsa?_x_tr_sl=en&_x_tr_tl=tr&_x_tr_hl=tr&_x_tr_pto=tc

URL8: https://heybeliadakutuphanedernegi.org/heybeliada-halk-kutuphanesi-1967-2008

URL9: http://www.antalya.gov.tr/bebek-ve-cocuk-kutuphanesinin-acilisi-gerceklestirildi

URL10: https://ramikutuphanesi.gov.tr/tr

URL11: https://dacistanbul.com/tarihi-rami-kislasi-kutuphaneye-donusturuldu

VEKAM (Vehbi Koç Ankara Araştırmaları Uygulama ve Araştırma Merkezi). (2014). Korumada Sivil Mimarlık. Kasım 2014, Ankara. ISBN: 978-975-97802-2-7.

Wong, L. (2017). Adaptive Reuse Extending the Lives of Buildings. Birkhäuser Verlag GmbH, Basel.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Spatial and Functional Suggestions for the Sustainability of Traditional Marketplaces: from Consumption to Production

Ayşe Seda ÇALIŞKAN [1]*

ORCID 1: 0000-0001-7804-6533
[1]Res. Asst., Konya Technical University, Faculty of Architecture and Design, Department of Interior Architecture, Konya-Türkiye
ascaliskan@ktun.edu.tr **(**Responsible Author)

Özge KANDEMİR [2]

ORCID 2: 0000-0001-7999-5845
[2]Assoc. Prof., Eskişehir Technical University, Faculty of Architecture and Design, Department of Interior Architecture, Eskişehir-Türkiye
ozgekandemir@eskisehir.edu.tr

Abstract

Neighbourhood markets are social and traditional trading spaces that reflect cultures, provide a platform for social interaction, and bring together large numbers of people living in the same city according to their production and consumption habits. Markets are not merely places where shopping is done, serving commercial and economic purposes, but also urban spaces that reflect and perpetuate the local and traditional culture, daily activities, and habits of the community in which they are located. In different cultures, street markets hold significant potential in the context of urban culture production. In our country, markets are examined under two headings depending on the area in which they are established. The first is open markets established randomly on streets and avenues, while the second is markets consisting of closed or semi-open spaces, often established by local authorities for this purpose, known as covered markets. This study, which stems from the problem of markets in the second category in our country being used on certain days of the week and remaining inactive on other days, investigates what functions could be integrated into these markets and how the sustainability of these markets can be ensured. Markets from different cultures were examined in terms of their spatial and functional characteristics in order to identify potential functions that could be assigned to these markets, ensure their sustainability, and offer various design proposals. The marketplaces examined were designed and approached using an interdisciplinary approach. This research highlights the local and cultural importance of markets and offers recommendations for marketplace structures to be built in our country.

Keywords: Bazaar, indoor marketplace, production of space, space of consumption, traditional market

1. Introduction

As a social product, the production process of space is based on the actors involved in the production process, the relationships between them, and the daily life practices of the people living in that space. In a sense, space is the result of a reciprocal relationship process that contributes to the formation of society and is created by society, and we can only access real information about space to the extent that we can understand this relationship. Space is a social product, and what makes space what it is are the diverse relationships that form within that space (Lefebvre, 2014).

Marketplaces, which have existed in cities since the agoras of ancient times, represent the world's oldest shopping tradition. Weekly markets, set up at various locations in cities on specific days of the week, serve as both an alternative and a complement to shopping centers and established bazaars. They are preferred by many users due to their positive features, such as catering to various income levels, offering consumers choices, and being easily accessible (Özgüç ve Mitchell, 2000).

Marketplaces are temporary or permanent shopping venues established on specific days of the week at locations easily accessible to the public. Neighbourhood markets, on the other hand, are traditional shopping venues typically set up on one day of the week at specific locations within the city. While the primary purpose of traditional neighbourhood markets, which are urban spaces, is shopping, the consumption that takes place in these spaces differs from the consumption habits of the contemporary capitalist system. In addition to their economic and commercial functions, markets provide opportunities for encounters, communication and interaction, sharing and togetherness, offering spatial potential in public and social terms (Uzgören, 2021).

Street markets have developed by creating temporary spaces for consumption and socialising that stand out for their sensory and emotional richness. While it is debatable whether street markets can be considered "architectural", despite their open-air locations, changing forms and lack of infrastructure, street markets create a sense of enclosure and intimacy and a sense of place through their lights, sounds and occupation of space. Even when realised through "makeshift" (geçici, derme çatma) and "improvised" (doğaçlama) means, street markets possess the potential to "place-making" (Kelley, 2020).

Street markets are not merely shopping venues for the community; they are perceived as public spaces where the city's users, sellers, consumers and visitors develop their own understanding of physical space and specific spatial routines, both physically, mentally and symbolically. (Gvion, 2017).

Street markets are urban spaces in a global sense. Although street markets are typically small-scale and located in accessible public areas, they significantly influence the quality of urban spaces. Street markets have the potential to represent local culture. In other words, street markets are urban cultural spaces. Alongside shopping activities, they are a visible urban culture that enriches the city's public life by enabling users to interact with each other and experience different products, cultures and various activities (Kamarudin et al., 2015).

Markets are commercial and economically based spaces, but they are not merely places for shopping; they are urban spaces that reflect the culture, traditions, daily activities and habits of the community in which they are located.

Markets have taken on many different forms in different geographical areas and therefore different cultures, being used in various spatial configurations from streets to squares and from town squares to water surfaces. Consequently, it can be said that marketplaces around the world exhibit a rich diversity. Marketplaces are classified in different ways by different researchers in the literature.

According to Öztekin (2009), marketplaces can be classified as follows:

According to their location:

- Linear markets: A market typology consisting of two rows facing each other, formed by sales units lined up side by side along a linear axis on a street or avenue.
- Area markets: These are markets established by local authorities with defined boundaries.

According to their roof;

- Open markets: This is a market typology where the sales units and circulation areas are not covered by a roof. Temporary covering systems are used by sellers.
- Covered markets: These are markets where both the sales units and circulation areas are covered by a permanent roof. Only the top of the market area may be covered, or the side surfaces may also be covered.

According to when they are set up;

- Periodic markets: These are markets set up at regular intervals in a specific place. Weekly markets are an example of this group.
- Permanent markets: These are markets set up every day without interruption in a specific location.

According to the product sold;

These are markets where a specific product group is sold. The market is named after this product or product group. Livestock markets are an example of this group.

According to Heathcott (2019):

- Linear type: This is the most common market typology, involving a simple, linear layout along a street or road.
- Circuit type: This is a settlement type that starts at one point in the city and branches out to other streets and roads. The branches may be connected to each other, creating continuity, or they may be disconnected.
- Cluster type: Clustered markets are arrangements of various sales units that come together in different forms.
- Contour type: This is a settlement pattern that emerges when sales units follow the natural or man-made features of the city. This could be a roundabout or a traffic island, or it could be the shape of a valley or street itself.
- Hybrid type: This is when two or more of the other typologies come together to form a hybrid typology. For example, a market displaying the characteristics of both the linear and cluster types at the same time.

There are five street market typologies.

According to Liu (2024);

- Nodal bazaars: These are markets that adapt to the conditions of their surroundings, such as the natural environment, traffic and crowds. Their spatial arrangements are flexible, they have no clear boundaries and they evoke a strong sense of community. They are usually located in part of city squares or along extensions of streets and avenues.
- Linear bazaars: These refer to market areas that have developed from traditional streets or were built later as part of rural tourism. Such markets are integrated with the streets and function as a natural part of the transport system. The flexible layout of the streets and their natural extensions bring vitality to the market. The shops lining the street and the stalls on both sides establish a complementary relationship. Fixed shops provide storage, rest, water, and electricity facilities to mobile stalls, while the stalls increase visitor traffic, boosting the sales potential of the shops. Like point markets, linear markets also gather human flow along transport routes and create an intimate spatial scale. This arrangement offers visitors the

opportunity to experience different spatial experiences along the street and encourages a desire to explore. The most distinctive feature of linear markets is the linear arrangement of the space.

- Area bazaars: These refer to large-scale market areas that have developed in close proximity to each other, often growing out of point or linear markets, with their interiors divided by roads. Their spatial layout is flexible, often combining both point and linear market forms. The layout of these markets is generally scattered, with weak spatial connections between different market sections and no clearly defined boundaries for these areas.

According to Kamarudin et al. (2015);

Street markets vary according to their location in the city's open spaces. There are two general types of street markets found in different countries: permanent and temporary street markets.

- Permanent street market: Permanent street markets are daily street markets that are open continuously every day or on specific days of the week or month. These markets typically sell vegetables, meat, poultry, fish, and other daily goods for local residents to purchase. Permanent street markets usually have fixed stalls where sellers rent their own stalls.
- Temporary street market: Temporary street markets are set up for seasonal events, festivals and special days and are usually held in a public area of the city. Although certain streets are temporarily occupied by market vendors to sell special products based on local culture, events and festivals held at the market, temporary street market events add vibrancy to the urban environment. (Abdulazeez and Pathmanathan, 2015; Medina, 2002; akt. Kamarudin et al. 2015).

Street markets have serious negative effects on accessibility, the construction of illegal structures, traffic congestion, solid waste production, car accidents and the deterioration of urban aesthetics (Adedeji et al., 2014). In this sense, locating markets in spaces designed and built for this purpose eliminates these negative effects.

2. Materials and Methods

This study, which stems from the problem of markets consisting of enclosed or semi-enclosed spaces, mostly established by local authorities in our country specifically to serve this function, being used only on certain days of the week and remaining unused on other days, investigates what functions could be integrated into these markets and how the sustainability of these markets can be ensured.

This study was conducted to identify potential functions that could be assigned to market structures, to ensure the sustainable use of market structures, and to present various design proposals in this context. Market structures from different cultures were examined in terms of their spatial and functional characteristics. The marketplaces examined were approached from an interdisciplinary perspective and designed accordingly.

The research highlights the importance of markets in terms of local identity and cultural memory; it also offers guiding recommendations for the design of market structures to be built in Turkey in the future.

3. Findings and Discussion

3.1. Targ Blonie Market

The renovation project for the market in Blonie, a small town near Warsaw, the capital of Poland, was carried out by Aleksandra Wasilkowska Architectural Studio (Table 1). The

market, where the local community has maintained its centuries-old tradition, provides access to affordable and high-quality food sold directly by producers and farmers. It was decided to renovate the market to address its poor comfort standards and lack of basic market infrastructure, and the project was completed in 2022 (Ott, 2023).

Table 1. Targ Blonie Market (Ott, 2023)



Project:	Targ Blonie Market
Location:	Blonie, Varşova, Polonya
Architect:	Aleksandra Wasilkowska Architectural Studio
Project Year:	2022

A mixed-use public space combining two social functions: market and park, has been created. Multi-functional white canopies that reflect sunlight and provide shelter from rain have been planned (Figure 1) (Ott, 2023).



Figure 1. Targ Blonie Market canopies (Ott, 2023)

When the market closes, the wood-panelled display units serve as seating elements, and the market area can be used for various events (Figure 2). Small-scale structures for administrative, commercial, and service units have been designed on the outer perimeter of the white canopy (Figure 3) (Ott, 2023).



Figure 2. When the market closes, display units with wooden cladding that will serve as seating elements (Ott, 2023)



Figure 3. Small-scale structures built on the outer edges of the white canopy (Ott, 2023)

At the centre of the market, a play area and seating units have been designed for children (Figure 4). Around the structure, there is an access road to facilitate product delivery, as well as open stalls for the mobile trade of vehicles and agricultural products. Furthermore, the market and its surroundings have been planned at the same level, designed to ensure accessible and safe movement for all users (Ott, 2023).



Figure 4. Children's play area and seating units designed to serve the park function integrated into the market (Ott, 2023)

Green islands were designed around the roofs and pavilions to provide food and shelter for birds and insects, while also aiming for the trees to provide shade for the open trading points. Rainwater from the roof is collected to water the plants and seep into the soil (Figure 5). (Ott, 2023).



Figure 5. The green islands of the market (Ott, 2023)

Various street furniture, lighting fixtures, white circular information boards, bicycle racks, rocks, bird and insect houses, a bar and seating areas have been designed to create a sense of unity. Serving various functions, the public space microclimate improves, strengthens micro-entrepreneurship, and aims to increase the city's resilience in the event of a pandemic, food, and climate crises by providing users with access to locally produced food outdoors (Ott, 2023).

3.2. Mercado Municipal de Braga

The project to renovate and expand the Braga Municipal Market, which has been in use since the 1950s, with the aim of preserving and continuing its architectural and cultural heritage, was designed by the Apto Arquitectura architecture office and completed in 2020 (Table 2) (Figure 6) (Moreira, 2023).

Table 2. Mercado Municipal de Braga (Moreira, 2023)



Project:	Mercado Municipal de Braga
Location:	Braga, Portugal
Architect:	Apto Arquitectura
Project Year:	2020



Figure 6. Mercado Municipal de Braga entrance facades (Moreira, 2023)

With the new structure added to the existing one, the previously scattered functional distribution of the market has been reorganised, circulation areas have been designed around a central square, thus enabling users to perceive and experience the space as a whole, see and reach all market stalls from the square, and strengthening buyer-seller communication. (Figure 7) (Moreira, 2023).



Figure 7. Mercado Municipal de Braga indoor circulation areas (Moreira, 2023)

The market has two pedestrian entrances located at different corners of the building. One of these entrances is planned as the main entrance, while the other is the secondary entrance. The entrances are strategically positioned. The main entrance door, placed diagonally at the corner of the square plan, directs users to the square and secondary circulation areas. Circulation within the market has been carefully planned, which helps to minimise crowding. Stalls selling fresh fruit and vegetables are located in the center of the market, and this area has been designed to be the focal point of the market (Figure 8). Shops, restaurants, kitchens, and other commercial establishments surround the market area (Moreira and Concatto, 2023). Thus, the distribution of different types of businesses and various consumer goods offers visitors alternatives to explore.

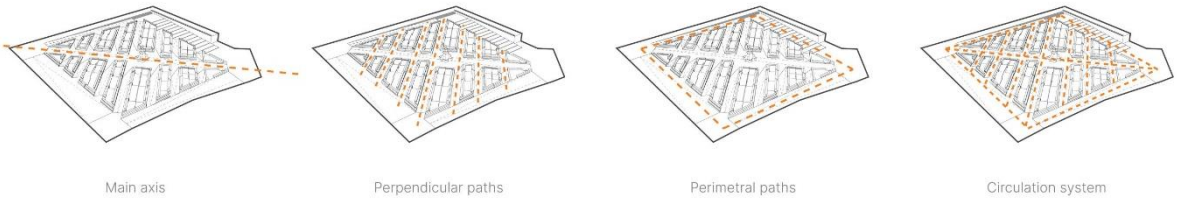


Figure 8. Mercado Municipal de Braga circulation diagram (Moreira, 2023)

The functions within the market include fruit and vegetable sales areas, flower sales areas, fish sales areas, butchers, kitchens, waste bins, live animal sales areas, information points, loading and unloading areas, dining areas, and multi-purpose rooms (Figure 9) (Moreira and Concatto, 2023).

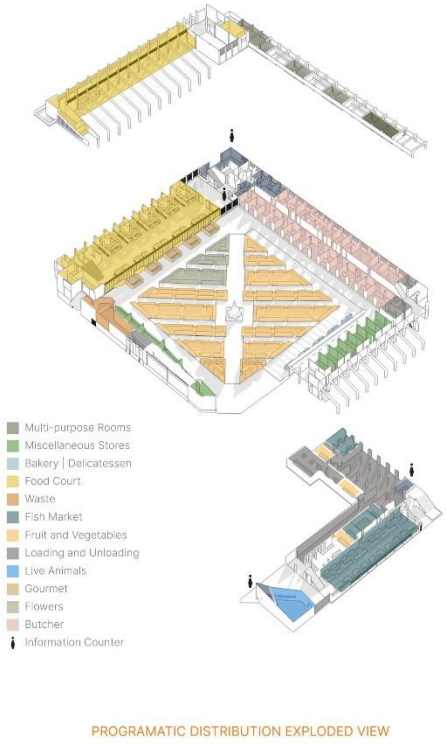


Figure 9. Mercado Municipal de Braga functional diagram (Moreira, 2023)

Service units and technical areas are separated from areas with high consumer traffic. The spaces where the loading and unloading processes of products are carried out have been consolidated into a single area, and a waste disposal process has been established. A food and beverage space has been integrated into the market to both generate revenue for the market and turn it into a center of attraction (Figure 10) (Moreira, 2023).



Figure 10. Cafe designed in conjunction with the Mercado Municipal de Braga (Moreira, 2023).

The building's location on sloping terrain has resulted in level differences within the interior space, which have guided the interior design, with different heights connected by stairs and ramps (Figure 11). (Moreira and Concatto, 2023). This has removed barriers to movement, created an accessible interior for disadvantaged users, and facilitated logistical operations.



Figure 11. Ramps and staircases designed to connect level differences within an interior space (Moreira, 2023)

Parametric design methods were utilised to balance the scale of the space and create a dynamic interior, and wooden ceiling elements were designed using this method (Figure 12). The truss system, which forms the structure's load-bearing framework, controls light while incorporating a rainwater drainage system and supporting the wooden ceiling elements and glass. The aim is to design and construct the market as a fast, technically accurate, and economically sustainable structure (Moreira, 2023).

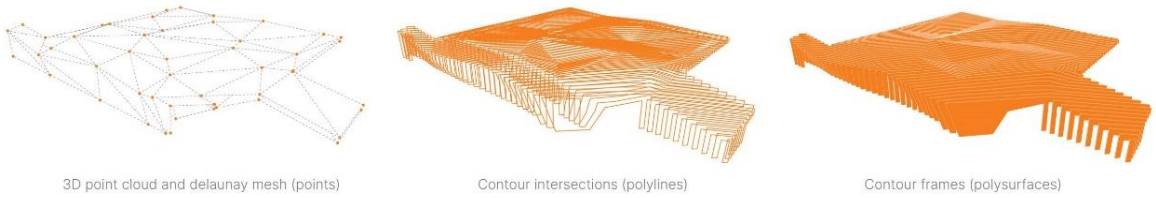


Figure 12. Wooden ceiling elements designed using the parametric design method and characterising the space (Moreira, 2023)

The roof system, composed of non-structural wooden beams, contributes to the interior space in many ways. The glass roof allows natural light into the interior, while the parametric wooden beam system ensures that natural light is controlled. Acoustic comfort is provided by the sound changing direction when it hits the wooden beams. Furthermore, the geometry of the interior space facilitates the circulation of air through convection (Figure 13) (Moreira and Concatto, 2023).



Figure 13. The passive sustainability contributions of wooden ceiling elements to the space, such as air circulation, controlled intake of natural light and acoustics (Moreira, 2023)

The fundamental spatial configuration of the structure consists of a steel support system for the glass roof and non-structural wooden beams (Moreira and Concatto, 2023).

Braga Market brings together the present and the past while preserving a significant part of its original structure. It also stands out for its spaciousness and capacity to host various activities, including a fish market and a variety of restaurants. Furthermore, strategically placed information stands within the interior guide visitors. The market offers a smooth and enjoyable shopping experience by organising different sectors together. The project not only preserves the old market but also promotes better working conditions and efficient commercial activities, acknowledging the critical role played by the market's vendors in the local economy and the preservation of traditions. Therefore, Braga's market is not just a trading center, but also a place that encapsulates the history, culture and economy of the region. By preserving the past and investing in the future, it has become not just a place of trade, but also a symbol of respect and appreciation for fishermen and merchants, shaping the city's identity (Moreira and Concatto, 2023).

3.3. Tula Farmers Market

The Tula Farmers' Market project, located in the city of Tula, the capital of Russia's Tula Oblast, was designed by the 8 Lines architecture office and constructed in 2017 (Table 3) (Figure 14). The architectural form of the farmers' market reflects the idea that each farmer is first and foremost an individual and that when they come together, they form a rural cooperative (Maggiora, 2019).

Table 3. Tula farmers market (Maggiora, 2019)



Project:	Tula Farmers Market
Location:	Tula, Tula, Russia
Architect:	8 Lines
Project Year:	2017



Figure 14. Tula Farmers Market entrance facade (Maggiora, 2019)

Tula Farmers' Market includes sales areas for farm products and agricultural supplies, a cafeteria, a product quality control laboratory, a play area, a space for various events, a relaxation area, sanitary facilities, offices, storage areas, and workshops. These functions ensure that the market is not merely a place of trade, but also a social hub where connections are made, projects emerge, and interactions occur. Additionally, a small area has been designed in front of the building for temporary art installations (Figure 15) (Maggiora, 2019).

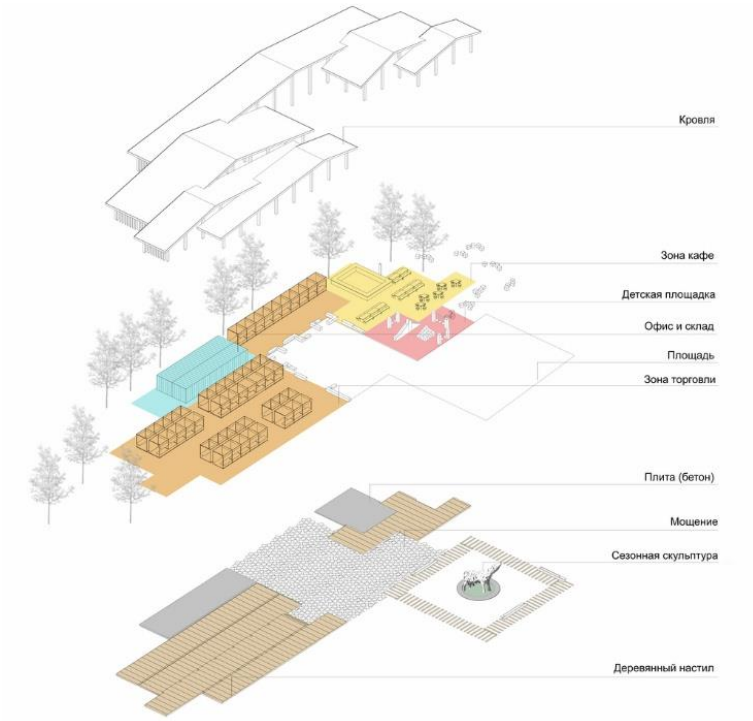


Figure 15. The architectural form of Tula farmers' market reflects the idea of rural cooperation, where each farmer is an individual and they come together and functional diagram (Maggiora, 2019).

Tula farmers' market offers a unique shopping experience with its interior space within a spatial unity. (Figures 16, 17).



Figure 16. Semi-open spaces of Tula Farmers Market (Maggiora, 2019)



Figure 17. Interior of Tula Farmers Market (Maggiora, 2019)

The Tula Farmers' Market project was awarded the prize for the best wooden architecture of the year in the 'Wooden Public Buildings' category at the 2018 'Archiwood' competition (Maggiora, 2019).

4. Conclusion and Recommendations

Markets can be defined as consumption areas that play heterogeneous roles and reveal the commercial, social and cultural characteristics of societies. This study discusses what architectural qualities could animate market structures as urban cultural spaces and offers recommendations in this regard. These recommendations aim to prevent market structures from becoming idle by ensuring that markets can also be used when markets are not held. The findings obtained from the markets examined within the scope of the research are as follows:

It is seen that the markets examined were designed with a concept, and their architectural forms reflect an idea. It can be stated that the architectural form of the Tula Farmers' Market, in particular, reflects the idea of rural cooperation formed when farmers come together, with each farmer being primarily an individual, and that this form is highly compatible with the function of the structure and makes it unique.

Each of the markets examined has been designed as accessible spaces for disadvantaged users such as disabled people, the elderly, and children. Targ Blonie Market and its surroundings have been planned at the same level, thus creating an accessible and safe shopping environment for all users. Due to the sloping terrain of Braga Municipal Market, the level differences created in the interior have guided the market's design, with different level heights connected by ramps, thus creating an accessible market for users from all groups.

The circulation and direction of the markets examined within the scope of the study are found to be legible, and the stalls are found to be locatable. Circulation at Braga Municipal Market is designed to enable users to perceive and experience the space as a whole, to see and reach all market stalls from the square. In addition, information stands have been placed inside the market to guide visitors.

Landscaping can be considered an element that enhances visitor comfort in markets. Arrangements such as landscaping, the design of seating units, the provision of a pedestrian-friendly environment, and the presence of shaded areas will make markets more desirable. Mehta (2013) found that seating areas are one of the most important elements in 'keeping people in public spaces' (Kamarudin et al. 2015). This means that seating units in markets are important for facilitating the shopping experience of users, encouraging them to spend more time in the market, and allowing them to rest.

The markets examined were designed and conceived to serve not only shopping but also various other functions. Seating elements and a children's play area were designed at the centre of Targ Blonie Market, thus creating a mixed public space that combines two social functions: market and park. Furthermore, when the market is not in operation, the wood-clad display units (sales stalls) serve as seating elements, enabling the market area to be used for various events. An integrated food and beverage venue has been designed to make Braga Municipal Market a centre of attraction. Tula Farmers' Market, on the other hand, includes sales areas for agricultural materials and farm products, along with a cafeteria, play area, relaxation area, product quality control laboratory, sanitary facilities, offices, storage, and workshops.

When designed correctly, markets have the potential to draw users away from shopping centres, where they meet various needs in one place, towards marketplaces. Markets should be designed to encourage interaction and be interactive between users, sellers and visitors, with units supporting social activities. This ensures that markets remain vibrant with the presence of the local community and host interesting local events, thereby sustaining cultural values. Markets can also become important social spaces where various public events are held. When properly designed, markets will attract visitors from other countries, contribute to trade and cultural tourism in the region, and become a meeting and socialising point for the community.

Other functions that can be integrated into markets include:

- Children's play areas
- Cafeterias
- Units where users can consume the products they have purchased
- Seating and relaxation areas
- Exhibition units
- Various gastronomy-related events and festivals
- Open-air film screenings
- Various children's activities
- Local cultural events, fairs

Markets should be designed as flexible, openable and closable, adaptable to current conditions, experience-oriented spaces that can serve various functions.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Adedeji, J.A., Fadamiro, J.A., & Adeoye, A. (2014). Spatial Implications of Street Trading in Osogbo Traditional City Centre, Nigeria, *Architecture Research*, 4(1A), 34-44.

Gvion, L. (2017). Space, gentrification and traditional open-air markets: how do vendors in the Carmel market in Tel Aviv interpret changes? *Community, Work & Family*, 20(3): 346-365, doi: 10.1080/13668803.2015.1117420

Heathcott, J. (2019). Architecture, urban form, and assemblage aesthetics in Mexico City's street markets. *Archnet-IJAR: International Journal of Architectural Research,* 13(1), 72-92.

Kamarudin, A.M., Wahab, N.A., & Zakariya, K. (2015). Discovering the qualities of Ferringhi Night Market as an urban cultural space. *Umran2015: A Vision of Establishing Green Built Environment*, 1-16.

Kelley, V. (2020). London's Street Markets: The Shifting Interiors of Informal Architecture, *The London Journal*, 45(2): 189-210, doi: 10.1080/03058034.2019.1703432

Lefebvre, H. (2014). Mekânın üretimi. Çev.: Işık Ergüden, Sel Yayıncılık, İstanbul.

Liu, Y. (2024). Study on the architectural design of rural bazaar from the perspective of urban-rural integration, Doctoral Thesis, Unıversity of Hawaı'ı at Mānoa Graduate Division, Hawaiian Islands.

Maggiora, M. V. D. (2019, 14 July). Tula Farmers Market / 8 Lines, *Archdaily*, https://www.archdaily.com/921148/tula-farmers-market-project-group-8-lines?ad_source=search&ad_medium=projects_tab

Moreira, A. C. M., & Concatto, S. (2023). A ımportâncıa de um mercado do peıxe para a cıdade de navegantes-sc: uma análıse arquıtetônıca do caso do mercado munıcıpal de braga em portugal. *Revista Científica Sophia,* 15(1), 1-7. doi: https://doi.org/10.5281/zenodo.10233536.

Moreira, S. (2023, 5 January). Braga Municipal Market / APTO Architecture, Archdaily, https://www.archdaily.com/994445/braga-municipal-market-apto-architecture?ad_medium=gallery

Ott, C. (2023, 1 May). Targ Blonie Market / Aleksandra Wasilkowska Architectural Studio, *Archdaily,* https://www.archdaily.com/1000251/targ-blonie-market-aleksandra-wasilkowska-architectural-studio?ad_medium=gallery

Özgüç, N. & Mitchell W. (2000), "Şehirlerin alternatif alışveriş mekânları: İstanbul'da haftalık pazarlar", *Tasarım Kuram*, 2(2): 35-58.

Öztekin, T. G. (2009). *Eskişehir Kent Dinamiği İçerisinde Pazaryeri Kavramının İncelenmesi, Yüksek Lisans Tezi, Eskişehir Osmangazi Üniversitesi Fen Bilimleri Enstitüsü, Eskişehir.*

Uzgören, G. (2021). Semt pazarlarının kentsel yaşamda sosyallik temelli kamusallığın geliştirilmesindeki rolü. *Tasarım Kuram,* 17(32): 1-19 doi: 10.14744/tasarimkuram.2020.83702

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Conceptual Transitions and Reflections from Landscape Performance Assessment to Design Practice

Mahmut Can AST [1]*

ORCID 1: 0009-0005-7628-1093
[1] Graduate Student, Çanakkale Onsekiz Mart University, Graduate Education Institute, Department of Landscape Architecture, Çanakkale-Türkiye
mahmutcanast@gmail.com (Responsible Author)

Elif SAĞLIK [2]

ORCID 2: 0000-0002-5230-3869
[2] Assoc. Prof. Dr., Çanakkale Onsekiz Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale- Türkiye
elifsaglik@gmail.com

Abstract

Landscape Performance Assessment (LPA) presents a research approach in which the environmental, social, and economic benefits of implemented landscape design are supported by quantitative data on their contributions to sustainability. Supported by the Landscape Architecture Foundation (LAF), LPA focuses on landscape areas with the potential to demonstrate high performance. Performance findings inform the design process, helping to design more sustainable and high-performing landscape areas as well as to improve/redesign existing areas. When the 210 studies published by LAF are examined, it is noteworthy that no assessment study has yet been conducted in Türkiye and that it is not a common research approach in the fields of practice and academia. This study aims to focus on LPA studies and to examine conceptual relationships through the method of content analysis. It has been investigated which performance themes and design strategies most frequently produce the reported benefits, the relationship between the identified performance themes and design strategies, and which concepts are sought in defining a high-performing project. The analyses, within a conceptual framework, provided a perspective on the design of high-performing landscape areas through the relationship established between performance themes and design strategies. As a result of the research, recommendations have been developed regarding which themes, design strategies, and concepts should be included in the design of high-performing landscape areas in Türkiye and in future participation LPA studies. This research not only provides a reflection for landscape design in Türkiye but also offers an important framework that supports studies in other countries.

Keywords: Conceptual approach, landscape performance, landscape design, sustainability, design process

1. Introduction

Today, landscape architects face significant and complex challenges such as providing climate-resilient landscape spaces, coping with rapid urbanization, adapting to natural disasters, conducting ecological restoration of degraded urban areas, managing water resources, addressing urban growth, and integrating ecological knowledge into design process (Yang et al., 2016; Barnes et al., 2025). In response to the environmental issues of the 21st century, the field of landscape architecture continues to expand and transform through interaction with numerous professional disciplines, while the need and demand for stronger justification of actions in design and planning studies have also increased (Swaffield & Deming, 2011). In this context, design plays a crucial role in addressing environmental issues and achieving sustainability (Çelik, 2013).

In order to effectively address these challenges, landscape architects increasingly require empirical information, reliable evidence, and research to inform design and support decision-making processes in the planning, design, and management of landscape spaces (Brown & Corry, 2011; Meijering et al., 2015; Yang et al., 2016). However, decision-making processes

in contemporary landscape architecture practice often rely on beliefs and experience-based approaches (Brown & Corry, 2011; Shen et al., 2023). Landscape architecture is an evidence-based design discipline that depends on reliable data to advance and guide design practices (Luo, 2014). Therefore, evaluating the outcomes of implemented design and planning projects is crucial for the creation of successful landscape spaces, as it enables the determination of the accuracy of design approaches and the assessment of their environmental, social, and economic values through quantitative research (Luo, 2014; Yang et al., 2016).

The Landscape Performance Series (LPS) measures the outcomes of sustainable development across three benefit areas – environmental, social, and economic – and utilizes the quantitative data collected to inform future design practices (Luo, 2014). The Landscape Architecture Foundation (LAF) defines the concept of landscape performance as *"a measure of the effectiveness with which landscape solutions fulfill their intended purpose and contribute to sustainability"* ("Landscape Architecture Foundation (LAF)", n.d.). Regardless of how sustainability is defined, sustainable development and landscape are inseparable entities. In this context, landscape performance plays a significant role (Shen et al., 2023) and regards sustainability as one of the primary objectives of design and planning project (Ndubisi et al., 2015). Within the scope of LPS studies, LAF established the Case Study Investigation (CSI) Program in 2011 to support practitioners working collaboratively with academic and student research teams. The LPS and CSI initiatives aim to promote the design of project with performance objectives, the documentation of project goals and design intentions, and the systematic collection of performance data (Barnes, 2024).

Understanding landscape performance provides critical insights for the creation of future high-performance and resilient landscape design projects by informing the shaping of design objectives and supporting the appropriate selection of spatial and functional design principles and elements (Aydınlı, 2017; Özdil, 2018; Güler, 2019). Consequently, such feedback can aid in the management of landscape spaces, indicate the need for improvements to enhance low-performing or underperforming areas, or suggest the necessity for redesigning certain landscape areas (Chen, 2024). Therefore, it is essential to investigate the conceptual transitions and potential implications of performance outcomes produced within the scope of LPS for the landscape architecture design process.

This study focuses on 210 landscape design projects evaluated within the CSI Program under the LPS framework. The aim was to identify and relate the generated benefits, performance themes, and design methods in order to highlight the design concepts that should be considered in defining a high-performance project. Accordingly, recommendations have been developed regarding which performance themes and design methods should be incorporated into projects to achieve high-performance landscape designs in Türkiye.

2. Materials and Methods

This study, which presents a research approach focused on design, is structured around four main components: the formulation of the research aim and questions, the establishment of the sample area, the development of evaluation criteria for the data analysis process, and the analysis of the data.

The aim of this study is to examine the benefits generated in Landscape Performance Assessment (LPA) studies using a content analysis approach. Specifically, the study seeks to identify the most frequently addressed performance themes in LPS studies, the design methods

applied in the evaluated projects, the relationships between the applied design methods and the performance themes, and the concepts to be considered in defining a high-performance project. In addition, based on the findings, the study aims to provide conceptual recommendations regarding which performance themes and design methods should be incorporated into the design process to achieve high-performance landscape designs in Türkiye. Accordingly, the four research questions developed are presented below. These are:

- **RQ$_1$:** *What are the most frequently addressed performance themes in Landscape Performance Assessment studies from environmental, social, and economic perspectives?*
- **RQ$_2$:** *What design methods are applied to generate environmental, social, and economic benefits in Landscape Performance Assessment studies?*
- **RQ$_3$:** *How are the applied design methods in Landscape Performance Assessment studies associated with specific performance themes?*
- **RQ$_4$:** *What concepts should be considered in the design process to define a high-performance project based on Landscape Performance Assessment studies?*

The content analysis method was selected for analyzing the materials and addressing the research questions. Content analysis is a research technique that uses written or textual documents within their context to obtain reproducible and valid inferences, providing new sights, enhancing the researcher's understanding of specific ideas, and/or informing practical actions (Krippendorff, 2004, p.12). Janis (1943-1965) classified research methods within content analysis into three categories: (1) Pragmatic content analysis, which categorizes the possible causes or effects of signs present in the text; (2) Semantic content analysis, which categorizes the signs in the text based on their meanings; and (3) Sign-instrument analysis, which categorizes signs according to their psychophysical characteristics (Krippendorff, 2004, pp.44-45). According to these definitions, the semantic content analysis method is deemed most suitable for the purpose of this study.

The unit of analysis for this study was determined as the reports of LPA studies supported by the LAF. LPA reports are publicly accessible through the *"Case Study Brief"* database on the official LPS website (https://www.landscapeperformance.org/). Accordingly, all 210 CSI reports published between 2010 and 2024 constitute the sample of this study.

A coding scheme was developed for the analysis LPA reports. This scheme was informed by guidelines developed by the American Society of Landscape Architects (ASLA) and the LAF. Specifically, the references used were *Landscape Architecture Technical Information Series (LATIS), A Landscape Performance – Metrics Primer for Landscape Architects: Measuring Landscape Performance on the Ground* (McCoy, 2018) and *Evaluating Landscape Performance: A Guidebook for Metric and Methods Selection* (Canfield et al., 2018). The performance themes defined for environmental, social, and economic benefits in these guides were used as indicators in the coding scheme. The resulting coding scheme is presented in Figure 1.



Figure 1. Performance themes and coding (adapted from Canfield, et al. 2018 & McCoy, 2018)

The texts included in the LPA reports were examined during the analysis phase. However, texts provided under heading such as "*uncertain benefits," "features," "additional information," "lessons learned," "cost comparison," "limitations,"* and *"supplementary information"* were not included in the analysis. This exclusion is due to the fact that findings reported under these headings cannot be considered definitive benefits within the scope landscape performance. Inferences drawn from the texts in the reports were marked on the coding scheme, while no marking was made when no inference could be identified. Additionally, the outcomes of landscape designs can be evaluated under one or multiple performance themes. This is because, unlike building which are closed systems, landscape are open systems, and the implemented designs can generate diverse performance outcomes. An example of marking under single and/or multiple performance themes is presented in Figure 2. The analysis was conducted by a single coder in a one-time evaluation of the reports.

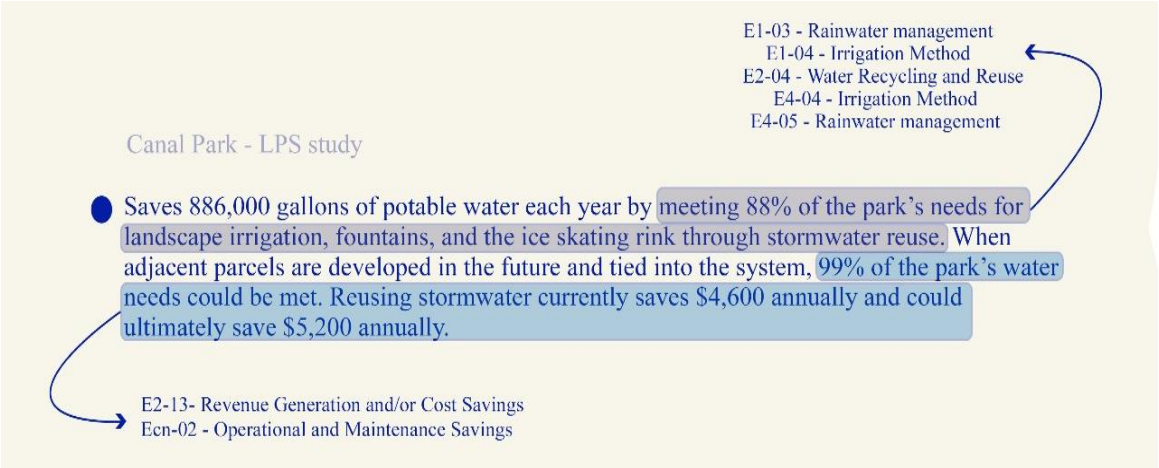


Figure 2. Linking and coding texts with Performance themes (adapted from Salazar, 2015)

Based on the coding scheme developed from the analysis, a frequency analysis was conducted. The results of the analysis are presented both textually and visually (e.g., diagrams, tables). This approach enabled the identification of performance themes to be prioritized in high-performance landscape projects, the most frequently used design methods, and the relationship between these methods and performance outcomes, thereby revealing the key concepts to be considered in creating high-performance landscape designs. Using the resulting conceptual map, recommendations were developed for the design and implementation of high-performance landscape areas in Türkiye.

3. Findings and Discussion

The LAF continues its efforts to inform landscape architecture design through LPS studies and to promote the development of an evidence-based design approach. The 210 LPS studies conducted under the CSI Program between 2010 and 2024 represent a significant source of knowledge and information. The fact that this knowledge has been generated across different countries, regions, and project types contributes to the diversity of the data produced. Upon examination, 32 project types were identified, including parks/open spaces, courtyards/squares, and coastal redevelopment. The landscape design projects included in the 210 LPS studies evaluated in this research correspond to the project types listed in Table 1 below.

Table 1. Distribution of projects by type in LPS studies ("Landscape Performance Series (LPS)", n.d.)

Project Types	Total	Project Types	Total
01. Coastal Redevelopment Project	**28**	17. Park/Open Area	**90**
02. Community	**6**	18. Playground Area	**6**
03. Conference/Retreat Center	**2**	19. Rainwater Management Facility	**24**
04. Courtyard/Square	**29**	20. Recreation Trail	**11**
05. Garden/Arboretum	**11**	21. Retail	**6**
06. Golf Course	**1**	22. School/University	**30**
07. Health Facility	**9**	23. Single-Family Home	**5**
08. Holiday Village/Hotel	**5**	24. Sports Facility	**1**
09. Hybrid Development	**3**	25. Stream Restoration	**15**
10. Industrial Park	**1**	26. Street Landscape	**19**
11. Multi-family Housing	**4**	27. Transportation	**8**
12. Municipal/Government Facility	**7**	28. Urban Agriculture	**4**
13. Museum/Cultural Center	**8**	29. Wetland Creation/Restoration	**18**
14. Nature Reserve	**18**	30. Work Environment	**2**
15. Office	**7**	31. Youth/Community Center	**3**
16. Other	**4**	32. Zoo	**1**

In this section of the study, 210 LPS studies were analyzed using the content analysis method, and answers were sought for the four research questions (RQ_1, RQ_2, RQ_3, and RQ_4). During the research process, each LPS study was coded once, and the analysis of the most frequently

addressed performance themes is presented in Figure 3. For the investigation related to the first research question, a total of 3,399 data entries were processed. The data were analyzed based on three dimensions: frequency of use within each theme, within each benefit category, and across all themes. Environmental benefits were divided into five subcategories, each containing distinct or overlapping performance themes. This categorization led to variations in the results of category-based analyses within the environmental benefit category. However, similar category-based calculations could not be applied to the social and economic benefit categories, as each theme in these categories represents a unique and independent topic.

Performance Benefit	Performance Theme	Code	Frequency of Occurrence in Total LPS Studies (n=210)	Rate of Occurrence within Theme (%)	Rate of Occurrence within Benefit Category (%)	Overall Occurrence Rate (%)
ENVIRONMENTAL BENEFIT	E1 – Land/Property	E1-01	10	2.37	0.46	0.294
		E1-02	15	3.55	0.69	0.441
		E1-03	124	29.38	5.70	3.648
		E1-04	47	11.14	2.16	1.382
		E1-05	2	0.47	0.09	0.058
		E1-06	2	0.47	0.09	0.058
		E1-07	1	0.24	0.05	0.029
		E1-08	44	10.43	2.02	1.294
		E1-09	9	2.13	0.41	0.264
		E1-10	23	5.45	1.06	0.676
		E1-11	3	0.71	0.14	0.088
		E1-12	10	2.37	0.46	0.294
		E1-13	80	18.96	3.68	2.353
		E1-14	10	2.37	0.46	0.294
		E1-15	6	1.42	0.28	0.176
		E1-16	11	2.61	0.51	0.323
		E1-17	25	5.92	1.15	0.735
		Total	*422*	*99,99*		-
	E2 - Water	E2-01	53	11.96	2.44	1.559
		E2-02	120	27.09	5.52	3.530
		E2-03	57	12.87	2.62	1.676
		E2-04	48	10.83	2.21	1.412
		E2-05	2	0.45	0.09	0.058
		E2-06	8	1.80	0.37	0.235
		E2-07	12	2.71	0.55	0.353
		E2-08	15	3.39	0.69	0.441
		E2-09	25	5.64	1.15	0.735
		E2-10	4	0.9	0.18	0.117
		E2-11	22	4.97	1.01	0.647
		E2-12	15	3.39	0.69	0.441
		E2-13	49	11.06	2.25	1.441
		E2-14	13	2.93	0.60	0.382
		Total	*443*	*99,99*	-	-
	E3 - Vegetation	E3-01	6	0.98	0.28	0.176
		E3-02	82	13.35	3.77	2.412
		E3-03	90	14.66	4.14	2.648
		E3-04	19	3.09	0.87	0.559
		E3-05	6	0.98	0.28	0.176
		E3-06	90	14.66	4.14	2.648
		E3-07	39	6.35	1.79	1.147
		E3-08	51	8.31	2.35	1.500
		E3-09	14	2.28	0.64	0.412
		E3-10	5	0.81	0.23	0.147
		E3-11	4	0.65	0.18	0.118
		E3-12	74	12.05	3.40	2.177
		E3-13	15	2.44	0.69	0.441
		E3-14	17	2.77	0.78	0.500
		E3-15	27	4.40	1.24	0.794
		E3-16	42	6.84	1.93	1.236
		E3-17	10	1.63	0.46	0.294
		E3-18	10	1.63	0.46	0.294
		E3-19	13	2.12	0.60	0.382
		Total	*614*	*100*	-	-

Performance Benefit	Performance Theme and	Code	Frequency of Occurrence in Total LPS Studies (n=210)	Rate of Occurrence within Theme (%)	Rate of Occurrence within Benefit Category (%)	Overall Occurrence Rate (%)
ENVIRONMENTAL BENEFIT	E4 – Carbon, Energy, and Air Quality	E4-01	50	8.14	2.30	1.471
		E4-02	3	0.49	0.14	0.088
		E4-03	4	0.65	0.18	0.118
		E4-04	60	9.77	2.76	1.765
		E4-05	141	22.96	6.49	4.148
		E4-06	18	2.93	0.83	0.529
		E4-07	52	8.47	2.39	1.530
		E4-08	92	14.98	4.23	2.71
		E4-09	22	3.58	1.01	0.647
		E4-10	24	3.91	1.10	0.706
		E4-11	44	7.17	2.02	1.294
		E4-12	104	16.94	4.78	3.060
		Total	*614*	*99,99*	-	-
	E5 – Materials and Waste	E5-01	50	61.73	2.30	1.471
		E5-02	31	38.27	1.43	0.912
		Total	*81*	*100*	*99,97*	-
SOCIAL BENEFIT		S-01	54	6.03	6.03	1.589
		S-02	94	10.50	10.50	2.765
		S-03	68	7.60	7.60	2.000
		S-04	111	12.40	12.40	3.266
		S-05	57	6.37	6.37	1.677
		S-06	88	9.83	9.83	2.589
		S-07	42	4.69	4.69	1,236
		S-08	60	6.70	6.70	1.765
		S-09	49	5.47	5.47	1.442
		S-10	58	6.48	6.48	1.706
		S-11	90	10.06	10.06	2.648
		S-12	28	3.13	3.13	0.824
		S-13	21	2.35	2.35	0.618
		S-14	4	0.45	0.45	0.118
		S-15	13	1.45	1.45	0.382
		S-16	41	4.58	4.58	1.206
		S-17	17	1.90	1.90	0.500
		Total	*895*	*99,99*	*99,99*	-
ECONOMIC BENEFIT		Ecn-01	48	14.54	14.54	1.412
		Ecn-02	81	24.54	24.54	2.383
		Ecn-03	38	11.51	11.51	1.118
		Ecn-04	42	12.73	12.73	1.236
		Ecn-05	42	12.73	12.73	1.236
		Ecn-06	19	5.76	5.76	0.559
		Ecn-07	60	18.18	18.18	1.765
		Total	*330*	*99,99*	*99,98*	*99,984*
Grand Total			**3,399**	**99,99**	**99,98**	**99,984**

Note:

The attributes representing three different values are given on the side.

Highest Value

Medium High Value

High Value

Figure 3. Most frequently addressed Performance themes in LPS studies

A total of 614 data entries were recorded under the environmental benefit category. Accordingly, the most frequently addressed performance themes within each environmental subcategory are listed below:

- ***Within the Soil/Land (E1) performance theme*****,** the most frequently addressed topics were stormwater management (E1-03), habitat quality and biodiversity (E1-13), and irrigation method (E1-04).
- ***Within the Water (E2) performance theme*****,** the most frequently addressed topics were stormwater quantity (E2-02), reduction and efficiency of irrigation demand (E2-03), and stormwater quality (E2-01).
- ***Within the Vegetation (E3) performance theme*****,** the most frequently addressed topics were reducing stormwater runoff and promoting infiltration (E3-03), acting as a carbon sink (E3-06), contributing to improved air quality (E3-02), and providing habitat, food, and shelter for wildlife (E3-12).
- ***Within the Carbon, Energy, and Air Quality (E4) performance theme*****,** the most frequently addressed topics were stormwater management (E4-05), carbon sequestration and avoidance (E4-12), and air quality (E4-08).
- ***Within the Materials and Waste (E5) performance theme*****,** the most frequently addressed topics were reuse and recycling of materials (E5-01) and waste reduction (E5-02). Since this theme is associated with two sub-performance themes, a comparison was made to identify which of the two was more frequently addressed.

A total of 895 data entries were recorded under the social benefit category. Accordingly, the most frequently addressed performance themes were identified as activity and health (S-04), preference (S-02), and spiritual enrichment (S-11). In the economic benefit category, a total of 330 data entries were recorded. The most frequently addressed performance themes within this category were operations and maintenance savings (Ecn-02), economic development (Ecn-07), and property value (Ecn-01). Across the benefits categories, a total of 2,174 data entries were recorded under the environmental benefit category. Within this category, the most frequently addressed performance themes were stormwater management (E4-05), stormwater management (E1-03), and stormwater quantity (E2-02). The values in the social and economic categories correspond to the same themes identified above. Among all performance themes and the 3,399 total data entries, the most frequently addressed themes were E4-05, E1-03, and E2-02, all of which are associated with the environmental benefit category.

The realization of each theme may result from the implementation of one or more design methods. The investigation addressing the second and third research questions examined the design methods applied and their relationship with the performance themes, as presented in Figure 4.

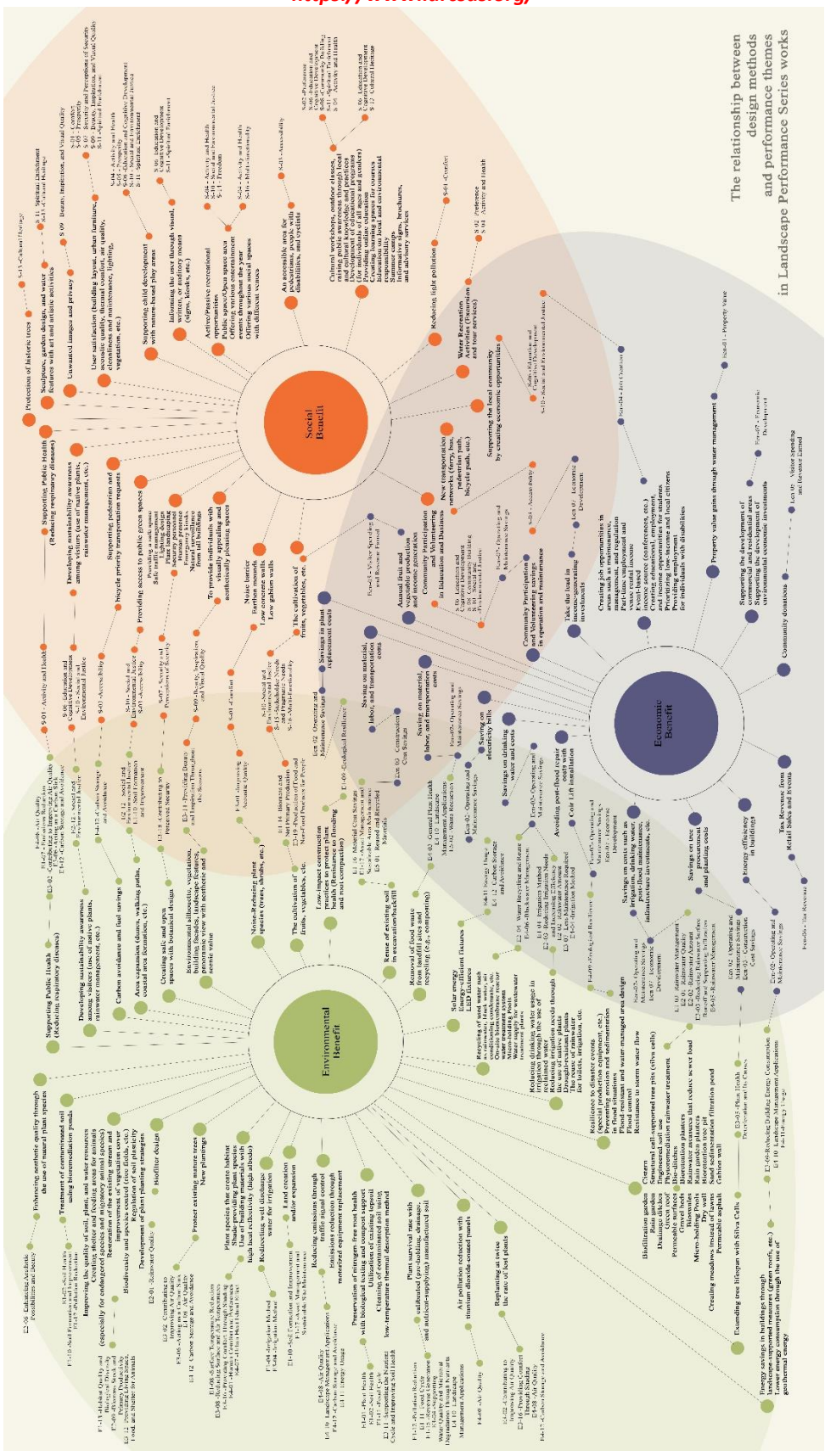


Figure 4. Landscape design methods and their relationship with Performance themes

The visual highlights the prominent design methods. This focus was chosen because, considering the diversity of project types presented in Table 1, factors such as project location, economic investment, natural and cultural values, and the needs of both the community and the city lead to significant variation in design approaches. When the findings related to research question RQ_1, RQ_2, and RQ_3 are correlated, it is observed that many of the design methods are primarily implemented within the scope of environmental benefits.

4. Conclusion and Recommendations

In contemporary practice, creating landscape spaces that address environmental challenges, provide high-quality living environments, and manage and/or enhance existing resources represents a crucial spatial quality within a sustainable life cycle. Therefore, designing high-performance landscapes within the framework of sustainability not only contributes to environmental benefits but also facilities the emergence of social and economic gains. Aligning high-performance landscape design with performance themes occurs through the implementation of specific design methods that respond to designer and client goals. Generally, performance themes such as *stormwater management, reduction of irrigation demand, activity and health, operation and maintenance cost savings, and construction cost savings* are developed through the design and implementation process. However, certain themes – *such as providing habitat and food for wildlife, preference, comfort, sense of place, property value, and economic development* – represent performance outcomes that can be assessed after the landscape design has been implemented. Ultimately, the creation of a high-performance landscape depends on the success of the project's implementation. The LPS evaluates and measures this success by quantitatively assessing the environmental, social, and economic benefits generated by the implemented design.

When the LPS studies published between 2010 and 2024 are evaluated as a whole, it becomes evident that the evaluation process has evolved and its scope has expanded over time. The growing understanding of the purpose of performance assessments conducted by researches, along with their significant contributions to the field of sustainability, has been further supported by advances in technology and the increasing variety of research methods. This demonstrates that LPA is not a static field of study. Moreover, the performance outcomes published within an open-access database that includes the results of CSI projects serve as a valuable professional resource across academia, education, and practice. The analysis of these performance results provides critical insights for the design process, supporting the creation of more sustainable and high-performing landscapes as well as the enhancement or redesign of existing sites. Accordingly, this study explores the conceptual transitions and reflections from landscape performance assessment to design practice, contributing to a deeper understanding of how performance-based evaluation informs and shapes contemporary landscape design.

Based on the responses to the research questions, the most frequently addressed performance themes in the environmental, social, and economic benefit categories were identified as stormwater management (E4-05/E1-03/E2-02), activity and health (S-04), and operations and maintenance savings (Ecn-02), respectively. Analysis across all performance themes further highlighted the prominence of stormwater management (E4-05/E1-03/E2-02) within the environmental benefits category. As noted in most studies, one reason for the prominence of stormwater management is its support through local and regional regulations. However, identifying the most frequently addressed themes does not imply that other performance themes are unimportant. In practice, performance themes generated by the implementation of one

design method can function independently, while the application of another method may contribute to or reinforce additional themes. Consequently, all performance themes are directly or indirectly interconnected under the umbrella of sustainability. Therefore, future landscape designs should incorporate a broader range of performance themes, and the design methods applied to achieve these themes should be carefully examined and evaluated.

Due to the extensive and detailed nature of design methods, the approaches applied in the studies were addressed only at a conceptual level. The conceptual map presented in Figure 4 provides guidance on the methods that can be implemented in the design of a high-performance landscape. It is observed that design methods are most frequently applied within the environmental benefit category, which can be attributed to the fundamental goal of landscape architecture: creating natural and livable spaces for people through the use of natural resources and materials. As an example, within the stormwater management theme, parameters such as site grading and vegetation used in the design of rain gardens serve functions including water direction, infiltration, flow attenuation, treatment, and storage. Additionally, the water stored in rain gardens contributes to operations and maintenance cost savings for the landscape while mitigating the destructive effects of flooding during heavy rainfall, thereby creating a safe environment for users. This functional system also fosters cognitive development and environmental awareness among individuals.

In most LPS studies, the design methods applied are not fully specified; however, some studies provide textual and/or visual support (e.g., technical drawings, plans, renders, real-world images). The sharing of materials that illustrate the design and its details may depend on the design firms and clients involved. Nevertheless, presenting research findings within the CSI framework, supported by design methods and analyses, can help readers interpret the information, integrate it into the design/implementation process, enhance it, or develop new solutions. Therefore, establishing a clear and standardized framework for presenting LPS studies would facilitate future academic and professional work in the field.

Based on the analyses and findings, a high-performance landscape can be defined as follows:

"It should be a space designed with foresight not only for today's resources but also for those of the future. Such spaces effectively manage water resources, enhance habitat quality and biodiversity, reduce water use and demand, act as a carbon sink, provide habitat and foraging opportunities for wildlife, improve air quality, reuse existing materials, and minimize waste generation. They offer users a variety of active and passive recreational opportunities, support individual and public health, provide diverse choices and encourage people to prefer the space. These landscapes enrich individuals spiritually and foster spaces with strong social interactions. At the same time, they contribute to operational and maintenance cost savings, support economic development in the surrounding area, and enhance property values."

In conclusion, based on the analyses conducted, the study identifies the themes, design solutions, and concepts that should be incorporated in the design of high-performance landscapes in Türkiye and in future participation in LPS studies. Designing high-performance landscapes in Türkiye will contribute to sustainability goals at both local and national levels and will lay the foundation for creating resilient and high-quality living environments. This research not only provides a reference for landscape design practices in Türkiye but also offers a valuable framework that can support studies and applications in other countries.

Thanks and Information Note

This study was produced from the master's thesis of Mahmut Can AST, conducted under the supervision of Elif SAĞLIK.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Aydınlı, M. (2017). *Beşiktaş ilçesi atıl mekânların kent kurgusuna katılımlarına yönelik performans temelli yaklaşımlar. (Master's thesis). Institute of Natural Sciences, Department of Landscape Architecture, İstanbul Technical University.*

Barnes, M. (2024) Landscape performance in practice: Insights and recommendations. *Landscape Review*, 20(2), 18–26.

Barnes, M., Zhu, R., Newman, G. & Tao, Z. (2025). Defining and Explaining Landscape Performance. G. Newman, R. Zhu, D. Li, and M. Barnes (Eds.). in: *Contemporary Landscape Performance Methods and Techniques*. (s. 3-11). Routledge: New York.

Brown, R. D. & Cory, R. C. (2011). Evidence-based landscape architecture: The maturing of a profession. *Landscape and Urban Planning. 100*, 327 – 329. doi: 10.1016/j.landurbplan.2011.01.017

Canfield, J., Yang, B., & Whitlow, H. (2018). *Evaluating landscape performance: A guidebook for metrics and methods selection.* Washington, DC: Landscape Architecture Foundation (LAF).

Chen, G. (2024). *Measuring landscape performance: Context, mechanisms, strategies, approaches, and theories* (PhD thesis). Lincoln University.

Çelik, F. (2013). Ecological landscape design. *Advances in Landscape Architecture – InTech*, 325 – 350, doi: http://dx.doi.org/10.5772/55760

Güler, K. E. (2019). *Beylikdüzü- İstanbul kentsel yeşil alanlarında peyzaj performansının sosyal yarar açısından değerlendirilmesi. (Master's thesis). Institute of Natural Sciences, Department of Landscape Architecture, Bartın University.*

Krippendorff, K. (2004). *Content Analysis: An introduction to its methodology* – 2nd ed. Sage Publications.

Landscape Architecture Foundation (LAF). (n.d.). *About landscape performance*. Landscape Performance Series. Access Address (13.06.2025): https://www.landscapeperformance.org/about-landscape-performance

Landscape Performance Series (LPS) (n.d.). Case study briefs. Access Address (13.06.2025): https://www.landscapeperformance.org/case-study-briefs

Luo, Y. (2014). *Enhancing quantification of a landscape project's environmental, economic and social benefits: A study of Landscape Architecture Foundation's Landscape Performance Series* (PhD thesis). Texas A&M University.

McCoy, E. (2018). *A Landscape Performance + Metrics Primer for Landscape Architects: Measuring Landscape Performance on the Ground.* Washington, DC: American Society

of Landscape Architects (ASLA), Landscape Architecture Technical Information Series (LATIS).

Meijering, J. V., Tobi, H., van den Brink, A., Morris, F. & Bruins, D. (2015). Exploring Research Priorities in Landscape Architecture: An International Delphi Study. *Landscape and Urban Planning. 137*, 85 – 94. Doi: http://dx.doi.org/10.1016/j.landurbplan.2015.01.002

Ndubisi, F., Whitlow, H., Deutsch, B., Duan, S. L. & Zhang, X. W. (2015). Landscape Performance: Past, Present, and Future. *Landscape Architecture*. 1, 41 – 51. DOI: 10.14085/j.fjyl.2015.01.0040.12.

Özdil, T. R. (2018). Kentsel Peyzajın Sanatı mı, Bilimi mi? Amerika'da performans Araştırmaları Akımı. *Mimarlık Dergisi.* Ed. T. E. Altan vd. Sayı 402 Pp. 50-54

Salazar, J. (2015). Canal Park. *Landscape Performance Series*. *Landscape Architecture Foundation.* Doi: https://doi.org/10.31353/cs0870 Access Address: https://www.landscapeperformance.org/case-study-briefs/canal-park

Shen, Z., Peng, X., Du, C. & Kim, M. (2023). Quantifying sustainability and landscape performance: A smart devices assisted alternative framework. *Sustainability. 15*, 13239. Doi: https://doi.org/10.3390/su151713239

Swaffield, S. & Deming, M. E. (2011). Research strategies in landscape architecture: mapping the terrain. *Journal of Landscape Architecture. 6*(1), 34 – 45. Doi: 10.1080/18626033.2011.9723445

Yang, B., Li, S. & Binder, C. (2016). A research frontier in landscape architecture: Landscape performance and assessment of social benefits. *Landscape Research*, 41(3), 314 – 329. Doi: http://dx.doi.org/10.1080/01426397.2015.1077944.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Virtual Reality (VR)- Augmented Reality (AR) and Mobile Applications in Urban Recreation Areas

Seyhan SEYHAN [1*]

ORCID 1: 0000-0002-6046-5024
[1] Research Assistant Doctor., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
seyhanseyhan2@gmail.com (Responsible Author)

Banu Çiçek KURDOĞLU[2]

ORCID 2: 0000-0003-4683-8581
[2] Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
banukurdoglu@gmail.com

Abstract

The use, planning, and experience of urban spaces are radically transforming with the rapid development of digital technologies. Urban recreation areas, impacted by this situation, are not only spaces where users spend their free time but are also transforming into hybrid social spaces by integrating with digital technologies. They are integrating digital technologies such as virtual reality (VR), augmented reality (AR), and mobile applications to increase functionality, accessibility, and interactivity. VR applications are used in the planning process of urban recreation areas to gather the ideas and opinions of different users through virtual simulations and to enable users with other disabilities to experience the spaces in a digital environment. AR technologies provide interactive information about cultural elements, historical textures, and plant species. Gamified experiences also enable more active use of urban recreation areas. Mobile applications also personalize user experiences within areas, such as orientation, event calendars, density information, and health and sports tracking, and support more efficient use of the spaces. This study investigates the integration of virtual reality (VR), augmented reality (AR), and mobile applications in urban recreation areas. The contributions and opportunities offered by these digital technologies have been evaluated. The study highlights how integrating digital technologies into urban recreation areas in sustainable urban planning will provide an innovative perspective, improving the functionality of spaces and the quality of social life in cities.

Keywords: Urban recreation areas, virtual reality, augmented reality, mobile applications

1. Introduction

Society moving away from rural areas and towards urban areas has increased the population in cities, causing pressure on the urban structure. Society has started to experience physical, social, and psychological pressures within urban life. However, in the cities they live in, their environment is rapidly becoming depleted and polluted by developing technology. This situation leads to psychological, personal, and physical deterioration in people. The need for recreation has emerged in society to escape this pressure (Uzun & Müderrisoğlu, 2010). This recreation need felt by society consists of the' social and personal benefits. It comes to the fore with the benefits it provides for social integration and solidarity and the formation of democratic societies. It also responds to personal benefits such as gaining mental health, socialization, creativity, improving physical health, developing personal skills and abilities, providing economic impact, and ensuring work efficiency and success (Belli & Gürbüz, 2012). At this point, recreation areas in urban areas (Figure 1) come to the fore in meeting the recreation need. These areas offer activities held in open or closed areas in the city center. People can access these activities easily in short periods and immediate surroundings (Eren & Koçyiğit, 2020). They are seen as basic public spaces where they meet their physical, psychological, and social

needs. They play an important role in experiencing urban belonging, socialization, and physical activities (Whyte, 1980). City squares, city parks, theme parks and gardens, and museums are examples of urban recreation areas (Yavuz & Altınay, 2016).



Figure 1. Sample applications of urban recreation areas (Url-1; Url-2)

The use and experience of urban recreational spaces have been evolving in recent years due to increasing urbanization, digitalization, technological advancements, and diversified user expectations. In this regard, digital technologies such as virtual reality (VR), augmented reality (AR), and mobile applications stand out for their rich potential in experiencing and using public spaces.

Virtual Reality (VR) technologies are computer-generated three-dimensional artificial environments that evoke the senses through visual, auditory, and textural cues. Users, wholly or partially isolated from the physical world, can spend time in virtual environments using specialized devices such as VR headsets, gloves, and head-mounted displays (Slater & Sanchez-Vives, 2016). Augmented reality (AR), on the other hand, provides users with a realistic experience by integrating data generated by transferring visual, auditory, and other sensory content from the real world into a digital environment. Unlike VR, it does not immerse the user in an entirely virtual environment but superimposes virtual objects onto the real environment (Azuma, 1997; Billinghurst et al., 2015). Mobile applications encompass software programs designed to run on portable devices. They are a part of mobile information technologies widely used in many areas such as communication, commerce, education, and entertainment. They enable users to interact via touchscreens, voice commands, or sensors (Kim, 2008; Gao et al., 2014). Ultimately, digital technologies such as VR, AR, and mobile applications enable users to experience, interact, and participate. Proper design and delivery of these technologies can increase individual well-being and contribute to cities' sustainable goals.

2. Integration of Virtual Reality (VR), Augmented Reality (AR) Technologies, and Mobile Applications into Urban Recreation Areas

Literature on integrating digital technologies such as VR, AR, and mobile applications into urban recreational area is ongoing. With the integration of these technologies into urban spaces;

- **VR technology (Figure 2)** allows users to transform urban recreational spaces fully into virtual environments. This allows users to experience physical spaces digitally. It will also

enable individuals with access restrictions to access public spaces through virtual simulations (Slater & Wilbur, 1997). Enabling the introduction of urban parks or cultural landscapes through virtual tours contributes to preserving and sharing natural and cultural heritage (Bekele et al., 2018).



Figure 2. VR technology (Url-3)

- **AR technologies (Figure 3)** offer users an "enriched" experience by adding digital layers to physical spaces (Azuma, 1997; Milgram & Kishino, 1994). AR-supported navigation systems in urban recreation areas facilitate the discovery of natural walking routes and can strengthen environmental education by providing interactive information about plant and animal species (Billinghurst & Kato, 2002). Gamification applications using these technologies also contribute to users' more active exploration of urban spaces and increased levels of physical mobility (Laato et al., 2023).



Figure 3. AR technology (Url-4)

- **Mobile applications** play a significant role in the sustainable management of urban recreational areas. Location-based services allow users to learn about park density, access online event calendars, and provide instant feedback (Yang et al., 2025). Mobile health and

exercise applications also support the health-focused functions of recreational areas by encouraging physical activity among park users (Pereira, 2024).

3.Conclusion

Within the scope of the study, the integration of Virtual Reality (VR), Augmented Reality (AR) and mobile applications was examined in the context of supporting urban recreation areas with digital technologies. Findings from the literature indicate that these technologies not only enrich the user experience but also have the potential to increase participation, strengthen urban identity, and contribute to sustainability goals. VR technologies, in particular, are a powerful tool for users to experience spaces, pre- and post-design simulations, and interactive exploration. By adding digital layers to the physical environment, AR technologies provide information, guidance, and cultural content to individuals using urban recreation areas. Mobile applications, in turn, facilitate the accessibility, interaction, and user-focused services in urban recreation areas, enabling a broader audience to reach. Combining these technologies offers city residents and users more inclusive, interactive, and innovative recreation experiences.

Furthermore, collecting and analyzing user data through digital integration enables the development of participatory and data-based decision-making mechanisms in urban planning processes. However, resolving issues such as technical infrastructure, cost, digital inequality, and privacy are critical to the sustainable implementation of these technologies. Consequently, integrating VR, AR, and mobile applications into urban recreational spaces is a key tool in building smart, user-centric cities of the future. Therefore, interdisciplinary collaboration among urban designers, municipalities, and technology developers is essential to the success of this integration.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Azuma, R. T. (1997). A survey of augmented reality. Presence: *Teleoperators & Virtual Environments*, 6(4), 355-385.

Belli, E. & Gürbüz, A. (2012). *Mimar sinan güzel sanatlar üniversitesi akademik personelinin rekreasyon faaliyetlerinin incelenmesi*, 1. Rekreasyon Araştırmaları Kongresi, Kemer, Antalya, ss. 168-176, 10-12 Nisan 2012.

Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A survey of augmented, virtual, and mixed reality for cultural heritage. *Journal on Computing and Cultural Heritage* (JOCCH), 11(2), 1-36.

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends® in Human–Computer Interaction*, 8(2-3), 73-272.

Billinghurst, M., & Kato, H. (2002). Collaborative augmented reality. *Communications of the ACM*, 45(7), 64-70.

Eren, C., & Koçyiğit, M. (2020). Kent imajının ve kentsel rekreasyon alanlarına yönelik algının ölçümü. *Aksaray İletişim Dergisi*, 2(1), 66-81.

Gao, S., Krogstie, J., & Siau, K. (2014). Adoption of mobile information services: An empirical study. *Mobile Information Systems*, 10(2), 147-171.

Kim, S. H. (2008). Moderating effects of job relevance and experience on mobile wireless technology acceptance: Adoption of a smartphone by individuals. *Information & Management*, 45(6), 387-393.

Laato, S., Fernández Galeote, D., Altarriba Bertran, F., Papangelis, K., & Hamari, J. (2023). How location-based games incentivize moving about: A study in the context of nature-going. *Proceedings of the ACM on Human-Computer Interaction*, 7(CHI PLAY), 642-664.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12), 1321-1329.

Pereira, C. G. (2024). How smart cities can promote healthy behaviors. *In Environmental Health Behavior* (pp. 113-145). Academic Press.

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, 3, 74.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and virtual environments*, 6(6), 603-616.

Url-1: https://pin.it/1TQNovjU3. 30.09.2025

Url-2: https://pin.it/5UbZwC8vF. 30.09.2025

Url-3: https://pin.it/1cKpkm711. 01.10.2025

Url-4: https://pin.it/5PY6vwLpp 01.10.2025

Uzun, S. & Müderrisoğlu, H. (2010). Kırsal rekreasyon alanlarında kullanıcı memnuniyeti: Bolu Gölcük Orman İçi Dinlenme Yeri Örneği. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi* Seri: A, Sayı: 1, ISSN: 1302- 7085, Sayfa: 67-82

Yang, K., Zhen, F., & Zhang, S. (2025). Evolution of Smart Parks and Development of Park Information Modeling (PIM): Concept and Design Application. *Chinese Geographical Science*, 1-17.

Yavuz, E., & Altınay, M. (2016). Kentsel rekreasyon alanlarında hizmet kalitesi: Ankara İli Örneği. *Journal of Recreation and Tourism Research*, 3(2), 60-72.

Whyte, W. H. (1980). *The social life of small urban spaces* (Vol. 116). Washington, DC: Conservation Foundation.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

How Do Urban Recreation Areas Contribute to Social Solidarity and Integration?

Seyhan SEYHAN [1*]

ORCID 1: 0000-0002-6046-5024
[1] Research Assistant Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
seyhanseyhan2@gmail.com (Responsible Author)

Banu Çiçek KURDOĞLU[2]

ORCID 2: 0000-0003-4683-8581
[2] Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
banukurdoglu@gmail.com

Abstract

Urban recreation areas are essential spaces where society meets its social, physical, and spiritual needs and strengthens social solidarity and integration. They are indispensable components of urban life. Rapid urbanization, coupled with increased population density, spatial fragmentation, and social alienation, limits city residents' communication and interaction and weakens social ties. Urban recreation areas, which host a wide range of activities such as squares, parks, community gardens, walking and cycling paths, and cultural and artistic activities, bring together individuals of different genders, ages, languages, religions, races, cultural backgrounds, and socioeconomic backgrounds, enabling them to share experiences. They foster communication and interaction among individuals and support disadvantaged groups' participation in urban life. Thus, social integration is achieved by ignoring social differences. Social solidarity and integration are the coming together, acting together, and uniting urban areas, communities, and individuals towards a common purpose, goal, value, and responsibility. This study explores and examines how urban recreation areas contribute to social solidarity and integration in national and international literature. The study emphasizes that urban recreation areas are places where individuals spend their free time and are strategically crucial for social solidarity and integration sustainability. In this respect, the study will provide a new perspective on the literature and urban planning and management.

Keywords: Urban recreation areas, social solidarity, integration

1. Introduction

Urban recreation areas, planned and designed to meet society's social, physical, and cultural needs, offer opportunities for individuals to spend their free time through their open and closed spaces (Figure 1). They encompass many areas such as community gardens, squares, parks, playgrounds, and sports facilities in cities (Chiesura, 2004). These areas are considered spaces where physical and psychological needs within society are met and sociocultural platforms where social relationships are developed and social integration is strengthened. The stress of today's urban life, the intense workload, long working hours, and individuals' tendency towards individualism can limit their ability to socialize and integrate (Gehl, 2011). In this regard, urban recreation areas provide opportunities for individuals of different genders, ages, races, languages, religions, cultures, and socioeconomic backgrounds to come together and interact. In this way, they support social cohesion, social solidarity, and integration (Peter et al., 2010).



Figure 1. Sample applications of urban recreation areas (Url-1; Url-2)

Social solidarity and integration in urban areas is the coming together, acting, and uniting of individuals in a society towards common goals, objectives, values, and responsibilities (Putnam, 2000). It mediates the formation of trust and social bonds among individuals. It is a fundamental dimension of social cohesion. Trust is associated with perceptions of cooperation and equality (Dragolov et al., 2016). It increases social resilience in times of crisis. It is one of the most fundamental elements facilitating compliance with implemented welfare and health policies (Borkowska & Laurence, 2021). It reflects inclusive social values by supporting the coexistence of communities with different languages, religions, cultures, ethnicities, and socioeconomic characteristics (Doreian & Fararo, 2012). It increases social solidarity and integration by forming emotional bonds, a sense of belonging, and community loyalty between society and individuals (Hu et al., 2023).

Considering the contribution of urban recreation areas to social solidarity and integration (Figure 2), they serve as spaces where communities spend their free time and as social platforms where social interaction is fostered and a sense of trust and belonging is developed. They directly contribute to social solidarity and integration. The diversity of activities and spaces they accommodate increases interaction among different socio-cultural and economic groups. Thus, they reinforce mutual trust and solidarity among individuals. They strengthen ties between communities (Cattell et al., 2008). They create opportunities for interaction and encounters in cities with multicultural characteristics. They encourage intercultural harmony. They facilitate social interactions between residents and individuals from different cultures (Seeland et al., 2009). They foster social belonging and neighborhood identity. Urban recreation areas designed at the neighborhood level foster a sense of belonging among individuals and strengthen community ties. They also increase mutual trust among users and support social integration (Francis et al., 2012). It enables the experience of cultural diversity. This, in turn, increases inclusiveness by reducing social conflicts (Low et al., 2005).







Figure 2. Examples of social solidarity and integration in urban recreation areas (Url-3; Url-4; Url-5)

2. Sample Applications

In this part of the study, randomly selected urban recreation areas were discussed, and their orientation towards social solidarity and integration was explained.

- **New York – Bryant Park (Figure 3)**

In the 1970s and 1980s, Bryant Park was perceived and known as an area where users felt unsafe, crime rates were high, and social exclusion was widespread. This resulted in the park's weakness in terms of social solidarity and integration (Whyte, 1980). William H. Whyte's 1980 study, "The Social Life of Small Urban Spaces," referenced the park's redesign. The study investigated how people behave in public spaces and what physical arrangements encourage social interaction. Attention was paid to implementing activity formats to increase social interaction and foster participation among diverse communities (Madden, 2010). Strategies for social integration were developed. Free and accessible activities, emphasizing open public space, and security and belonging were prioritized.



Figure 3. Bryant Park- New York (Url-6; Url-7)

- **Barselona – Parc Güell (Figure 4)**

Designed by Antoni Gaudí between 1900 and 1914, the project was initially planned as a residential garden project but was never completed, eventually gaining a new function as a public park. It was created based on the idea that social relationships would be strengthened and spaces harmonious with nature could bring people together (Kent & Prindle, 1993). Located at the park's center, "Plaça de la Natura" was planned as a public meeting and interaction area. It serves as a social space that can be used for collective events. Its multifunctional structure contributes to the coming together of people from different social classes and strengthens social integration. The structures adorned with mosaics within the park functioned both aesthetically and to establish a shared cultural identity (McNeill, 2000). Over time, transforming it from private property into public space reflected a more inclusive approach to public space by reducing social inequalities (Arias-Sans & Russo, 2016).



Figure 4. Parc Güell- Barcelona (Url-8; Url-9)

- **Zurich – Urban Forests and Parks (Figure 5)**

Since the 19th century, it has been one of the cities that has planned public green spaces as a tool for social integration. The municipality defines green spaces as nature conservation, social gathering, democratic sharing, and recreation (Seelan et al., 2009). It embraces the principle of public space open to all. Different social classes are encouraged to share the same spaces. It is a city with a high immigrant population, and its urban forests and parks provide a platform for diverse ethnic groups to integrate (Kabisch & Haase, 2014; Haase et al., 2017).



Figure 5. Rieterpark- Zurich (Url-10)

- **İstanbul – Maçka Demokrasi Park (Figure 6)**

The park emerged as part of the green belt project planned around the İnönü Gezi Park and Dolmabahçe Valley in the 1950s as part of the urban development activities (Tekeli, 2009). Known as Makça Park, it was redesigned after September 12, 1980, and renamed Democracy Park. This transformation allowed the park to function as a recreational space, a political memorial, and a social gathering space (Kuyucu, 2014). Its central location makes it a common space, enabling diverse socio-economic groups to unite. This increases the park's potential for social integration. It hosts various events to strengthen the solidarity practices of citizens (Erkip, 2000).



Figure 6. Maçka Demokrasi Parkı- Türkiye (Url-11)

3. Conclusion

In conclusion, as in the examples above, urban recreation areas not only serve the functions necessary for society to utilize its leisure time but also serve as a tool for establishing cultural and social relationships, fostering the integration of ethnic differences, and fostering and strengthening social harmony. Therefore, in planning these areas, it is crucial to consider functions that foster aesthetic, ecological, and social solidarity and integration.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Arias-Sans, A., & Russo, A. P. (2016*). The right to Gaudí: What can we learn from the commoning of Park Güell, Barcelona? In Protest and resistance in the tourist city* (pp. 261-277). Routledge.

Borkowska, M., & Laurence, J. (2021). Coming together or coming apart? Changes in social cohesion during the Covid-19 pandemic in England. *European Societies,* 23(S1), S618-S636.

Cattell, V., Dines, N., Gesler, W., & Curtis, S. (2008). Mingling, observing, and lingering: Everyday public spaces and their implications for well-being and social relations. *Health & place*, 14(3), 544-561.

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, 68(1), 129-138.

Dragolov, G., Ignácz, Z. S., Lorenz, J., Delhey, J., Boehnke, K., & Unzicker, K. (2016). Social cohesion in the western world: What holds societies together: Insights from the social cohesion radar. *Springer*.

Doreian, P., & Fararo, T. J. (2012). *The problem of solidarity: Theories and models*. Routledge.

Francis, J., Giles-Corti, B., Wood, L., & Knuiman, M. (2012). Creating sense of community: The role of public space. *Journal of Environmental Psychology*, 32(4), 401-409.

Gehl, J. (2011). *Life between buildings*.

Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., Baró, F., ... & Wolff, M. (2017). Greening cities–To be socially inclusive? About the alleged paradox of society and ecology in cities. *Habitat International*, 64, 41-48.

Hu, J., Ying, J., Zhang, Y., Shen, Y., & Wu, X. (2023). From landscapes to bonds: Exploring the influencing mechanism of community parks on social integration. *Sustainability,* 15(10), 8065.

Low, S., Taplin, D., & Scheld, S. (2005). *Rethinking urban parks: Public space and cultural diversity*. University of Texas Press.

Kabisch, N., & Haase, D. (2014). Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and Urban Planning*, 122, 129-139.

Kent, C., & Prindle, D. (1993). *Park Gúell.* Princeton Architectural Press.

Kuyucu, T. (2014). Law, Property and Ambiguity: The Uses and Abuses of Legal Ambiguity in Remaking I stanbul's Informal Settlements. *International Journal of Urban and Regional Research*, 38(2), 609-627.

Madden, D. J. (2010). Revisiting the end of public space: Assembling the public in an urban park. *City & Community,* 9(2), 187-207.

McNeill, D. (2000). McGuggenisation? National identity and globalisation in the Basque country. *Political Geography*, 19(4), 473-494.

Peters, K., Elands, B., & Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion?. *Urban Forestry & Urban Greening*, 9(2), 93-100.

Putnam, R. D. (2000). Bowling alone: The collapse and revival of American community. *Simon and Schuster.*

Seeland, K., Dübendorfer, S., & Hansmann, R. (2009). Making friends in Zurich's urban forests and parks: The role of public green space for social inclusion of youths from different cultures. *Forest Policy and Economics*, 11(1), 10-17.

Tekeli, İ. (2009). *Cumhuriyetin belediyecilik öyküsü,* 1923-1990 (Vol. 4). Tarih Vakfı Yurt Yayınları.

Whyte, W. H. (1980). *The social life of small urban spaces* (Vol. 116). Washington, DC: Conservation Foundation.

Url-1: https://pin.it/7coDZRNes. 29.09.2025

Url-2: https://pin.it/4VJij6vZc. 29.09.2025

Url-3: https://pin.it/4GNzpgjd4. 29.09.2025

Url-4: https://pin.it/4ifflri6t. 29.09.2025

Url-5: https://pin.it/5w3sSjiJv. 29.09.2025.

Url-6: https://pin.it/6XP15xA68 29.09.2025

Url-7: https://pin.it/3FSKylUc1 29.09.2025

Url-8: https://pin.it/1YijRa7R1. 30.09.2025

Url-9: https://pin.it/3hcbdFvxZ. 30.09.2025

Url-10:https://www.stadt-zuerich.ch/de/stadtleben/sport-und-erholung/park-und-gruenanlagen/rieterpark.html. 30.09.2025

Url-11: https://www.canercangul.com/10496/macka-demokrasi-parki/ , 30.05.2025

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Comparative Assessment of Simulation Tools in the Scope of Indoor Air Quality

Rana KİBAROĞLU KANTARCI [1]*

ORCID 1: 0009-0000-3221-5223
[1]Architect, Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
r.kibaroglu2021@gtu.edu.tr (Responsible Author)

Elif ÖZER YÜKSEL [2]

ORCID 2: 0000-0002-1041-8748
[2]Assistant Professor, Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
e.yuksel@gtu.edu.tr

Abstract

Indoor air contamination is primarily caused by three mechanisms: occupant bio-effluents, building product emissions, and external pollutant ingress. These hazards introduce adverse agents causing specific health problems, often linked to insufficient awareness among design and user groups. Evaluating Indoor Air Quality (IAQ) pollutants during design and operation requires simulation tools that concurrently integrate complex factors. Accurate assessment necessitates understanding each tool's characteristics, as results depend significantly on regional climate, construction materials, occupant profile, and ventilation strategy. Tools derive calculations from IAQ limit values defined by the national standards of their country of development. This study comparatively evaluates four accessible IAQ simulation tools: CONTAM (USA), MODELICA (Canada/Asia), IA-QUEST (Canada), and EPA's IAQX. CONTAM was identified as the most current, largely due to its integration with other programs and 2D drawing capabilities. Given the tools' reliance on specific national data, utilizing a simulation tool tailored to local conditions is expected to yield more accurate results.

Keywords: Indoor air quality, indoor air pollutants, simulation tool, CONTAM

1. Introduction

Indoor air can be contaminated due to the biological and physiological actions of occupants and as a result of building products. This contamination in Indoor Air Quality (IAQ) directly affects the health of the space occupant. Risk groups, particularly the sick, the elderly, and children, are more severely affected. These effects may be short-term or can lead to long-term health problems.

Studies concerning Indoor Air Quality (IAQ) have increased in developed countries in recent years. This is due to the rise in Sick Building Syndrome and building-related illnesses. While there are studies and measurement stations regarding outdoor air quality in our country, the number of studies conducted within the scope of Indoor Air Quality (IAQ) is insufficient. An examination of the Ulusal Tez Merkezi determined that the number of thesis studies conducted within the scope of Indoor Air Quality (IAQ) is insufficient. A total of 26 Master's and PhD theses were written up to September 2025.

Regulations and standards concerning Indoor Air Quality (IAQ) exist both in our country and globally. These regulations, which aim to determine the limit values of Indoor Air Quality (IAQ) pollutants, may vary according to the local characteristics of countries. These limit values are employed in the simulation tools used to simulate Indoor Air Quality (IAQ). When evaluating the results of a simulation tool, it must be remembered that the limit values used in the tool are country-specific. If the tool is to be used in a different country, attention must be

paid to the similarity of the climatic and geographical features. Thus, the closest result can be achieved.

The simulation tools used to measure Indoor Air Quality (IAQ) possess various distinct features. Advantages such as library diversity, offering the possibility of two-dimensional (2D) drawing, and integration with different programs play a role in the selection of the simulation tool. The user should identify the strengths of these tools and determine the most appropriate simulation tool for their study.

1.1. Indoor Air Quality and Indoor Air Pollutants

Indoor air, which is composed of atmospheric gases from the external environment, contains certain ratios of nitrogen, oxygen, argon, and carbon dioxide. In addition to these gases, the air contains very small amounts of neon, helium, methane, krypton, hydrogen, xenon, nitrogen dioxide, and ozone (Tünay & Alp, 1996; Vural & Balanlı, 2005). As a result of natural actions occurring in the atmosphere, the ratios of the air's components remain constant. As long as this balance is maintained, the air is considered to be "of high quality."

According to the title “Ventilation for Acceptable Indoor Air Quality” in the ASHRAE 62-1989 Standard: “It is air in which there are no known pollutants at harmful concentration levels determined by authoritative bodies, and in which 80% or more of the occupants are not expressing dissatisfaction with the air quality” (Aslan, 1997).

To ensure comfort conditions, a human requires an average of 25 to 39 m^3 of air per hour. During respiration, oxygen from the air is consumed, producing carbon dioxide and water vapor. The amount of oxygen required by an individual is related to their weight, age, nutrition, and actions (Balanlı, 2007; Darçın, 2008).

Both short- and long-term exposure to Indoor Air Pollution can lead to various health problems, including respiratory diseases, heart diseases, cognitive deficiencies, and cancer. The World Health Organization estimates that 3.8 million people die globally each year due to illnesses related to harmful IAQ originating from dirty cookstoves and fuels (WEB 1, NIEHS, 2025).

IAQ is directly related to occupant health and comfort. Ensuring its protection requires maintaining its control. This monitoring can be achieved through solutions applied during the design or utilization phases, such as particle control (filtration), ventilation control, and pressurization (Aslan, 1997).

The main physical properties of air are related to temperature, humidity, air movements, pressure, and radiation from the atmosphere. Temperature, humidity, and air movements gain importance in terms of IAQ (Gültekin, 2001). The World Health Organization stated that for indoor air to provide comfort conditions, the temperature should be 19-23 °C, the relative humidity 40-60%, and the air velocity 0.1 m/s (WHO, 1987).

Temperatures between 20-26 °C in the indoor environment remain within the comfort limits for most people. However, complaints about building-related illnesses increase above 22 °C. This is because the emission of Volatile Organic Compounds (VOCs) from building materials increases at temperatures between 20-26 °C (Hays et al., 1995; Gültekin, 2001).

Air pollution is constituted by the accumulation of pollutants—which can compromise the composition of air and mix with it from various sources—to a level that affects living organisms (Balanlı, 2007; Darçın, 2008). Indoor air is known to be contaminated in three ways: as a result of the biological and physiological actions of occupants, by air pollutants originating from

building products, and by the ingress of pollutants from the external atmosphere into the building (Balanlı & Taygun, 2005; Ceylan, 2011).

Darçın classified indoor air pollutants as follows (Darçın, 2014):

- According to their Physical Properties: gases/vapors, particulates (Table 1),
- According to their Chemical Properties: organic, inorganic,
- According to their Sources: originating from outside the building, from building products, from the space occupant/actions,
- According to their Health Effects: causing cancer, non-cancer illnesses, and Sick Building Syndrome,
- According to their Origin: natural and artificial.

Table 1. Classification of Indoor Air Pollutants According to Their Physical Properties (Darçın, 2014)

Indoor air pollutants in the form of gas/vapor:	Carbon monoxide, carbon dioxide, nitrogen monoxide, nitrogen dioxide, sulfur dioxide, radon, ozone, mercury, Volatile Organic Compounds (VOCs), polycyclic aromatic hydrocarbons
Indoor air pollutants in the form of particulates (PM):	• Fibers: asbestos, vegetable fibers, rock wool, glass wool • Metals: lead • Biological pollutants: viruses, bacteria, mold fungi, pollens, arthropods, skin flakes
Some pollutant groups:	Various waste groups resulting from combustion (smoke, etc.), pesticides

The concentration of the pollutant in the form of gas and vapor is determined by volume or weight. For volume determination, the unit ppm (parts per million), which indicates the gas volume in one million total volume, or ppb (parts per billion), which indicates the pollutant volume in one billion total volume, is used (Tichenor, 2006; Ceylan, 2011). Particulates, on the other hand, are substances dispersed in the air in solid and liquid states. They can be removed from the area where they are suspended due to reasons such as sedimentation, diffusion, and evaporation (Velicangil, 1985; Gültekin, 2001).

According to their size, particulates are classified as:

- PM_{10} (coarse particulates): those with diameters between 10 µm and 2,5 µm
- $PM_{2,5}$ (fine particulates): those with diameters smaller than 2,5 µm,
- $PM_{0,1}$ (ultrafine particulates): those with diameters smaller than 0,1 µm (Darçın, 2014).

Ventilation can be defined as the clean air taken into the indoor environment of the building from the outside environment (Öztürk et al., 2005). The purpose of providing ventilation in a building is the occupant's need for breathing and protection from indoor air pollutants. For the building to be adequately ventilated by natural methods, external air of suitable quality must reach the building, this air must be introduced into the building via the building envelope, sufficient and appropriate air circulation must be ensured within the building, and the contaminated air must be expelled from the building (Darçın & Balanlı, 2012). The types of ventilation systems are indicated in Figure 1.

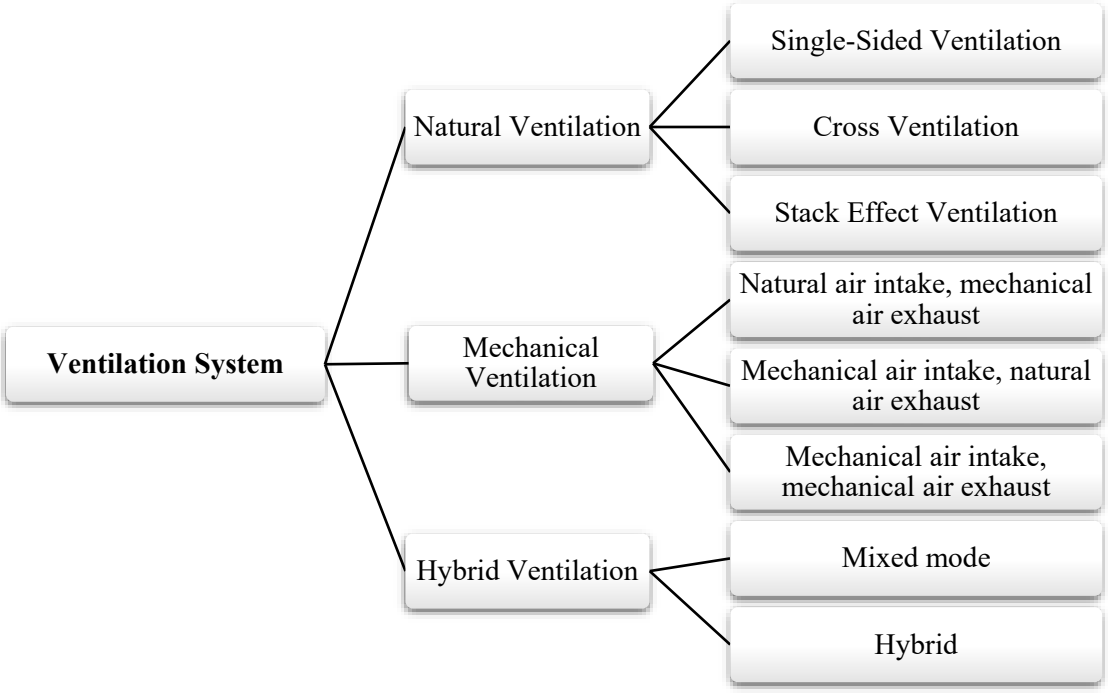


Figure 1. Types of Ventilation Systems.

1.2. Effects of Indoor Air on Human Health

Indoor air pollutants, given the formation of specific conditions, can generate different types of health problems in humans, who are the principal occupants of the building (Darçın, 2014). In children, the immune, respiratory, digestive, nervous, and reproductive systems have not completed their development. The rate at which airborne Particulate Matter (PM) reaches the lungs may be higher in children compared to adults (Maeseno, 2013; Ertürk, 2017).

Indoor air pollutants can be classified based on their effects on occupant health as: toxic (poisonous), carcinogenic (causing cancer), mutagenic (causing genetic effects), allergenic (causing allergies), irritant (affecting respiration and vision), and infectious (Cengiz Yılan, 2008). Bulgurcu also classified indoor air pollutants in the context of their health effects as: irritant, asphyxiant, narcotic, poisonous, pathological-allergenic, and carcinogenic (Bulgurcu, 2015). According to this classification:

- Volatile Organic Compounds (VOCs): irritant, asphyxiant, narcotic, poisonous, carcinogenic,
- Formaldehyde, biological pollutants, environmental tobacco smoke, polycyclic aromatic hydrocarbons, asbestos, and radon: irritant, carcinogenic,
- Pesticides and lead: irritant, poisonous, carcinogenic,
- Carbon dioxide and carbon monoxide: asphyxiant,
- Nitrogen dioxide and sulfur dioxide: irritant,
- Radon: determined as carcinogenic.

Another illness caused by Indoor Air Pollution is Sick Building Syndrome (SBS). Symptoms begin shortly after the occupant enters the building and cease shortly after they leave. Although the causes of Sick Building Syndrome cannot be determined definitively, one accepted hypothesis is that certain air pollutants, present as a mixture at low concentration levels in the indoor air, cause the discomfort symptoms associated with SBS (EPA, 1994).

Pollutants thought to be associated with SBS are listed as (Bernstein, 2008):

- dust,
- Volatile Organic Compounds (VOCs),
- endotoxins, and
- molds.

Furthermore, the discomfort caused by odors generated by indoor air pollutants, falling under the scope of cacosmia (bad odor syndrome) which can be observed in occupants inside the building, is also considered one of the causes of SBS (Balanlı, 2012; Darçın, 2014).

1.3. Regulations and Standards Related to IAQ in Our Country and Worldwide

There are several regulations and standards in our country and worldwide that determine the limit values for indoor air quality. Some of these include:

- Türkiye Air Quality Assessment and Management Regulation (2008),
- National Air Quality Index,
- ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard,
- European Union Standards,
- World Health Organization Standards,
- Limit values determined by the TOBB Türkiye Climatization Council IAQ Commission (2025).

The limit values for indoor air pollutants have been determined through these regulations and standards. These limit values vary (Table 2). The Türkiye Air Quality Assessment and Management Regulation determines the limit values for outdoor air pollutants. However, it is kept within the scope because a healthy IAQ cannot be achieved in an environment where the outdoor air quality is poor. Most spaces in Türkiye are ventilated using natural ventilation. Therefore, outdoor air pollutants are also observed indoors.

The National Air Quality Index was established by adapting the EPA Air Quality Index to our national legislation and limit values. The air quality index is calculated for five basic pollutants. These are: Particulate Matter (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) (Istanbul Air Quality Monitoring Center, WEB 2, 2025).

ASHRAE is an international society that focuses on heating, cooling, and air-conditioning. Founded in 1894, ASHRAE aims to advance human well-being through sustainable technology for the built environment. The society and its members focus on building systems, energy efficiency, IAQ, refrigeration, and sustainability in the industry (ASHRAE, WEB 3, 2025).

The main purpose of the European Union's air quality standards is to assess the exposure of humans and vegetation to pollution, to evaluate the actions carried out by competent authorities to reduce pollution or maintain air quality, and to inform the public about air quality (IBB Department of Environmental Protection and Control, WEB 4, 2025).

The World Health Organization (WHO), in its guidance documents published in 2000 and 2005, recommended exposure levels (concentrations and durations) for which there is no evidence of adverse effects on human health and vegetation (IBB Department of Environmental Protection and Control, WEB 5, 2025).

The Limit Values Working Group was established within the TOBB Türkiye Climatization Council IAQ Commission. The members of the LVWG examined the literature regarding indoor environment emission sources, concentrations in schools, the health effects of these emissions, and existing limit values. They identified the indoor air pollutants to be addressed and made recommendations for limit values for schools in Türkiye (Sofuoğlu et al., 2025).

Table 2. Comparison of Regulations and Standards

	TAQAMR	NAQI	ASHRAE	EUS	WHOS	TCCS
SO_2 (Sulfur dioxide)	350 µg/m³ (hourly)	380 µg/m³ (hourly)	x	350 µg/m³ (hourly)	500 µg/m³ (10minutes)	x
NO_2 (Nitrogen dioxide)	200+20 µg/m³ (hourly)	260 µg/m³ (hourly)	x	200 µg/m³ (hourly)	200 µg/m³ (hourly)	100 ppb (hourly)
NOx (Nitrogen oxide)	x	x	x	200 µg/m³ (annual)	x	x
PM_{10} (Particulate Matter Pollutant)	50 µg/m³ (24-hour)	60 µg/m³ (24-hour)	50 µg/m³ (short-term)	50 µg/m³ (24-hour)	45 µg/m³ (24-hour)	45 µg/m³ (8-hour)
$PM_{2,5}$ (Particulate Matter Pollutant)	x	12 µg/m³ (24-hour)	x	25 µg/m³ (annual)	5 µg/m³ (annual)	15 µg/m³ (8-hour)
Pb (Lead)	0.5 µg/m³ (annual)	x	x	0.5 µg/m³ (annual)	0.5 µg/m³ (annual)	x
	TAQAMR	**NAQI**	**ASHRAE**	**EUS**	**WHOS**	**TCCS**
C6H6 (Benzene)	5 µg/m³	x	x	5 µg/m³	5 µg/m³	5 µg/m³ (8-hour)
CO (Carbon Monoxide)	10.000 µg/m³ (8-hour)	10.000 µg/m³ (8-hour)	10.000 µg/m³ (short-term)	10.000 µg/m³ (8-hour)	10.000 µg/m³ (8-hour)	9 ppm (8-hour)
O_3 (Ozone)	120 µg/m³	120 µg/m³	235 µg/m³	120 µg/m³	100 µg/m³	70 ppb

	(8-hour)	(8-hour)	(short-term)	(8-hour)	(8-hour)	(8-hour)
Arsenic	0.006 µg/m³ (annual)	x	x	0.006 µg/m³ (annual)	0.006 µg/m³ (annual)	x
Cadmium	0.005 µg/m³ (annual)	x	x	0.005 µg/m³ (annual)	0.005 µg/m³ (annual)	x
Nickel	0.02 µg/m³ (annual)	x	x	0.02 µg/m³ (annual)	0.02 µg/m³ (annual)	x
Benzo(a)pyrene	0.001 µg/m³ (annual)	x	x	0.001 µg/m³ (annual)	0.001 µg/m³ (annual)	x

2. Materials and Methods

The scope of IAQ includes the building system, the materials used to construct the building, the materials brought into the building by occupants and visitors, the occupants' actions within the building, and 'Heating, Ventilation, and Air Conditioning (HVAC) and air filtration systems' (Yan, Song et al., 2008). Evaluating all these factors that arise during the utilization phase requires design tools capable of considering all these factors simultaneously. Various simulation tools are utilized to assess IAQ.

This study will examine four different IAQ simulation tools. These simulation tools were chosen due to their ease of access and the distinctions they offer:

- CONTAM in the USA,
- MODELICA in Canada and Asia,
- IA-Quest software in Canada are used to simulate IAQ.
- EPA's IAQX (Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure) simulation software is also available.

3. Findings and Discussion

CONTAM was developed by government employees at the National Institute of Standards and Technology (NIST, 2020). CONTAM is intended for use in the field of air flow and pollutant dispersion in buildings. The software is a methodology used to calculate air flows and pollutant transfer within a building. The calculations are based on a simplified model of actual buildings.

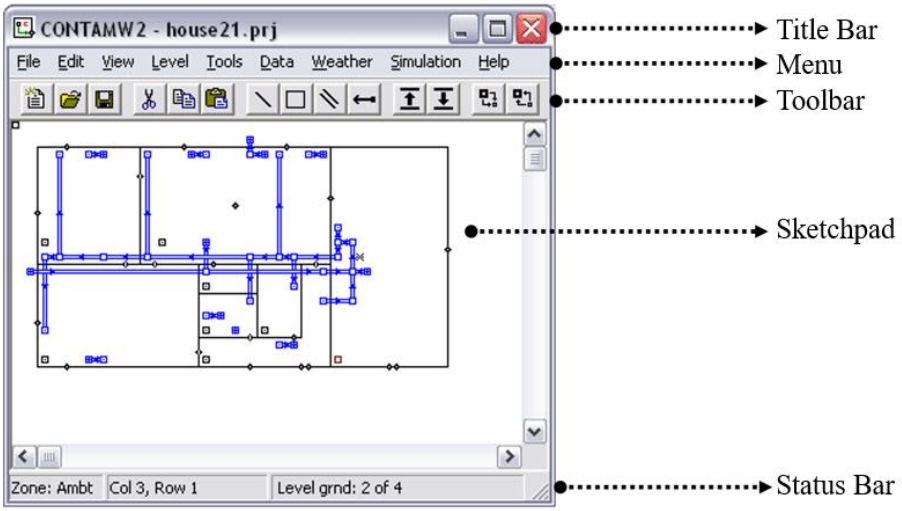


Figure 2. Interface of the CONTAM Software (WEB 6, 2025)

The use of CONTAM to analyze indoor air flow or pollutant transfer involves five distinct steps:

1. Building Idealization: Creating an idealization or a specific model of the building.
2. Schematic Representation: Creating a schematic representation of the idealized building using the ContamW SketchPad to draw the building components.
3. Defining Building Components: Collecting and entering the data associated with each of the building components represented in the SketchPad.
4. Simulation: Selecting the type of analysis desired, setting the simulation parameters, and generating the simulation.
5. Saving Results: Reviewing the simulation results and saving selected portions of the results.

CONTAM can also be integrated with EnergyPlus. EnergyPlus is a whole building energy simulation program used by engineers, architects, and researchers to model both energy consumption (for heating, cooling, ventilation, and lighting loads) and water use in buildings (EnergyPlus, WEB 7, 2025). CONTAM can be combined with EnergyPlus to perform air flow and heat transfer simulations (NIST, 2020).

The following are transferred from EnergyPlus to CONTAM:

- Zone temperatures,
- Ventilation system airflow rates,
- Outdoor airflow fractions for outdoor airflow controllers,
- Exhaust fan airflow rates,
- Energy recovery fan airflow rates,
- Outdoor environmental data, including temperature, barometric pressure, wind speed, and wind direction, obtained from the EnergyPlus weather (.epw) files.

The following are transferred from CONTAM to EnergyPlus:

- Zone airflow rates,
- Interzone airflow rates obtained via airflow paths,
- Control values exposed through the CONTAM control network (e.g., a signal calling for ventilation airflow due to a high pollutant level).

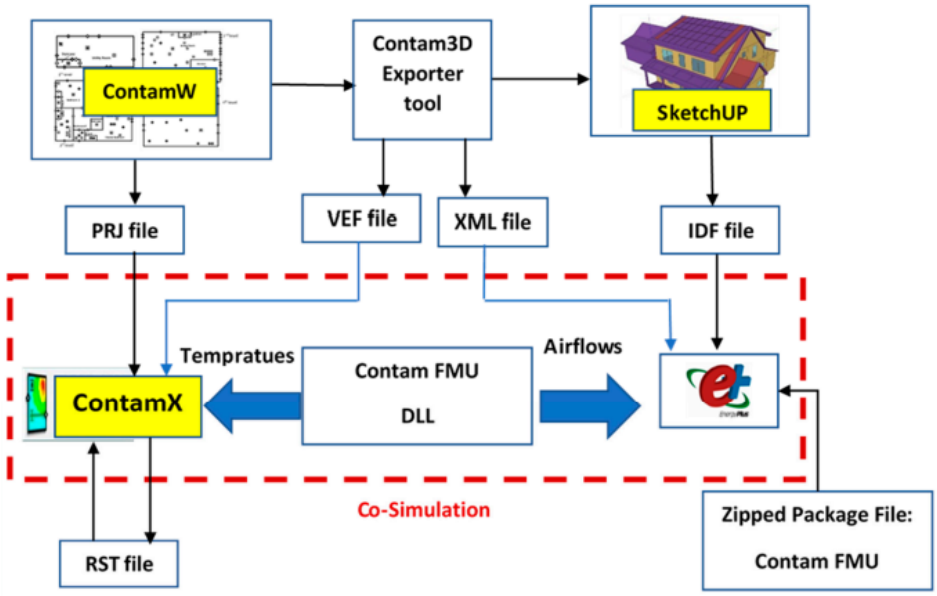


Figure 3. CONTAM-EnergyPlus Relationship (Heibati et al., 2019)

Modelica was developed to support the research and development of building energy and control systems. Primary applications include control design, energy analysis, and model-based study. It was developed by Canada and Asian countries.

It is a language that supports the connection of components governed by mathematical equations to facilitate modeling. It provides object-oriented structures that facilitate the reuse of models and can be readily used to model complex systems containing mechanical, electrical, electronic, magnetic, hydraulic, thermal, control, electric power, or process-oriented sub-components (Modelica, 2023). Many free libraries are available on the Modelica website. Previous versions can also be accessed from the site. Information about books written for the software and universities where courses are taught can be accessed.

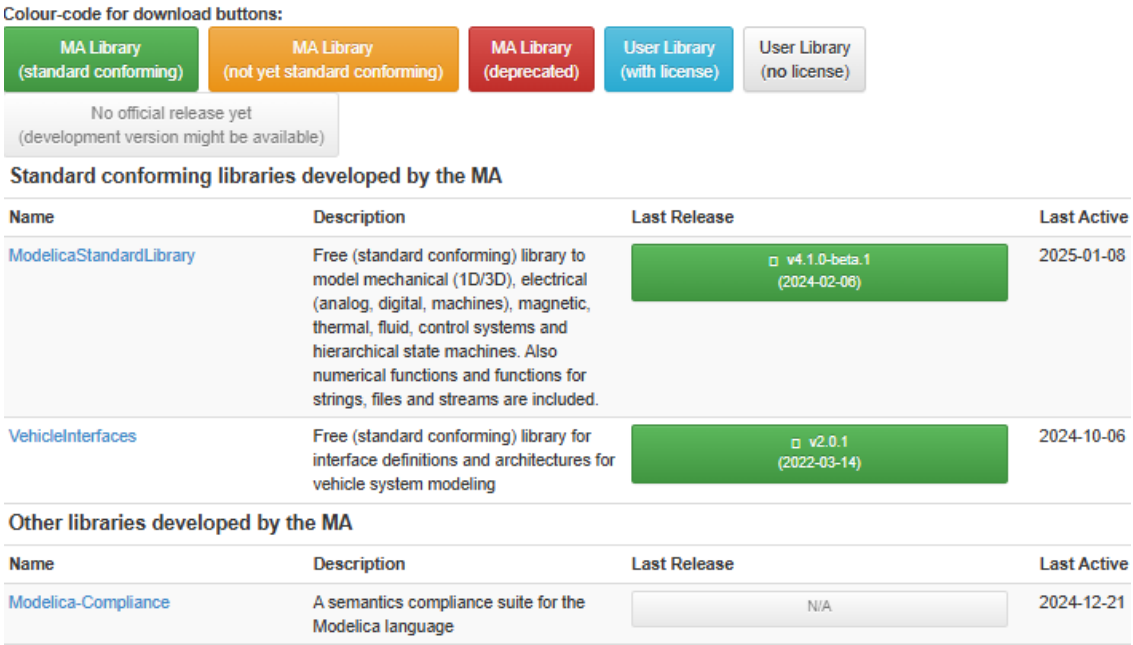


Figure 4. Modelica Libraries (Modelica Library, WEB 8, 2025)

IA-Quest (Indoor Air Quality Emission Simulation Tool) includes a materials database that allows for the selection of materials based on low emissions and contains their measured emissions. Furthermore, the tool aids in quantifying the impact of low-emission materials and effective ventilation strategies on IAQ by estimating the emission of Volatile Organic Compounds (VOCs) from building materials and furniture. It was developed in Canada.

The IA-Quest software consists of two parts: a database and a simulation component:

- The database provides information on health-relevant target Volatile Organic Compounds (VOCs) from building materials commonly used in Canada.
- The simulation component calculates pollutant concentrations that may arise due to emissions from the materials present in a room with a known ventilation rate and schedule. The emission properties of the materials are obtained from the database within the software (NRCC, WEB 9).

To simulate the indoor air concentrations of chemicals originating from building materials, occupants must possess the following information (NRCC, WEB 9):

- The volume of the space,
- The ventilation rate and schedule,
- Materials (selected from the database),
- For each material: the exposed/emitting surface area,
- Simulation duration.

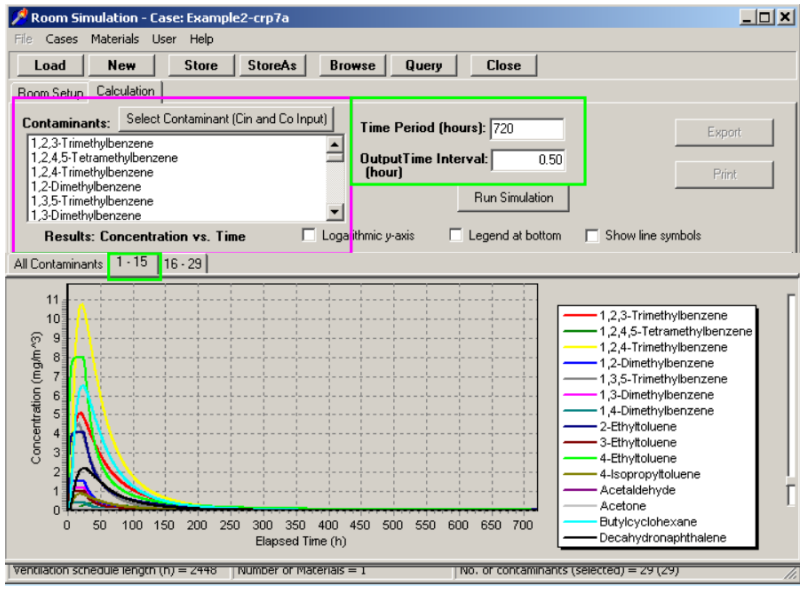


Figure 5. Interface of the IA-Quest Software (Won, 2008)

IAQX (Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure) is a Microsoft Windows-based IAQ simulation tool. In addition to performing traditional IAQ simulations that calculate pollutant concentrations, IAQX can estimate the adequate ventilation rate when specific air quality criteria need to be met.

The outputs provided by the program include:

- Estimation of Volatile Organic Compound (VOC) emissions from solvent-based indoor coating materials based on product formulation,
- Indoor solvent spills,

- VOC emissions from carpets,
- Particulate Matter (EPA, 2000).

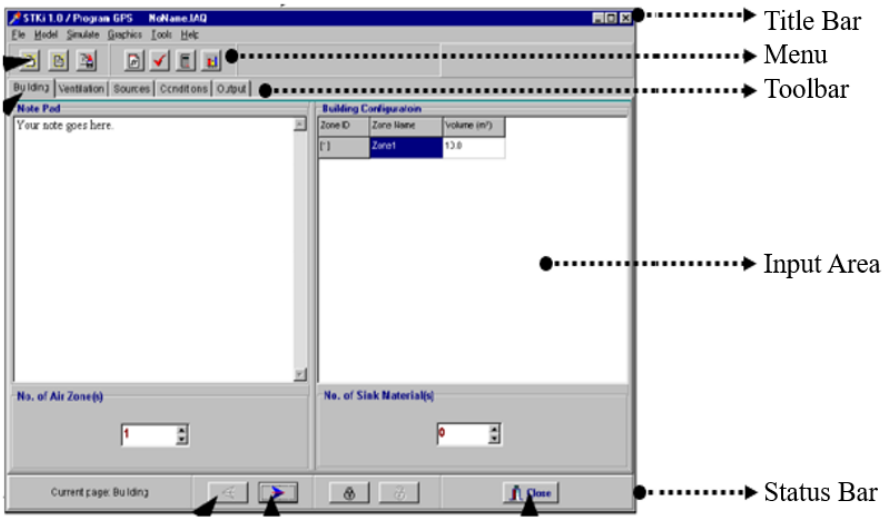


Figure 6. Interface of the IAQX Software (EPA, 2000)

IAQ is directly related to human health. The exposure of the occupant group to pollutants in the indoor air poses a threat to their health. These health problems can be biological as well as having psychological effects. At this point, the designer must detail solutions that will enhance IAQ. Thereby, a portion of the pollution that may arise during the utilization phase will be eliminated. The occupant must also make conscious choices regarding the ventilation of the space and the control of actions performed within it, with the same level of awareness.

All simulation tools used to measure IAQ examined within the scope of this study are freely accessible. 2D drawing can only be performed in the CONTAM tool. All simulation tools except IA-Quest have a manual. Each program possesses a strength from the perspective of the occupant:

- CONTAM: Stands out due to its 2D drawing capability, integration with TRNSYS and EnergyPlus programs, and possession of video content.
- MODELICA: Stands out due to having the largest library.
- IA-QUEST: Stands out due to having an extensive materials database.
- IAQX: Stands out due to its manual introducing the program (Table 3).

Table 3. Comparison of Simulation Tools Used Within the Scope of IAQ

	CONTAM	MODELICA	IA-Quest	IAQX
Country/ Institution	USA	Canada and Asian Countries	Canada	EPA
Cost (Paid/Free)	Free	Free	Free	Free
2D Drawing Capability	2D Drawing is available	x	x	x
Guide	+	+	x	+

4. Conclusion and Recommendations

IAQ is a significant architectural factor that can affect the health of the occupant group. Indoor air can be contaminated as a result of the biological and physiological actions of the occupant, as well as originating from building products. The designer must take into account the effect on IAQ when determining the materials to be used in the building design during the production phase. Various simulation tools can be utilized to perform this calculation. These simulation tools can be used to determine indoor air pollution during the utilization phase as well as the design phase.

CONTAM in the USA, MODELICA in Canada and Asia, and IA-Quest software in Canada are used to simulate IAQ. EPA's IAQX (Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure) simulation software is also available. These simulation tools were chosen due to their ease of access and the distinctions they offer.

All examined software programs are freely accessible. No other software is integrated with another program except CONTAM. Detailed manuals are available for all simulation tools except IA-Quest. Modelica has the largest library and provides access to publications/university courses on its official website. The IA-Quest simulation tool includes a more extensive materials database. The manuals for CONTAM, Modelica and IAQX contain information on how to use the software and its interface.

All simulation programs possess a unique advantage compared to the others. CONTAM has been determined to be the most current simulation tool due to its integration with other programs and the possibility of 2D drawing. However, it is considered that the interface of all simulation tools, including CONTAM, needs to be updated and developed. However, real-time monitoring of this data by the occupant could be enabled by providing 3D integration.

There is no simulation tool produced in Türkiye. A simulation tool specific to Türkiye could be developed by creating a more user-friendly and modern interface design and by expanding the materials inventory. The limit values set for IAQ pollutants in the regulations should be utilized in these tools. Since simulation tools are developed considering the climatic data and material properties of countries, more accurate results can be achieved with a simulation tool specific to Türkiye.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. 1st Author %60, 2nd Author %40 contributed.

References

Aslan, D.E., (1997). “İç Hava Kalitesi ve Kontrolü”, Ill. Ulusal Tesisat Mühendisliği Kongresi ve Sergisi, Makine Mühendisleri Odası, 97’ Teskon Program Bildirileri/İHK 005, 55-63.

Bernstein, J. A., Alexis, N., Bacchus, H., vd., (2008). “The Health Effects of Nonindustrial Indoor Air Pollution”, *Journal of Allergy and Clinical Immunology*, 121(3): 585-591.

Bulgurcu, H., (2015). “Havalandırma ve İç Hava Kalitesi”, Deneysan Ders Notu.

Cengiz Yılan, T., (2008). *“Yapı Ürünlerinden Kaynaklanan Yapı İçi Hava Kirliliğinde Risk Yönetimi”, Doktora Tezi, Yıldız Teknik Üniversitesi, İstanbul.*

Ceylan, A., (2011). *"İklimlendirme Sistemlerinin Yapı İçi Hava Niteliği Üzerindeki Olumsuz Etkileri", Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi, İstanbul.*

Darçın, P., Balanlı, A., (2012). "Yapılarda Doğal Havalandırmanın Sağlanmasına Yönelik İlkeler", *Tesisat Mühendisliği Dergisi,* s.33-42.

Darçın, P., (2008). "*Yapı İçi Hava Kirliliğinin Giderilmesinde Doğal Havalandırma İlkeleri", Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi.*

Darçın, P., (2014). *"Yapı İçi Hava Kirliliğinin Değerlendirilmesine Yönelik Bir Yaklaşım", Doktora Tezi, Yıldız Teknik Üniversitesi.*

EPA, (1994). "Indoor Air Pollution: An Introduction for Health Professionals", EPA 402-R94-007, American Lung Association, Environmental Protection Agency, Consumer Product Safety Sommission, American Medical Association.

EPA Research anda Development, (2000). "Simulation Tool Kit For Indoor Air Quality And Inhalation Exposure (Iaqx) Version 1.0 User's Guide".

Ertürk M., (2017). "Yatılı okul yatakhanelerinde iç hava kalitesi probleminin araştırılması ve yeni bir sistem geliştirilmesi", *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi,* Doi:10.16984/saufenbilder.30075.

Gültekin,H., (2001). *"Yapay Ahşap Malzeme ve Yapı İçi Havanın Niteliğine Etkisi Üzerine Bir Araştırma", Yüksek Lisans Tezi, Mimar Sinan Üniversitesi- Fen Bilimleri Enstitüsü.*

Heibati, S., Maref, W., Saber, H.H., (2019). "Assessing the Energy and Indoor Air Quality Performance for a Three-Story Building Using an Integrated Model, Part One: The Need for Integration", *Energies,* 12, 4775; doi:10.3390/en12244775.

Modelica Language (2023). Modelica a Unified Object-Oriented Language for Systems Modeling Version 3.6.

NIST (National Institute of Standards and Technology) (2020). CONTAM User Guide and Program Documentation Version 3.4.

Öztürk, H.K., Yılancı, A., Atalay, Ö., (2005). "Konutlarda Doğal ve Zorlanmış Havalandırma Sistemleri", *Tesisat Mühendisliği Dergisi,* Sayı: 89, s. 21-26.

Sofuoğlu, S.C., Ari, A., Civan, M., Dumanoğlu, Y., Güllü, G., Menteşe, S., Onat, B., Alver Şahin, Ü., Toksoy, M., (2025). "A proposal of indoor air pollutant limit values for Turkish schools based on a literature review of emission sources, concentrations, health effects, and limits/guidelines", *Atmospheric Pollution Research,* S1309-1042(25)00345-9, APR 102743.

Vural, S. M. & Balanlı, A. (2005). "Yapı Ürünü Kaynaklı İç Hava Kirliliği ve Risk Değerlendirmede Ön Araştırma", *Megaron*, YTÜ Mim. Fak. E-Dergisi, Cilt 1, Sayı 1.

WEB 1, United States Government, National Institute of Environmental Health Sciences (NIEHS). (2025). *Indoor Air Quality*. Access Address (19/09/2025): https://www.niehs.nih.gov/health/topics/agents/indoor-air

WEB 2, İstanbul Hava Kalitesi İzleme Merkezi. (2025). *Hava Kalitesi İndeksi*. Access Address (11/01/2025): https://havakalitesi.ibb.gov.tr/Icerik/mevzuat/hava-kalitesi-indeksi

WEB 3, ASHRAE. (2025). *About ASHRAE*. Access Address (11/05/2025): https://www.ashrae.org/about

WEB 4, İBB Çevre Koruma ve Kontrol Dairesi Başkanlığı. (2025). *Avrupa Birliği Standartları*. Access Address (11/01/2025): https://cevre.ibb.istanbul/hava-kalitesi/avrupa-birligi-standartlari/

WEB 5, İBB Çevre Koruma ve Kontrol Dairesi Başkanlığı. (2025). *Dünya Sağlık Örgütü Standartları*. Access Address (11/01/2025): https://cevre.ibb.istanbul/hava-kalitesi/dunya-saglik-orgutu-standartlari/

WEB 6, File Extension. (2025). *CONTAM Download*. Access Address (12/01/2025): https://www.file-extension.info/downloads/contam

WEB 7, Energy Plus. (2025). *Energy Plus Website*. Access Address (15/01/2025): https://energyplus.net/

WEB 8, Modelica Libraries. (2025). *Modelica Libraries*. Access Address (13/01/2025): https://modelica.org/libraries/

WEB 9, NRCC (National Research Council Canada). (2025). *IA-Quest: Indoor Air Quality Emission Simulation Tool*. Access Address (13/11/2025): https://nrc.canada.ca/en/research-development/products-services/software-applications/ia-quest-indoor-air-quality-emission-simulation-tool

WHO, (1987). "Air Quality Guidelines for Europe", WHO Regional Publications, European Series No.23, Denmark.

Won, D. (2008). IA-QUEST (Indoor Air Quality Emission Simulation Tool), IRC-ORAL-850 Presentation. National Research Council Canada.

Yan, D., Song, F., & vd., (2008). "An integrated modeling tool for simultaneous analysis of thermal performance and indoor air quality in buildings", *Building and Environment* 43, s. 287–293.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

3D Topographic and Architectural Documentation of the Multi-Functional Underground Structure at Kaletepe, Miletus

Özel TERAMAN HEPDİNÇLER[1]*

ORCID 1: 0000-0003-0266-3476
[1] Asst. Prof., Mimar Sinan Fine Arts University, Faculty of Science and Letters, Department of Archaeology, İstanbul-Türkiye
ozel.teraman@msgsu.edu.tr (Responsible Author)

Nikolai TECHOW[2]

ORCID 2: 0009-0001-6948-3616
[2] M.Sc., Berliner Hochschule für Technik, Bauingenieur- und Geoinformationswesen, Berlin-Germany
techow.nikolai@gmail.com

Haralambos NİKOLAYİDİS[3]

ORCID 3: 0000-0001-5633-2723
[3] Asst. Prof., Bilecik Şeyh Edebali University, Faculty of Humanities and Social Sciences, Department of Archaeology, Bilecik-Türkiye
haralambos.nikolayidis@bilecik.edu.tr

Özlem KAYA[4]

ORCID 4: 0009-0007-9695-9062
[4] Undergraduate Student, Yıldız Technical University, Faculty of Architecture, Department of Architecture, İstanbul-Türkiye
ozlemkaya1265@gmail.com

Hasan Ersin GÜVENDİK [5]

ORCID 5: 0009-0008-1651-6593
[5] Undergraduate Student, Mimar Sinan Fine Arts University, Faculty of Science and Letters, Department of Archaeology, İstanbul-Türkiye
hasangasan422@gmail.com

Ece KIZILDAĞ[6]

ORCID 6: 0009-0009-3489-7016
[6] Undergraduate Student, Mimar Sinan Fine Arts University, Faculty of Science and Letters, Department of Archaeology, İstanbul-Türkiye
kizildagece157@gmail.com

Abstract

Since the early 2000s, two data collection methods—terrestrial laser scanning and photogrammetry—have been increasingly utilized in various fields of scientific research. These methods play a particularly significant role in the documentation of excavation sites and historical structures in archaeology. This study aims to conduct a detailed architectural documentation of an underground structure, discovered during the 2022 excavation season at the Kaletepe in the ancient city of Miletos, which must be evaluated together with the cistern it contains. For this purpose, tacheometry measurement techniques, terrestrial 3D laser scanning, and both terrestrial and UAV-supported photogrammetry will be employed. The intended outcome of this study includes the creation of architectural drawings, high-resolution 3D models, and orthophotos, which will provide a foundational basis for subsequent archaeological architectural research. In achieving this, the study first defines the fundamental theoretical concepts and applied measurement methods. It then presents the preparatory steps and methodological approaches for data collection. The collected data are comprehensively analyzed through a comparative evaluation using Metashape and Reality Capture software. Additionally, the study includes architectural

documentation of the structure, consisting of a niche corridor accessed by stairs and a cistern, using a combination of traditional measurement and photogrammetric methods.

Keywords: Miletus/Kaletepe, underground cistern, photogrammetry, terrestrial laser scanning, 3D Model

1. Introduction

Miletus is an ancient harbor city located on the western coast of Anatolia, near the mouth of the Maeander River. The archaeological remains of the city lie approximately 3 kilometers north of the modern village of Balat in Didim, Aydın. Although today it is situated about 10 kilometers inland, in antiquity Miletus owed its prosperity to its strategic location and four well-protected harbors, which made it a prominent center of trade and colonization. Because of this strategic importance, the city was besieged and conquered multiple times by various powers, but its eventual decline was brought about by the silting of the Maeander River. Sharing the same fate as its neighboring Ionian League cities—Priene and Myus—Miletus lost its maritime connection during the Early Christian period as its harbors silted up, leading to a decline in economic vitality and gradual abandonment (For further information, see Gorman, 2001; Greaves, 2002; Niewöhner, 2016).

The area known as Kaletepe, or alternatively Theater Hill, lies to the northwest of the city, between the ancient Theater Harbor and the Lion Harbor. Kaletepe, which began to serve as a residential area from the early periods onward, shows evidence of significant erosion in its southern section even prior to the Hellenistic and Roman periods, while archaeological data from the western and northern plateaus are comparatively more coherent. Excavations conducted in the northern part of the hilltop have yielded postholes indicative of Early Archaic structures, despite the scarcity of earlier material remains apart from a few fragments of Mycenaean and Geometric pottery. The archaeological record suggests that this area was predominantly used as a residential quarter from the Archaic period through the Byzantine and Ottoman eras (For further information, see Kleiner, 1961; Kleiner, 1964; Fildhuth, 2015; Müller-Wiener, 1982) (Fig. 1).



Figure 1. Miletus in Asia Minor, and Kaletepe/Theater Hill in the city plan (Filduth, 2015, p. 163-164)

The researches initiated in 2021 also focused on these residential quarter located north of the area referred to as Kaletepe or Theater Hill. One of the most striking discoveries made during the 2022 excavation season was a cave—previously described rather briefly as a ‘cellar/storeroom’ by the 1961 excavation team—along with an adjoining cistern (Kleiner, 1961, p. 46-48). During the two-week survey within the cave, 12 steps leading into an inner corridor enabling access to deeper sections of the structure were revealed. The most striking

feature of this formation, apart from the stairs totally carved into the natural limestone bedrock, the corridor, and the niches located on both sides of it, is the large underground cistern added to the building. Separated from the cave by a brick-built wall most likely added in a later period, the cistern stands out for its tall masonry walls, the high-quality mortar used in its construction, and the finely plastered surface of its broad dome (Teraman Hepdinçler, 2024, p. 90-94).

The intended function of this underground structure will be clarified through the archaeological assessment of the limited number of small finds recovered from the site, alongside comparative analyses with the extensive body of literature on ancient hydraulic installations. Furthermore, the detailed architectural documentation obtained in this study provides a basis for generating new hypotheses concerning the structure's form, construction phases, and potential functions.

2. General Information

2.1. Topographic Documentation

The primary objective of this study is to conduct a detailed topographic documentation of the cistern and its adjoining corridor with niches. As the term suggests, this documentation aims to ensure the precise measurement and recording of an existing structure. Regardless of the historical period to which the structure belongs, all constructive and aesthetic features—along with deformations, damages, alterations, and restorations that have occurred over time—must be systematically documented (Busen, Knechtel, Knobling, Nagel, Schuller & Todt, 2017). Traditionally, documentation has been understood as the measurement and recording of the existing condition, or as a 'graphic survey' of the current state. Architectural record drawings represent a carefully selected and differentiated presentation focusing on the essential elements of the structure. This selective process requires informed interpretation based on knowledge of historical construction techniques, architectural styles, interior decorations, and materials. Thus, architectural documentation is not merely the production of plans and drawings but also a process of knowledge acquisition, in which information is communicated through meaningful visual representation. In the light of technological advancements, the concept of documentation today should be approached from a broader perspective. Laser scanning technologies and modern photogrammetric methods provide new opportunities for documentation, and the modern understanding of architectural recording now encompasses not only traditional measured drawings but also a range of digital outputs. There is no universally applicable ideal method for all structures; rather, the methodological approach must be calibrated to local conditions and specific project requirements. For the documentation of the structure at Miletus, a combination of tacheometric surveying, terrestrial 3D laser scanning, and both ground- and UAV-based photogrammetry was employed. The intended outcome of this work includes the creation of high-resolution 3D models and orthophotos, which will form a foundational basis for architectural drawings and subsequent archaeological studies of the structure.

2.2. Photography

A fundamental requirement for accurate photogrammetric reconstruction is the availability of high-quality photographic data. Image resolution defines the precision of the details recorded in a photograph. In general, higher resolution increases accuracy in photogrammetric analysis, as it provides the computer with more detail for matching. Therefore, the most suitable choice is a high-resolution, full-frame camera capable of capturing images in RAW format, which offers the advantage of full control over image processing. The ideal focal length of a lens for photogrammetry depends on several factors, including the size and distance of the object, the

desired level of detail, physical accessibility, and the type of camera used. In general, a lens with a medium focal length is the most appropriate choice for photogrammetric purposes.

2.3. Photogrammetry

Photogrammetry is the technique of obtaining 3D information through the recording, measurement, and interpretation of image data. The measurements are made indirectly on images of the object rather than directly on the object itself. This is a measurement method based on a mathematical model of central-perspective imaging. The shape or position of an object is determined through the reconstruction of light rays, where each image point P′, together with the projection center O′, defines a spatial direction extending toward the corresponding object points. If the actual imaging geometry of the camera — namely, the interior orientation— and the position of the recording system in space — namely, the exterior orientation— are known, each image ray can be precisely defined in three-dimensional space. The intersection of at least two homologous and spatially distinct image rays forms a three-dimensional object point. Depending on the number of images, these methods can be classified as single-image photogrammetry, stereophotogrammetry or multi-image photogrammetry. When examined according to the location and distance of image acquisition, they can be further subdivided into space photogrammetry, aerial photography, terrestrial photogrammetry, close-range photogrammetry, underwater photogrammetry, and macro photogrammetry (Luhmann, 2018).

2.4. Total Station

A total station is a surveying instrument used to record points in 3D. This device measures and records polar coordinates -horizontal angle, zenith angle, and horizontal distance- from the position of the instrument. When both the instrument height and the target prism height above ground level are defined, the height difference relative to the ground elevation can also be accurately calculated. In modern total stations, distance and angle measurements are performed electronically. If the device includes a microprocessor, automated measurements, evaluations, and digital data transfer are also possible. Depending on the quality of the instrument, measurement accuracy can reach centimeter or even millimeter precision.

2.5. Laser Scanning

Another measurement method is 3D laser scanning. In this method, the surroundings are rapidly scanned with laser pulses in a surface-based manner. As a result, a large number of systematically arranged 3D points -known as a point cloud- are obtained. Various outputs can be derived from this 3D point cloud. The range of applications is broad, extending from simple measurements to the generation of 2D plans, the creation of 3D models, and even the transfer of data into augmented reality (AR) environments. In terrestrial applications, depending on the type of device, the measurement range is limited to a few hundred meters, whereas in airplane or drone-supported applications, a more comprehensive area can be recorded. Similar to photogrammetry, the locally referenced point cloud can be transferred into a larger coordinate system using tie points (Resnik & Bill, 2018).

2.6. Software

The Leica Cyclone FIELD 360 mobile application enables the creation of three-dimensional datasets in the field using the BLK360 Laser Scanner and allows data registration to be completed with the Leica Cyclone REGISTER 360 Post-Processing Software. Users can

automatically collect, merge, and verify scanning and visual data on-site. Once the modeling is complete, the 3D model can be prepared for export and subjected to further processing. Agisoft Metashape and Epic Games Reality Capture are software solutions for 3D reconstruction. These programs use photogrammetry as an evaluation method to automatically generate data from images, point clouds, or textured 3D models, and they produce georeferenced orthophotos. CloudCompare is a cross-platform, open-source application developed for processing point clouds and 3D geometries, including triangular meshes. The software's original purpose was to enable the fast and efficient comparison of high-density point clouds.

2.7. Hardware

A Nikon D810 camera combined with a Nikon 20mm F1.8 lens was used for recording image data. A Leica Viva TS15 total station was employed to determine the coordinates of the tie points. The instrument provides an angular measurement accuracy of 2" (0.6 mgon) for horizontal (Hz) and 3" (1 mgon) for vertical (V) measurements. Due to its compact design, a Leica BLK360 laser scanner was used. This device is a 3D scanner equipped with an integrated spherical imaging system and a thermographic panoramic sensor system. It can be connected to a tablet or smartphone via local network, allowing for on-site data pre-processing or single-scan operations at the touch of a button. For aerial photography, a DJI Mavic 2 Pro drone was used. The device features a 35 mm lens with a 77° field of view, a 20 MP camera, and a 1" CMOS sensor. Fieldwork operations were supported by a Dell Precision 7740 workstation equipped with an Intel Xeon E-2286M 9th generation processor (8 cores / 2.4 GHz), an NVIDIA Quadro RTX 4000 graphics card, 64 GB DDR4 SDRAM-ECC 2667 MHz memory, and two SSD drives with 512 GB and 1 TB storage capacities.

3. Application

3.1. Tacheometric Measurement

Firstly, based on preliminary data, the distribution of reference points in the area was planned as a sketch. Due to vegetation and deep shadows, the visibility of some reference points was occasionally reduced, causing minor deviations from the actual plan. To ensure visibility during drone flights, markers approximately ten times larger (about 30×30 cm) than those typically used indoors were employed and fixed in place. In indoor areas with limestone walls, the reference markers were wedged between tree roots, while on the cistern walls -where humidity was particularly high- temporary markings were made using wax-based paint (Fig. 2).

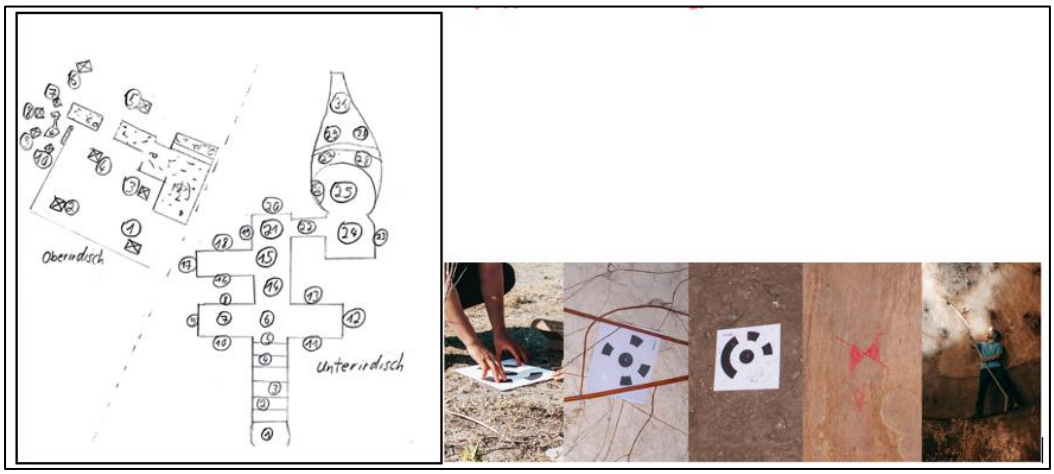


Figure 2. Sketch of reference points

A file containing previously established reference points was uploaded to the Leica TS15 total station, and the coordinates were recorded in the WGS 84 / UTM Zone 35N (EPSG: 32635) coordinate system, which was also used in this project. The total station was positioned by performing a free station setup based on four known points. Since the line of sight to all points was not always clear, the instrument was repositioned several times using repeated free station setups. The most challenging locations for establishing stations were the stairwell leading down to the cistern and the cistern itself. Access to the cistern was quite narrow, which restricted the field of view toward the reference points. This limitation was taken into account during the planning of the reference points, and additional markings were made specifically to facilitate the free station setup of the total station inside the cistern. In total, 10 reference points were measured above ground and 35 below ground, all of which were planned to be used later for georeferencing (Fig. 3).



Figure 3. Total station setup procedures

3.2. Photogrammetric Data Acquisition Process

To minimize harsh contrasts in the image data, the photogrammetric recording was planned to take place on a cloudy day. However, since the weather forecast predicted clear skies throughout the entire measurement campaign, it was decided to carry out the shooting before sunrise. In preparation for image acquisition, the day before the survey, the shading covers over the excavation trenches were removed so that both the trenches and the excavation area could be included in the capture. Image recording began with UAV flights at an altitude of approximately 20 meters. The drone first conducted a circular flight around the excavation area, followed by detailed image captures at an altitude of approximately 5–10 meters using cross-grid mapping. To ensure maximum consistency between aerial and terrestrial image datasets, immediately after the flight, images of the exterior area up to the cistern entrance were taken with a DSLR camera. The documentation started with general overview photographs of the corridor leading to the cistern, providing reference orientation. Subsequently, photographs parallel to the floor and walls were taken, followed by oblique-angle shots and finally close-up images of specific sections. Inside the cistern, the images were captured along circular trajectories, using automatic camera focusing at 3-second intervals. Before each shot, the target area was illuminated with a flashlight to ensure proper focus. In total, approximately 2,400 ground-based photographs and 360 aerial photographs were captured (Fig. 4).

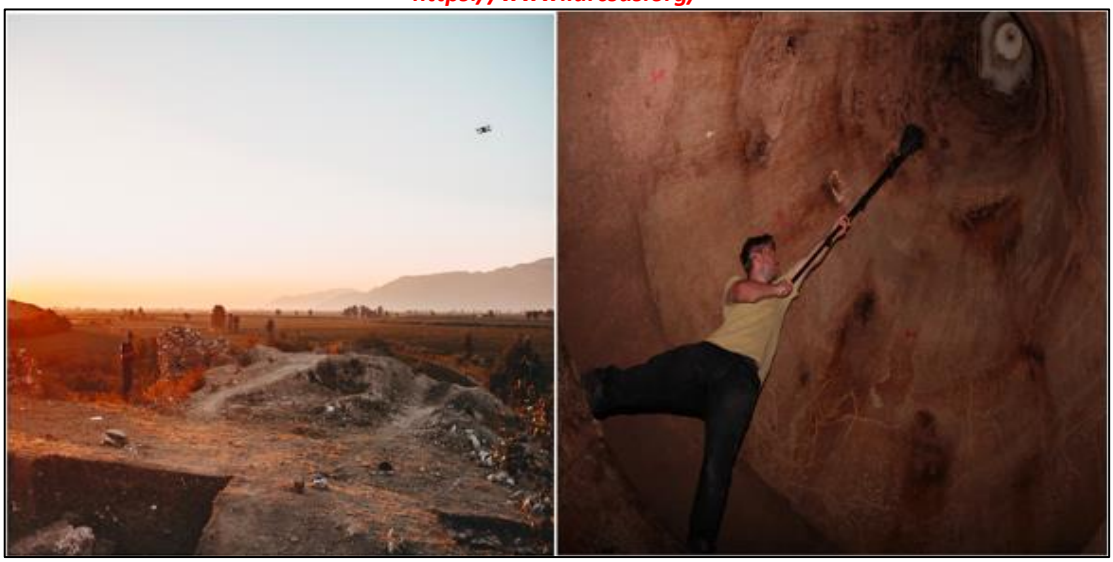


Figure 4. Photogrammetric data acquisition process

3.3. 3D Laser Scanning

In addition to photogrammetric imaging, terrestrial laser scanning was also carried out. The scanning operations began outdoors, with the distance between individual scans set at approximately 1,5 meters. This distance was reduced to 0,5 meters in the underground corridor with stairs and in the cistern, which was the focal area of the study. A total of 114 medium-resolution scans were performed. During the scanning process, the scans were correlated with each other and pre-registered (Fig. 5).



Figure 5. 3D Laser Scanning Process

4. Pre-Processing of Data

4.1. Radiometric Corrections of Image Data

In the first step, a catalog for the raw image data was created in Adobe Lightroom, and image summaries were calculated. Each photograph was then examined individually, and all blurry or under -or overexposed images were removed. To ensure as homogeneous lighting as possible within the database, automatic exposure correction was applied to all photos. Subsequently,

each image was reviewed again, and occasional color corrections were made, which was particularly necessary in the entrance area where natural light was still present. Finally, all photographs were exported in full resolution in JPEG format.

4.2. Processing of Laser Scanning Data

The laser data were processed using Leica Cyclone Register 360 software. For this purpose, the data were directly transferred from the Leica BLK 360 to the software via a local network connection. During the initial import, it was observed that most of the connections were highly inaccurate or provided insufficient overlap; the average accuracy of the connections at this stage was approximately 8 cm. Consequently, the connections between each scan position were analyzed and overlaps were adjusted. The overall alignment of the scans was then optimized. As a result, the strength of the connections (from 35% to 73%), overlap rate (from 43% to 80%), and accuracy (from 8 cm to 2 cm) were significantly improved.

To obtain the most detailed and complete 3D representation of the structure, it was planned to merge the laser scanning point cloud with the photogrammetric dataset. However, the distortions described above became the determining factor for excluding the laser data from further processing. As a test, an attempt was made to merge the point clouds obtained from the laser and photogrammetric datasets using Reality Capture and Agisoft Metashape software. For this, it was necessary to load and re-register the laser scanning positions separately in both programs. Reality Capture failed during the registration phase, successfully registering only 6 out of 85 scans. In Metashape, the registration was completed without any issues. However, a problem arose during the merging of the laser scanning and photogrammetric point clouds and manual tie points were required to align them. To this end, it was planned to use the reference points employed in the photogrammetric process. However, since the laser data lacked RGB information, accurately identifying the corresponding reference points proved highly challenging, and their exact centers could not be precisely located. Once the reorientation was completed, the point clouds were merged, but the laser scan data showed a slight misalignment. Moreover, since the photogrammetric point cloud was already very dense, the laser scanning data did not add significant value. All these factors led to the decision to proceed without using the laser data (Fig. 6-7). The final point cloud consists of approximately 357 million points and was exported in LAS and E57 formats (Fig. 8-9).

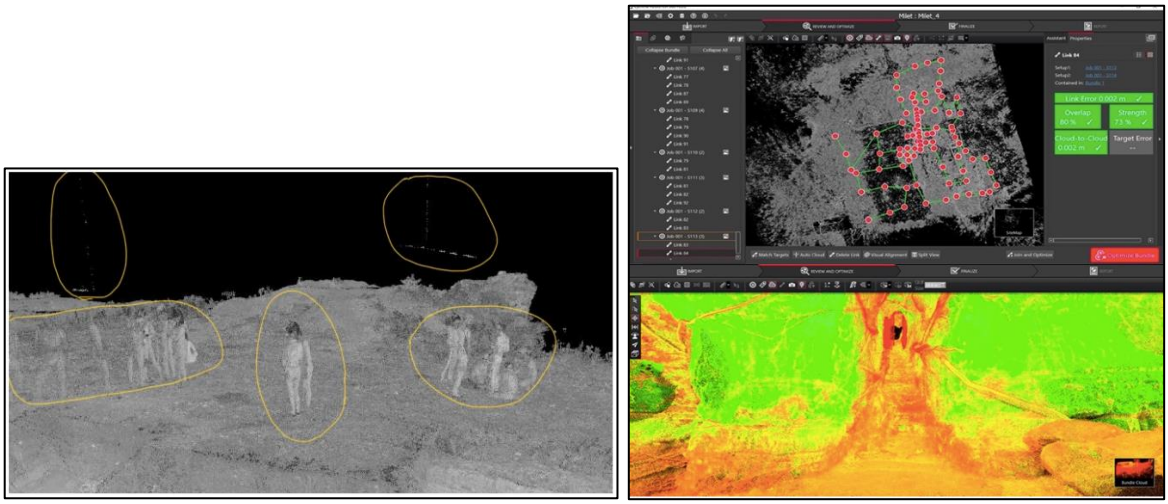


Figure 6-7. Data processing

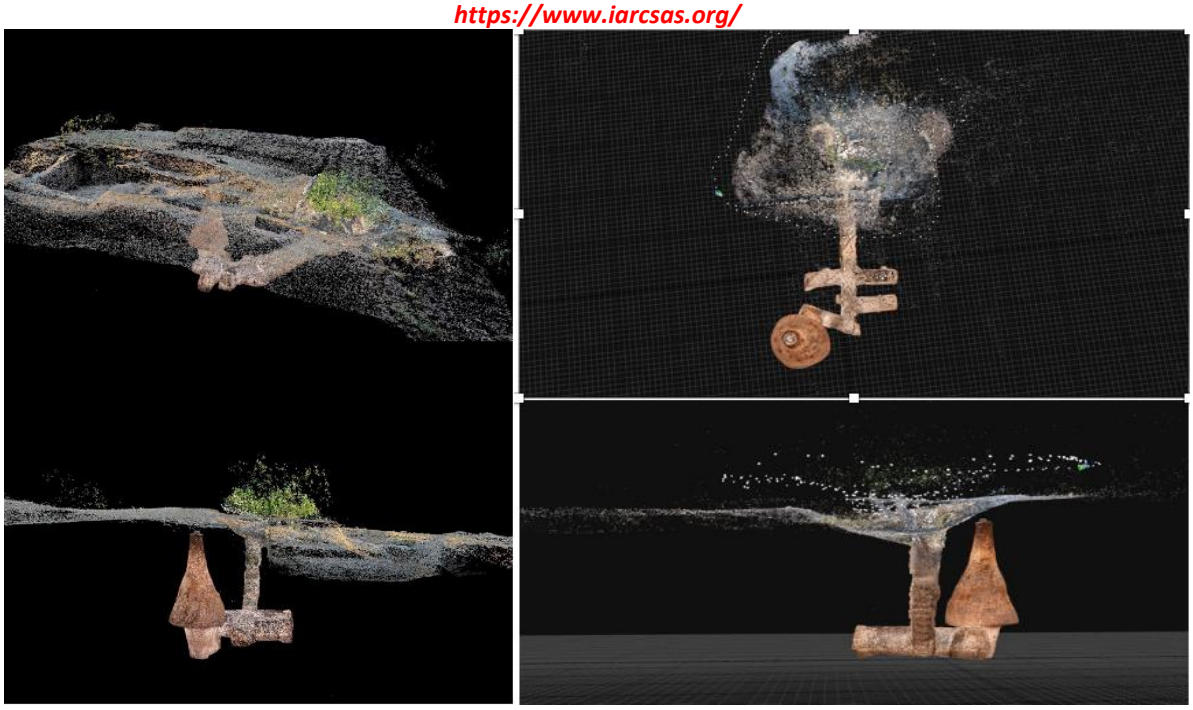


Figure 8-9. Final point cloud data

5. Photogrammetric Evaluation

The photogrammetric evaluation was carried out using Agisoft Metashape and EpicGames Reality Capture software. Metashape was used for the creation of orthomosaics, while Reality Capture was employed for 3D reconstructions. The orthomosaics presented in the figures were generated with a pixel size of 1 mm (Fig. 10-15). Due to the large amount of data, the 3D reconstruction was divided into 4 subsections. The models were exported in OBJ format and also published via the NIRA web viewer (Fig. 16).



Figure 10-11. Plan view and cross-section along the cistern

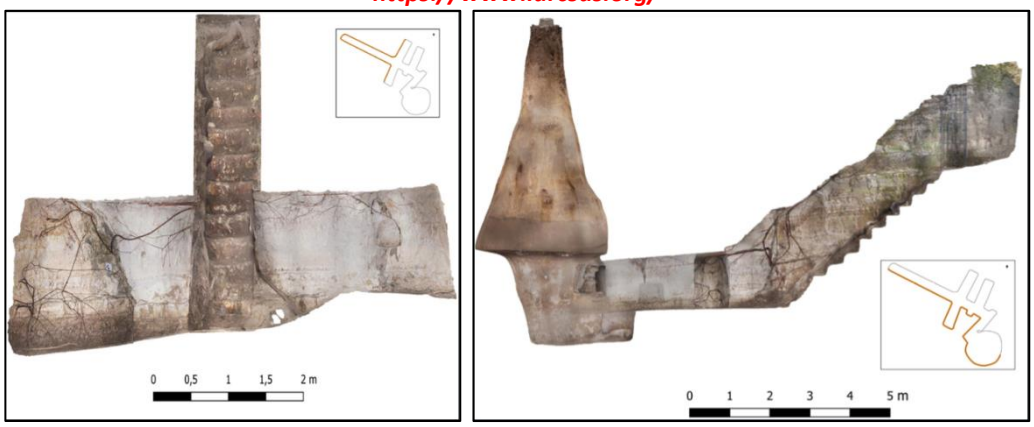


Figure 12-13. Cross section along the front niches and the staircase, and longitudinal section along the staircase

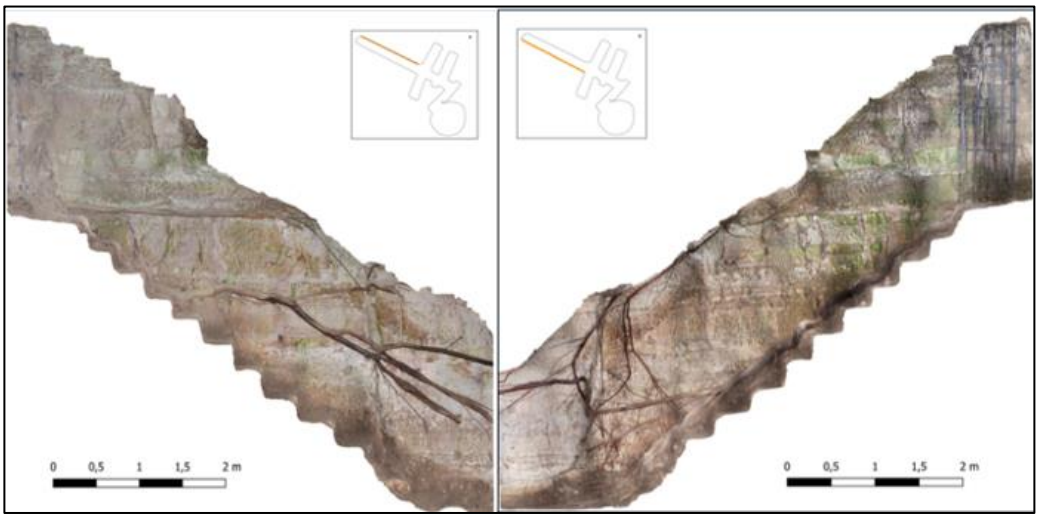


Figure 14-15. Detail views of the north and south walls of the staircase



Figure 16. Segmented 3D models

6. Architectural Documentation

Traditional speleological surveying methods were employed for the architectural documentation of the structure, and sketch drawings, as well as clinometer and compass readings were carried out. In order to complete the photogrammetric modeling and make the relationship between the above-ground structures and the cistern more comprehensible, photographs of the surface structures were also taken, marking the end of the fieldwork (Fig. 17).

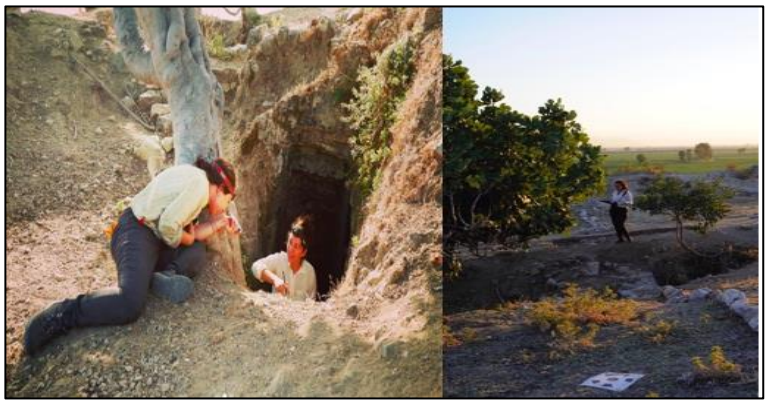


Figure 17. Architectural documentation process

After the completion of the fieldwork, the measurements obtained through traditional methods were entered into the Walls program, and base drawings were prepared. In Reality Capture and Agisoft Metashape, orthophotos were generated from point cloud data created by uploading the coordinates of the control points into the system, enabling architectural drawings to be produced (Fig. 18-19).

Once the orthophotos were finalized, measurements were verified on the photographs. Several points measured in the field were compared with the orthophotos, and drawings were initiated in AutoCAD. During the import of orthophotos into the program, special attention was paid to ensure that embedded GPS data were preserved (Fig. 19-20).

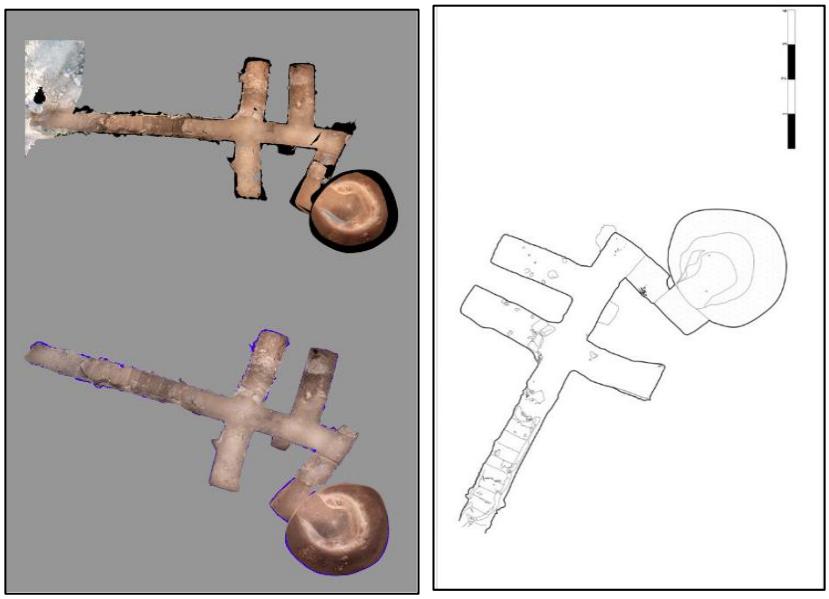


Figure 18-19. Orthoimages prepared for drafting and CAD drawings in AutoCAD

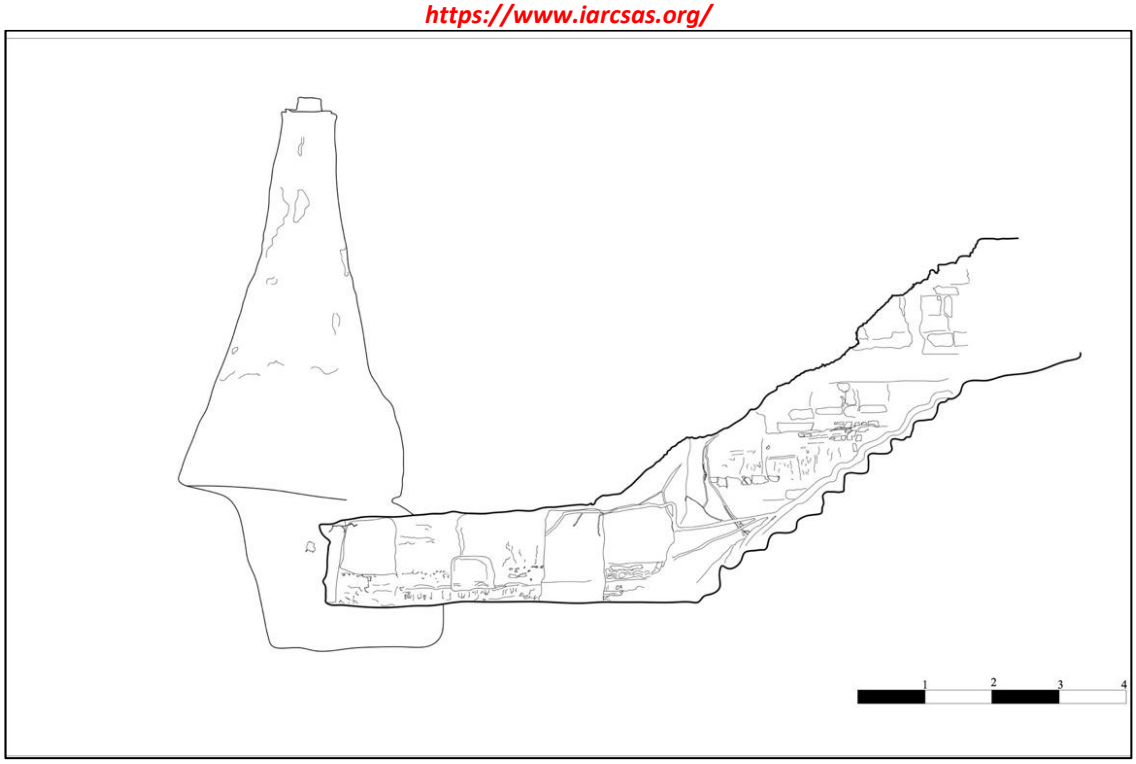


Figure 20. Final Drawing produced in AutoCAD

7. Conclusion and Recommendations

In the documentation of the structure, terrestrial and UAV-assisted photogrammetry were employed, and a terrestrial laser scan was additionally conducted using the Leica BLK 360. As the resulting model did not yield satisfactory results, these data were not used in subsequent processing steps. The execution of the photogrammetric survey ensured the acquisition of high-quality base data, from which high-resolution point clouds, textured 3D models, and orthomosaics could be generated.

The collected data provided a basis for comparing the photogrammetric analyses performed in Agisoft Metashape and Epic Games Reality Capture. The test series demonstrated that both programs have certain advantages and disadvantages: Reality Capture processes data much faster and can produce more complex results, but it frequently encounters error messages or interruptions. It can be said that improvements are needed in the visualization and editing of the results produced with this software. In contrast, Metashape generates less dense point clouds and meshes, requires longer processing times, but stands out as a more stable program, offering advantages in orthomosaic creation and 3D model editing. Desired results can be obtained with both software packages; however, each has its software-specific limitations. Nevertheless, both methods will continue to serve as important components in future projects. Considering that technological advancements have led to the optimization of processing algorithms and the development of more powerful computer components, facilitating the handling of large and complex datasets, it can be concluded that the methodology for architectural documentation will continue to evolve dynamically in the future.

Thanks and Information Note

This research was supported by the Scientific Research Projects Unit (BAP) of Mimar Sinan Fine Arts University (Project No: 2023-25). I would like to express my gratitude to

the Coordination Unit for their support. Part of the data presented in this study was also included in the master's thesis titled "Bauaufnahme einer antiken Zisterne auf der archäologischen Grabung in Milet, Türkei" (N. Techow, 2024), submitted to the Berliner Hochschule für Technik.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Busen, T., Knechtel, M., Knobling, C., Nagel, E., Schuller, M., & Todt, B. (2017). *Bauaufnahme*. DOI: 10.14459/2016md1353273. München: TUM University Press.

Fildhuth, J. (2015). Milet, Türkei: Die letzte byzantinische Siedlung auf dem Theaterhügel. *eDAI-F*, 2015(3), 163–165. Access Address (12.11.2025): https://publications.dainst.org/journals/efb/article/view/1647

Gorman, V. B. (2001). *Miletos, the Ornament of Ionia: A History of the City to 400 BCE*. ISBN: 978-0472037773. Ann Arbor: University of Michigan Press.

Greaves, A. M. (2002). *Miletos. A History*. ISBN: 978-0415238465. London: Routledge.

Kleiner, G. (1961). Bericht über die Grabung in Milet im Herbst 1961. *TAD*, 11(2), 46–48. Access Address (12.11.2025): https://dergipark.org.tr/tr/download/article-file/2158665

Kleiner, G. (1964). Die Grabung in Milet im Herbst 1963. *TAD*, 13(1), 57–61. Access Address (12.11.2025): https://dergipark.org.tr/en/download/article-file/2161929

Luhmann, T. (2018). *Nahbereichsphotogrammetrie. Grundlagen, Methoden und Anwendungen*. ISBN: 978-3879074792. Berlin: Herbert Wichmann Verlag.

Müller-Wiener, W. (1982). Milet 1981. Arbeiten im Stadtgebiet. Untersuchungen auf dem Theaterhügel*, IstMitt*, 32, p. 15–17.

Niewöhner, P. (Ed.). (2016). *Milet/Balat: Städtebau und Monumente von archaischer bis in türkische Zeit: ein Führer*. ISBN: 978-6059680073. İstanbul: Ege Yayınları.

Resnik, B., & Bill, R. (2018). *Vermessungskunde für den Planungs-, Bau-und Umweltbereich*. ISBN: 978-3879077465. Berlin: Herbert Wichmann Verlag.

Teraman Hepdinçler, Ö. (2024). Miletos Kaletepe Mevkii 2021-2023 Yılı Çalışmaları. *TEBE Haberler*, 48, p. 90-94. Access Address (12.11.2025): http://turkinst.org/my_documents/my_files/PDF/Haberler/yeni%20haberler_compressed.pdf

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Examination at the Intersection of Cinema and Architecture: The Rings of Power - The Land of Numenor

Tolgay İNANÇ [1]*

ORCID 1: 0009-0005-4610-6286
[1]KTO Karatay Üniversity, Faculty of Fine Arts and Desıgn , Department of Arcitecture, Konya- Türkiye
icmimartolgayinanc@gmail.com (Responsible Author)

Halil SEVİM [2]

ORCID 2: 0000-0002-0211-3397
[2]Assist. Prof. Dr., KTO Karatay Üniversity, Faculty of Fine Arts and Desıgn, Department of Arcitecture, Konya-Türkiye
halil.sevim@karatay.edu.tr

Abstract

Architecture has been defined in various ways and scopes throughout history. At this point, it has relationships with many disciplines on experimental or theoretical planes. Cinema is one of many disciplines related to architecture. While architecture becomes an image of representation in reflecting reality for cinema, cinema is an important field of experimentation for architecture. In cinema, reality and believability are two important concepts in terms of establishing a connection between the viewer and the film. The viewer strengthens their perception of time and space through small images and symbols within the film. At this point, the film's questions of reality and believability are left behind, and its impact on the viewer is greater. The concepts of architecture and space are also important in this regard. This study evaluates the country of Numenor in The Lord of the Rings: The Rings of Power series, adapted from J.R.R. Tolkien's The Lord of the Rings book. The aim of the study is to highlight the importance of the subject in terms of the reflection of architecture's role in cinema on the audience and its relation to reality. Within the scope of the study, the country of Númenor was analyzed in terms of different spaces. At this point, a visual analysis method was applied using scenes to be used in the study. The cinematic spaces of Númenor were examined using specific parameters within the scope of architectural literature. The parameters used in the analysis were established as scale, material, form language, lighting, and perception. These parameters enabled a comprehensive evaluation of the scenes from a spatial and perceptual perspective.

Keywords: Architecture, cinema, Numenor, space

1. Introduction

Architecture is a discipline that works in conjunction with various other disciplines, exchanging contributions with many of them at this point. In addition to all this, the relationship between cinema and architecture is far ahead of others in terms of their contribution to each other. While cinema offers approaches that shed light on the future for architecture, architecture strengthens cinema's credibility with the audience and, in this way, causes the exchange of data between the audience and the director to develop. The reflection of various architectural elements in cinema is key to understanding the past, present, and future from the viewer's perspective. The viewer avoids questioning the film's reality with elements found in the past or present and becomes tightly bound to the fictional universe and plot created.

The relationship between cinema and architecture has been one of mutual influence and development since the very inception of cinema as a concept, rather than simply a progression from cinema to architecture. In her book, Katherine Shonfield states that she brings films into the field of architecture in terms of their visual, conceptual, and methodological aspects. She argues that films are created every day in cities, buildings, and rooms, and that every day architects and urban planners make decisions about cities, buildings, and rooms, and that their areas of expertise are the same, only that they live in different worlds (Shonfield, 2000). Walter

Benjamin, in his essay "The Work of Art in the Age of Mechanical Reproduction," which focuses on architecture and film, states that both art forms are actually based on the sense of touch. Benjamin emphasizes that the flow of cinema transforms individuals from spectators into disembodied observers and experiencers. Both architecture and cinema indicate a kinesthetic way of experiencing space, and images stored in memory are shaped as tactile retinal images (Benjamin, 1993). At this point, spaces are also considered an important tool. In cinema, elements contained within spaces allow for the observation of time, circumstances, sociology, and socio-economic conditions. Materials, designs, colors, and styles that reveal period traces in architecture are important elements within spaces.

In the field of architecture, the purpose of creating volume with vertical and horizontal elements is to ensure the creation of a sense of space. Perception describes the expression and reflection of experiences as part of the formation of space (Arayıcı, 2018). In other words, for space to be formed in a perceptual sense, it does not need to be a closed box. With the advancement of technological capabilities today, creating a sense of space is much easier. Various computer programs can be used to create non-existent spaces, or sets prepared in studio environments can be enriched with spaces prepared in various computer environments thanks to equipment such as green screens. The elements that constitute space are listed as natural space, artificial space, and mixed space, depending on the nature of the elements that limit the space. In addition, the area created by enclosing part of the physical space with walls and ceilings is called interior space, while the area outside this is called exterior space (Altan, 1993).

In cinema films, locations are divided into two categories: physical locations and fictional locations. Fictional locations are further divided into physical fictional locations and virtual fictional locations. Physical locations are spaces that can be perceived on a plane along with their materials, spaces whose existence we are certain of through all of our senses. Physical spaces can be described as areas that actually exist, are perceived by the senses, comply with human ergonomics and anthropological rules, and are constructed in real places for a specific purpose (Karaduman, 2021). Fictional spaces are spaces that exist in the imaginary world and have no connection to reality. Kavut defines fictional space as a space that exists outside of the time in which one is present and cannot be translated into reality (Kavut, 2021). At this point, it can also be defined as spaces that do not exist in real life but are prepared with vertical and horizontal structural elements in reality or in a computer environment. Physical fictional spaces can also be defined as spaces that do not exist in reality but are not confined to computer environments and drawings. These spaces are also physically present in the sets created using models or visual elements. The architectural elements desired in the set environment are discussed using various design sketches. Once the design is decided, it is produced by creating technical drawings. In fact, the same steps are applied in a manner similar to the process of creating real locations. Decorations are then built in the set where they are needed. Since these locations are used in the performing arts, they are usually produced on a one-to-one scale. However, they can also be produced on a smaller scale depending on the purpose in the film. Virtual fictional locations, on the other hand, are locations that cannot exist in reality. They are an important means of representation for the distant future or past on the timeline. Virtual fiction narrates events that humanity may encounter or has encountered in the past, present, or future. It is an effort to learn the truth or to imagine by taking people into the world of imagination (Büyükarman, Öztürk & Şahin, 2015). The depictions of the future, especially in science fiction films, can be predictive in terms of architectural space. At this point, when science fiction films from the past to the present are examined, it is clear that the predictions made for certain periods

have been proven in various ways. Along with this, it can also be defined as an important means of representation within fantasy cinema. Since many of the spaces depicted in these works cannot exist in reality, they are reflected to the audience through drawings made in a virtual environment, i.e., a computer environment. The spaces created do not undergo a production-related process. They exist in computer environments. For this reason, it is not possible to perceive them physically. The concept of cinematic space is also quite important in the continuation of these definitions. The concept can be defined as the design of a space in a film, approached from a general framework, whether virtual or physical. All types of set design, including outdoor, indoor, or virtual spaces created throughout the film, are included in this definition. Throughout the filming, in addition to spatial elements, all kinds of equipment, including the camera and shooting angles, ensure that the viewer internalizes the film and views events from a powerful perspective in terms of perception. As mentioned at the beginning, the concept of cinematic space also plays a very important role in bringing the viewer closer to reality. While the imaginary universe that the author of the film wants to reflect is supported in various ways, it is provided in various visual wholes to strengthen the viewer's perception. At this point, geographical conditions and architectural elements are important tools of representation. When viewers can establish a close relationship with reality and achieve integrity, the film becomes impressive for them. Along with the concept of cinematic space, the concept of cinematic memory is also important in this context. The concept can be defined as the strengthening of the perception of reality for viewers through the use of real architectural elements in spaces that do not exist in reality and are produced in various ways.

2. Materials and Methods

Viewers can establish a strong connection with reality by observing details such as real-world architectural elements and various geographical landscapes in cinematic settings. As a result, viewers can establish a connection between the film and reality and believe that the events in the film could have taken place at specific times and locations. For this reason, a strong perceptual relationship can be established between the film and the viewer. The elements that cause the connection with reality are usually processed as stimuli in small points in the background. At this point, the elements mentioned are evaluated within the scope of certain parameters. Scale is an important parameter in revealing the relationship that the space establishes with individuals. In monumental spaces, concepts such as pressure, authority, and power are conveyed to users (Ching, 2014). Material is also an important parameter. It provides clues about the culture and nature of the society in which the space is located. Furthermore, different materials are fundamental reasons for the variation in perception within spaces (Zumthor, 2006). Another parameter is form. It is important in terms of examining the characteristics and aesthetic concerns of the space. The arrangement of architectural elements, proportions, and style choices provide an opportunity to evaluate the identity of the space (Ching, 2014). Another parameter is lighting. Natural and artificial light have a significant effect on the perception of space. As a result, dramatic, oppressive, authoritarian, or similar aspects of the space emerge (Zumthor, 2006). Finally, perception is an important parameter. It emerges through the influence of other parameters. Through this parameter, the spirit of the space, user experience, and sensory effects are evaluated (Norberg-Schulz, 1980). These real-world elements, present in cinematic spaces, not only strengthen the audience's perceptual engagement with the plot but also increase their belief in visual elements. Therefore, the concept is particularly important for works in the fantasy or science fiction genres. According to Juhani Pallasmaa, cinematic space has the ability to evoke feelings such as fear, tension, and

pain in the viewer. It can revive the viewer's forgotten memories. For this reason, the viewer's relationship with reality can be strengthened (Pallasmaa, 2007). The Lord of the Rings film is one of the most important works reflecting the concepts mentioned above. There are thesis studies evaluating the film, and within the scope of this study, the country of Numenor from The Lord of the Rings: The Rings of Power series, which reflects the events that developed in the years before the films and is a current series, will be discussed. Although J.R.R. Tolkien does not provide extensive information about the city in his work, it has been constructed by designers in a manner consistent with Middle-earth, the universe created by Tolkien. The city, which has a strong connection to reality between the viewer and the work, is an important example within the scope of this study.

3. Findings and Discussion

Númenor is an island city that emerged in the middle of the Western Sea as a gift to humanity for the suffering they endured, following the war against the evil Lord Morgoth, where humans and elves lived together. The island is shaped like a five-pointed star. At its center lies a mountain called Meneltarma, considered sacred by the Númenóreans. Only the king or queen is permitted to speak upon this mountain. Furthermore, Númenor is regarded as having significant potential due to its rich mineral deposits, powerful forests, and abundant food sources. Many rich plant species unknown and non-existent in Middle-earth are found in abundance in Númenor. In short, it is clear that the Valar bestowed all their riches upon this island, a gift to humanity. The White Tree, one of the important symbols of this wealth, will later become a symbol in the cities of Gornor and Arnor, which will be built by humans. The White Tree has been regarded as a representation of the continuation of life, the abundance of resources, and freedom from extinction in Númenor's history. The fact that the Queen of Númenor, who responded negatively to the requests of the Elf Princess Galadriel, realized she had made a wrong decision when the leaves of the White Tree scattered and changed her mind is also a valuable example of the importance of this issue.

3.1. Entrance to Numenor

In the story, Elendil, Lord of Númenor, who rescued Lady Galadriel, is taking her to Númenor. In this context, Númenor appears before the audience depicted for the first time. Between two mountains with enormous trees at their peaks, the coastal city of Romenna in Númenor can be seen (Figure 1).



Figure 1. Entrance to Numenor. *The Lord of the Rings: The Rings of Power* (2022), Episode 3, 07:00.

As you enter the valley, you encounter enormous human figures carved into the rocks on the mountain slopes (Figure 2).



Figure 2. Entrance to Numenor. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 07:35

There is a large bridge near the city whose structure is supported by massive columns. The columns on the bridge are covered with equally massive sculptures, creating a sense of harmony with the valley. Ornaments similar to those on the tower continue along the bridge. (Figure 3).



Figure 3. Entrance to Numenor. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 08:04

Numenor is an island nation with a layered structure. The massive columns adorned with sculptures, frequently observed marble surfaces, stone texture, and color palette largely align with the characteristics of the Neoclassical architectural movement (Figure 4). As a result, the table has been created in this manner according to the specified parameters. (Table 1).



Figure 4. Entrance to Numenor. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 08:25

Table 1. Spatial Analysis of City Entrances (The Lord of The Rings: The Rings of Power, 2022)

ENTRANCE TO NUMENOR				
				
SCALE	**MATERIAL**	**FORM**	**LIGHTING**	**PERCEPTION**
It is a valley formed by sculptures between two mountains on a large scale.	The stonework and entrance bridge feature gold-detailed column carvings.	As you approach the valley, there is a monumental bridge and tower. Along with this, there is a symmetrical arrangement of monumental structures throughout the valley.	There is a torch in the welcome tower to signal ships approaching the city across the valley. However, there is no other light source besides natural light.	The monumental structures and colossal statues in the valley represent the city's splendor and grandeur.

3.2. Port

There are many boats in the harbor. Blue marble and paint are used in places on the walls surrounding the harbor. Vertical lines find their place in many places in magnificent and imposing shapes. As this is a port city, chaos and noise prevail in the harbor areas. Various barrels and sacks are scattered around (Figure 5). Numenor is a country where trade is conducted and fertile lands are abundant.



Figure 5. Port. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 08:50

3.3. Street Texture

In the streets of Numenor, stone textures and blue paint are frequently preferred. As Numenor is an island nation, choices such as the sun, stars, and blue color—considered sacred as guides—are consistently used. Minimalist decorations are also found along the city streets. Hanging plants are used in some places. Various ground elements are observed along the streets. Irregular cobblestones are used on the street surfaces. (Figure 6).



Figure 6. Numenor Streets. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 09:10

In the sections closer to the square, larger blocks of stone are used. Decorative and period-style fixtures are used on the walls for street lighting. Shops where crafts are made are observed on the ground floors of the buildings in the square (Figure 7).



Figure 7. Numenor Streets. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 10:09

In Numenor, establishments such as bars and bakeries welcome their guests at tables and chairs placed on the streets. The venue is painted in blue and white. Wooden details are frequently used. The dining tables are also made of wood. Other shops and streets in the city can also be seen in this scene. Along with blue and white, yellow is used to represent the sun on the Numenor flag. The tables and chairs are covered with fabrics featuring various local symbols. In addition, plants are used at various points in the venue and at certain locations on the street where the venue is located. (Figure 8).



Figure 8. Numenor Streets. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 31:39

The streets in the outlying areas of the city are almost entirely dominated by stone masonry when compared to other streets. The use of paving stones is evident on the ground. Furthermore, stone masonry is also used on the wall surfaces (Figure 9). As a result, the table has been created in this manner according to the specified parameters (Table 2).



Figure 9. Numenor Streets. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 32:22

Table 2. Spatial Analysis of Numenor Streets (The Lord of The Rings: The Rings of Power, 2022)

STREET TEXTURE				
				
SCALE	**MATERIAL**	**FORM**	**LIGHTING**	**PERCEPTION**
These are generally medium and small sized venues.	The streets of Numenor are dominated by stone. Marble is also used at certain points to adorn doorways. Hanging plants are frequently found along the streets.	It is a symmetrical arrangement surrounding the city square in a simple and classical style.	Ornate, art deco style fixtures were used on the walls for street lighting.	In certain areas, a perception has been created that streets that are understood to be secluded but close to the city square are densely populated and used by everyday people.

3.4. City Square

Numenor City Square appears to be built on a large area. Stone and marble constitute the majority of the surface materials in this space. A structure that appears to be significant among

the elements above is covered with blue tiles up to a certain height, and sculptures have been placed in front of it to highlight its aesthetic appeal. This structure possesses enormous dimensions far exceeding human scale and detailed carvings created with geometric forms. (Figure 10).



Figure 10. City Square. *The Lord of the Rings: The Rings of Power* (2022). Episode 4, 07:22

3.5. Numenor Palace

This palace, which frequently uses stone and marble textures befitting the splendor of Númenor, stretches from the edge of the valley to its peak. The semicircular opening on the front facade of the palace opens onto a courtyard featuring the White Tree, one of the important symbols of Númenor. From this area, there is a water flow extending down to the lower valley (Figure 11), (Figure 12), (Figure 13).



Figure 11. White Tree. *The Lord of the Rings: The Rings of Power* (2022). Episode 4, 01:03:41



Figure 12. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 10:13



Figure 13. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 10:21

Inside the palace, there is a circular area surrounded by magnificent columns. The interior of the columns is used as a gathering place for Numenor meetings, while the outer area serves as an entrance corridor (Figure 14).



Figure 14. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 10:32

One side of the corridor faces the open assembly hall, while the other side consists of a closed wall. Blue paint is visible along the wall surface, and a wide door is visible in one section of the wall. There are carvings on the door. To the right and left of the door, there is a protrusion separate from the wall surface. This area appears to be covered with cream-colored marble. Continuing from the entrance corridor, there is a staircase leading to the aforementioned gathering space. It is evident that the entrance to the gathering space is a few meters lower than the entrance corridor. Marble cladding is used on the areas on the right and left sides of the entrance staircase. At the turning points of the marble cladding, there are gold-detailed carvings (Figure 15).



Figure 15. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 11:05

The space is predominantly characterized by marble and blue paint textures. Marble is used in areas intended for customization, such as the columns and the queen's throne. As seen on the entrance stairs, gold detailing adorns the marble surfaces throughout the space. Behind the queen's throne, curtains with burgundy and gold details are used. A large chandelier is used above the throne. Along with this, marble is used on the floor, which is at a different level from the throne. A burgundy carpet is placed on the marble floor. Light is seen coming from certain places to some of the people in the space. Therefore, it is clear that there are openings in certain sections of the ceiling (Figure 16).



Figure 16. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 11:59

The dome is encircled by gold-embellished bands. Additionally, protrusions made of marble cladding are located on both sides of the opening. These marble cladding surfaces feature gold-detailed embellishments. The marble flooring surrounding the right and left sides of the space consists of a few centimeters of elevation difference. The floor line is completed in the section where the opening is located (Figure 17).



Figure 17. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 4, 03:59

Gold-colored chandeliers are used to illuminate this space. Transparent white material is used at the points where the chandelier light is emitted. The connections are also made of gold-colored chains (Figure 18). As a result, the table has been created in this way according to the specified parameters (Table 3).



Figure 18. Numenor Palace. *The Lord of the Rings: The Rings of Power* (2022). Episode 4, 03:56

Table 3. Spatial Analysis of Numenor Palace (The Lord of The Rings: The Rings of Power, 2022)

NUMENOR PALACE				
				
SCALE	**MATERIAL**	**FORM**	**LIGHTING**	**PERCEPTION**
It is monumental in scale, and individuals appear quite small in comparison to the structure.	The gold details on the marble and columns are the standout materials for this space.	The entrance axis of the building features oval lines. Meanwhile, the space where the Queen's throne is located occupies a circular area. The palace is designed around a central system.	There is a powerful light coming from the dome at the center of the space. It is evident that there are openings in the ceiling of the space. Additionally, it is used in classic chandeliers.	By designing the space around an oval axis and placing the Queen's throne at its center, it reinforces the perception of power and authority.

3.6. Library

The library is generally a quiet and dark structure. Although dark tones are generally preferred, red is also used in the wall details. Documents rolled up are placed on black metal shelves. Small fixtures in metallic black are used for lighting. Above the red wall surface is a painting depicting prominent figures of the Elf race attending the library's opening. Immediately in front of it is a table made of dark wood (Figure 19).



Figure 19. Library. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 34:30

3.7. Prison

Numenor Prison consists of small dungeons built around a large hall. A large statue occupies the center of the hall. Large, ornate columns surround the statue. The surfaces are generally marble with a blue color reminiscent of ocean waves. Stone is used for the walls inside the dungeons. There is no light except for a small light source coming from the hall. Inside the dungeons, there are narrow windows through which natural light can enter. The dungeon doors are also made of iron and have ornate frames (Figure 20), (Figure 21).



Figure 20. Prison. *The Lord of the Rings: The Rings of Power* (2022). Episode 3, 54:23



Figure 21. Prison. *The Lord of the Rings: The Rings of Power* (2022). Episode 4, 11:29

The prominent locations of Númenor are compiled in the table below along with specific parameters. The locations were examined in terms of scale, material, form language, lighting, perception, and atmosphere (Table 4).

Table 4. Analysis Table Based on Spatial Parameters (The Lord of The Rings: The Rings of Power, 2022)

SPACE	SCALE	MATERIAL	FORM	LIGHTING	PERCEPTION
CITY ENTRANCE	Large Scale	Stone Texture	Symmetrical Array	Natural Light Source	Magnificence
PORT	Large Scale	Stone Texture and Wooden Skeleton	Functional and Distributed Array	Natural Light Source	The Wealth of Port Trade
STREET TEXTURE	Medium and Small-Scale Spaces	Stone Texture	Scattered Array	Natural Light Source and Ornamental Metal Lighting Fixture	Suitable for Daily Life
CITY SQUARE	Large-Scale Public Spaces	Stone Texture	Symmetrical Array	Natural Light Source and Ornamental Metal Lighting Fixture	Social Unity
NUMENOR PALACE	Monumental Scale	Stone Texture and Gold Embroidery	Center-Focused Array	Natural Light Source and Ornamental Metal Lighting Fixture	Magnificence and Power
PRISON	Small Scale	Stone Texture	Symmetrical Array	Natural Light Source and Torch	Atmosphere of Darkness and Loneliness
LIBRARY	Medium Scale	Metallic Surface and Wood Texture	Asymmetrical Array	Natural Light Source and Ornamental Metal Lighting Fixture	Rich Source

4. Conclusion and Recommendations

Within the scope of this study, the locations belonging to the city of Numenor depicted in The Lord of the Rings: The Rings of Power series were evaluated in terms of scale, material, form, lighting, and perception parameters. As a result, it was observed that the credibility of

completely fictional locations from the viewer's perspective is enhanced not only by visual aesthetics but also by the use of historical and architectural elements.

In this context, the presence of period architectural traces in spaces causes the viewer to situate the story within a historical timeline. Although the design elements in spaces do not directly refer to a specific period, they suggest the existence of a historical process to viewers. For example, metallic surfaces evoke associations with the beginning of the industrial age, while stone and wood-textured surfaces remind viewers of the architectural styles of earlier periods. In this context, even if architectural details are not specifically emphasized for particular periods, they reinforce viewers' belief in the narrative by evoking various reminders in their historical memory.

The data obtained as a result of all this shows that cinema is not just a backdrop for events, but an important tool for strengthening the bonds with the audience in terms of credibility. It is clearly demonstrated that architectural elements contribute to the credibility of cinematic spaces. Furthermore, the use of period symbols and styles in spaces plays an important role in making fictional spaces appear real to the audience.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. The authors of this article contributed equally.

References

Altan, İ. (2012). Mimarlıkta mekan kavramı. *Studies in Psychology, 19*, 75–88.

Arayıcı, O. (2018). Mekan algısının ve anlatımının subjektif yapısı. *Turkish Online Journal of Design Art and Communication, 8*(3), 560–564.

Benjamin, W. (1993). Kendi başına dil ve insan dili üzerine. In N. Gürbilek (Haz.), *Son Bakışta Aşk* (ss. 114–122). İstanbul: Metis Yayınları.

Büyükarman, F., Öztürk, E., & Şahin, D. (2015). *Edebiyatın İzinde - Fantastik ve Bilimkurgu*. İstanbul: Bağlam Yayın.

Ching, F. D. K. (2014). *Architecture: Form, Space, and Order* (5. baskı). Hoboken, NJ: Wiley.

Karaduman, B. (2021). *Fantastik edebiyattan uyarlanan sinema filmlerindeki kurgusal mekânların benzerlik açısından karşılaştırmalı analizi* (Yüksek lisans tezi). Mimar Sinan Güzel Sanatlar Üniversitesi, İstanbul.

Kavut, S. (2021). Kurgusal mekanlarda morfogenez etkisinin incelenmesi. *Mimarlık ve Yaşam Dergisi, 6*(3), 831–844.

Norberg-Schulz, C. (1980). *Genius Loci: Towards a Phenomenology of Architecture*. New York: Rizzoli.

Pallasmaa, J. (2009). *Space, Place, Memory, and Imagination: The Temporal dimension of existential space*. Routledge.

Shonfield, K. (2000). *Walls Have Feelings: Architecture, Film and the City*. Routledge.

Zumthor, P. (2006). *Thinking Architecture*. Basel: Birkhäuser.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Digitalization of Sustainability in Steel Structure Design Projects

Esin ŞAHİN [1*]

ORCID 1: 0009-0004-8158-2985
[1]Yildiz Technical University, Faculty of Civil Engineering, Department of Construction Management, Istanbul-Turkey
esin.sahin@std.yildiz.edu.tr (Responsible Author)

Kerim KOÇ [2]

ORCID 2: 0000-0002-6865-804X
[2]Assoc.Prof, Yildiz Technical University, Faculty of Civil Engineering, Department of Construction Management, Istanbul-Turkey
kerimkoc@yildiz.edu.tr

Abstract

The construction industry has reached a critical stage, accounting for almost 40% of global energy use and greenhouse gas emissions. Steel structures offer major sustainability benefits, including a high strength-to-weight ratio, flexibility, industrial production suitability, and recyclability, yet they also produce significant carbon emissions throughout their life cycle. Integrating Building Information Modeling (BIM) in early design stages is therefore crucial to embed sustainability within digital design processes, as traditional methods remain insufficient to meet environmental goals. This study examines the integration of BIM and Life Cycle Assessment (LCA) to assess sustainability in steel bridge and tower projects. BIM consolidates multidisciplinary data into a single 3D model, while LCA quantifies environmental impacts such as carbon footprint, energy use, and waste generation.Six case studies were analyzed: 1915 Çanakkale, Osman Gazi, and Yavuz Sultan Selim Bridges in Türkiye, and Akashi-Kaikyo (Japan), Russky (Russia), and The Blade (Saudi Arabia), using A1–A5 life cycle modules. Results show 10–25% carbon reductions, 8–22% energy savings, and 10–20% lower maintenance costs, extending service life by up to 20 years. Findings highlight the importance of early digital simulations for material and energy optimization. To encourage BIM–LCA adoption in Türkiye, the study recommends regulatory incentives, green financing tools, professional training, and digital twin integration to advance sustainable steel construction.

Keywords: BIM, LCA, sustainability, steel structures, carbon emissions, energy efficiency

1. Introduction

1.1. Background of the Study

The construction sector accounts for 34% of global energy consumption and 37% of CO_2 emissions from energy use (IEA, 2023; UNEP, 2022). These alarming figures underline the industry's decisive role in global climate action. Steel structures, particularly bridges and high-rise towers, are fundamental components of contemporary engineering due to their exceptional strength, flexibility, and adaptability to industrial production methods.

Yet, the environmental cost of steel production, characterized by energy-intensive processes and substantial CO_2 emissions, poses significant challenges to sustainability.

In this context, sustainable design practices have become indispensable. The increasing adoption of Building Information Modeling (BIM) provides opportunities for early-stage environmental analysis and optimization. BIM enables a data-driven design process in which environmental parameters such as embodied carbon, energy use, and material quantities can be monitored and optimized from the conceptual phase onward. When combined with Life Cycle Assessment (LCA), BIM extends its scope beyond visualization and coordination, enabling quantitative evaluation of a project's sustainability performance.

1.2. Problem Statement

Although steel structures are inherently recyclable—reaching up to 90% recyclability rates—the potential for sustainability optimization is often underutilized. In many cases, sustainability considerations are incorporated only in later stages, after design decisions are already finalized. This delayed approach limits opportunities to minimize embodied carbon, energy consumption, and material waste.

Traditional design workflows focus primarily on structural safety and cost-effectiveness, with limited integration of environmental data. As a result, critical decisions regarding material selection, transportation, and construction logistics are made without holistic evaluation of their life cycle impacts. Consequently, the construction sector faces persistent challenges in aligning economic efficiency with environmental sustainability.

1.3. Research Aim

The purpose of this study is to investigate the environmental, economic, and operational impacts of BIM–LCA integration in large-scale steel projects and to perform a comparative analysis between Turkish and international case studies. Specifically, the research aims to:

- Quantify reductions in carbon emissions, energy use, and maintenance costs through BIM–LCA integration.
- Compare the performance of Turkish mega bridge projects with international counterparts.
- Identify the contribution of digital tools—such as BIM, LCA, and digital twins—to enhancing sustainability outcomes.

1.4 Significance of the Study

This research contributes to Türkiye's goal of achieving net-zero carbon emissions by 2053. The study emphasizes that the integration of BIM and LCA enables early, data-driven decision-making, which can yield measurable improvements in environmental and economic performance. Moreover, it highlights the importance of digital transformation in construction, offering a framework through which engineers, contractors, and policymakers can coordinate sustainability strategies more effectively.

1.4. Literature Review

1.4.1. Building information modeling (BIM) and sustainability

Building Information Modeling (BIM) represents a paradigm shift in the construction industry. As a process integrating all project disciplines within a shared digital model, BIM facilitates collaboration, reduces information loss, and enables accurate simulation of real-world performance. Beyond coordination and visualization, BIM has evolved into a critical sustainability tool.

According to Azhar (2017), BIM provides a platform for early-stage energy simulations, carbon footprint assessments, and material optimization, allowing designers to make informed choices that minimize environmental impact. The use of parametric modeling enables automatic recalculation of quantities and energy consumption as design changes occur. These capabilities transform sustainability from a post-design verification process into an integral design driver.

Research by Wang and Chong (2022) further demonstrates that integrating BIM with life cycle cost analysis can reduce operational costs by 10–20%. In steel construction, where prefabrication and modular assembly are common, BIM supports precise material estimation, waste reduction, and improved logistics—all of which contribute to environmental and financial sustainability.

1.4.2. BIM Applications in Steel Structures

Steel structures stand out for their durability, strength-to-weight ratio, and recyclability. However, they are also energy-intensive to produce. Ding (2020) reported that steel production contributes substantially to global industrial carbon emissions. Early-stage integration of BIM helps mitigate these impacts by enabling optimization of prefabrication, transport, and on-site assembly.

For example, in the Akashi-Kaikyo Bridge project in Japan, digital modeling was later incorporated into an existing traditional design, enabling post-construction data integration and maintenance tracking. In Russia's Russky Bridge, BIM-based simulations were used to assess aerodynamic behavior under extreme wind loads, improving both safety and efficiency. In Saudi Arabia, *The Blade* tower project leveraged BIM-integrated digital twin systems and IoT-based monitoring, achieving a 22% improvement in energy efficiency (Lu et al., 2021).

These examples show that BIM not only enhances constructability but also provides measurable sustainability gains through performance monitoring, resource optimization, and lifecycle management.

1.4.3. Integration of BIM and LCA

The integration of BIM and Life Cycle Assessment (LCA) enables lifecycle-based computation of carbon emissions, energy consumption, and waste generation using data extracted from BIM models. International standards—namely ISO 14040/44 and EN 15978—structure the building lifecycle into distinct modules: A1–A3 (product stage: raw material supply, transport, and manufacturing), A4–A5 (construction process: transport to site and installation), B1–B7 (use stage: operation, maintenance, repair, replacement, refurbishment, operational energy and water use), C1–C4 (end-of-life: deconstruction, transport, waste processing, and disposal), and D (benefits and loads beyond the system boundary, including recycling and reuse) (EN 15978, 2011).

Abanda and Byers (2016) show that rigorous data mapping between BIM elements and LCA datasets can improve the accuracy of carbon accounting by up to 15%. Complementarily, Ding (2020) reports that in large-scale projects, BIM–LCA integration can reduce environmental impacts by 10–25%. These findings underline the value of linking model-based quantities (e.g., structural steel tonnage, connection types, coating systems) to environmental datasets to produce consistent and traceable results across project stages.

1.4.4. Digital Twin Technologies and the Internet of Things (IoT)

In recent years, digital twin technologies have extended the capabilities of BIM by creating a live, cyber-physical representation of the asset. Through IoT sensors, condition monitoring, and analytics, digital twins enhance operational efficiency and sustainability during the use phase. Lu et al. (2021) demonstrate that integrating digital twins can lower maintenance costs by up to 20% through predictive and condition-based strategies. In *The Blade* project, a BIM-integrated digital twin with IoT-supported monitoring achieved a 22% reduction in energy consumption and transitioned maintenance planning from periodic to data-driven practices.

This continuous feedback loop allows operational decisions (e.g., HVAC scheduling, façade control, or structural health monitoring) to be optimized in near real time.

1.4.5. Research Gaps in the Literature

A review of the extant literature highlights several gaps:
• **Scale and typology:** Most BIM–LCA studies focus on buildings; research for mega-scale steel bridges and towers remains limited.
• **Empirical validation:** Many contributions are theoretical or simulation-based; real-world case studies with measured outcomes are scarce.
• **Integrated ecosystems:** Studies that jointly examine BIM–LCA with digital twins and IoT are emerging but still few in number, limiting best-practice consolidation and benchmarking.

2. Materials and Methods

2.1. Research Approach

This study adopts a comparative case study approach combining both qualitative and quantitative methods.The aim is to evaluate the effects of BIM–LCA integration on the sustainability performance of steel structure projects.The research does not involve direct modeling or software-based LCA calculations.
Instead, it focuses on the systematic collection, analysis, and comparison of existing project data.Therefore, the study is based on secondary data analysis.

Six mega steel structure projects were selected as case studies: 1915 Çanakkale Bridge, Osman Gazi Bridge, Yavuz Sultan Selim Bridge, Akashi-Kaikyo Bridge (Japan), Russky Bridge (Russia), and The Blade Tower (Saudi Arabia).

These projects were chosen to represent different geographical regions and levels of digitalization maturity, enabling a comparative assessment of BIM–LCA applications and their environmental outcomes.

2.2. Data Collection Process

In the first stage, technical, environmental, and operational data were collected for the six selected projects.
Data were obtained from official government reports, academic studies, and technical bulletins published by engineering firms.

- For Turkish projects (1915 Çanakkale, Osman Gazi, Yavuz Sultan Selim): Data were gathered from the *Ministry of Transport and Infrastructure's Mega Projects Reports*, publicly available project documents, engineering presentations, and national academic proceedings.

- For international projects (Akashi-Kaikyo, Russky, The Blade): Data were derived from case studies published in *Journal of Cleaner Production*, *Automation in Construction*, and *Sustainable Cities and Society*, as well as from environmental impact assessment (EIA) reports.

All data were categorized under four main headings:

1. **Material usage:** steel quantity, section type, production process.
2. **Energy consumption:** energy used during production, transport, and erection.

3. **Carbon emissions:** reported embodied carbon values ($kgCO_2$/ton).

4. **Operational indicators:** recycling rate, maintenance frequency, and service life.

2.3. BIM–LCA Integration (Theoretical Framework)

In this study, BIM–LCA integration was not applied directly through software, but rather analyzed conceptually based on documented real-world applications in literature.

In general, BIM–LCA integration occurs when quantitative data (material quantities, transport distances, energy data) extracted from a BIM model are imported into an LCA calculation system.
In this study, that process was analyzed through previously documented case studies rather than direct modeling.

The level and purpose of BIM use in each project were examined:

- In some cases, BIM was used mainly for design coordination and quantity take-off,
- In others, it was used for environmental analysis, energy simulations, and digital twin applications.

These varying levels of BIM implementation were compared with the reported LCA outcomes (such as carbon emission reduction and energy efficiency improvements). Thus, the impact of BIM–LCA integration on environmental performance was evaluated indirectly through existing datasets rather than primary calculations.

2.4. Software and Tools

No BIM or LCA software was directly used during the study. However, to define the methodological framework, commonly referenced software tools in similar studies were acknowledged:

- Autodesk Revit: Used for BIM modeling and quantity extraction.
- One Click LCA: Used to transform BIM data into environmental impact calculations following EN 15978 standards.
- Excel & SPSS: Used for organizing, analyzing, and visualizing collected numerical data.

These tools were not directly applied in the analysis but are cited as the methodological foundation for the study's comparative approach.

2.5. LCA Modules

The scope of the LCA analysis followed the EN 15978 standard, focusing mainly on A1–A5 modules:

- A1–A3: Material production and embodied carbon.
- A4: Transport and fuel consumption.
- A5: Construction site activities and waste generation.

Additionally, C and D modules (recycling and recovery potential) were only qualitatively evaluated, not quantitatively analyzed.

2.6. Comparative Case Analysis

The collected data were comparatively analyzed based on environmental, economic, and operational performance indicators.

Evaluation criteria:

1. **Environmental Performance:** carbon emissions ($kgCO_2$/ton), energy consumption (MJ), recycling rate (%).
2. **Economic Performance:** material cost, maintenance and operational expenses.
3. **Operational Performance:** service life, maintenance frequency, digital twin integration.
4. **Sustainability Contributions:** waste reduction, reuse potential, carbon management practices.

All data were normalized (e.g., emissions per ton of steel) and ranked by performance levels. It was observed that projects with higher BIM implementation levels, such as *The Blade* and *Akashi-Kaikyo*, achieved significantly better environmental performance. This indicates a clear correlation between digitalization maturity and sustainability performance.

2.7. Validation through Literature

The findings were compared with results from prior studies, such as Ding (2020) and Lu et al. (2021), which reported 10–25% carbon emission reductions through BIM–LCA integration. The consistency between these findings confirms that the present study aligns with both academic literature and real-world evidence.

3. Findings and Discussion

3.1. Carbon Emissions

BIM–LCA assessments showed considerable variation in carbon emissions across projects, primarily reflecting differences in steel quantities, structural systems, and logistics. The large Turkish bridges—1915 Çanakkale, Osman Gazi, and Yavuz Sultan Selim—demonstrated high embodied carbon due to substantial steel tonnages and complex erection sequences. By contrast, *The Blade* exhibited lower net emissions after optimization, supported by model-based coordination, energy-focused design choices, and operations-stage efficiency measures enabled by its digital twin.

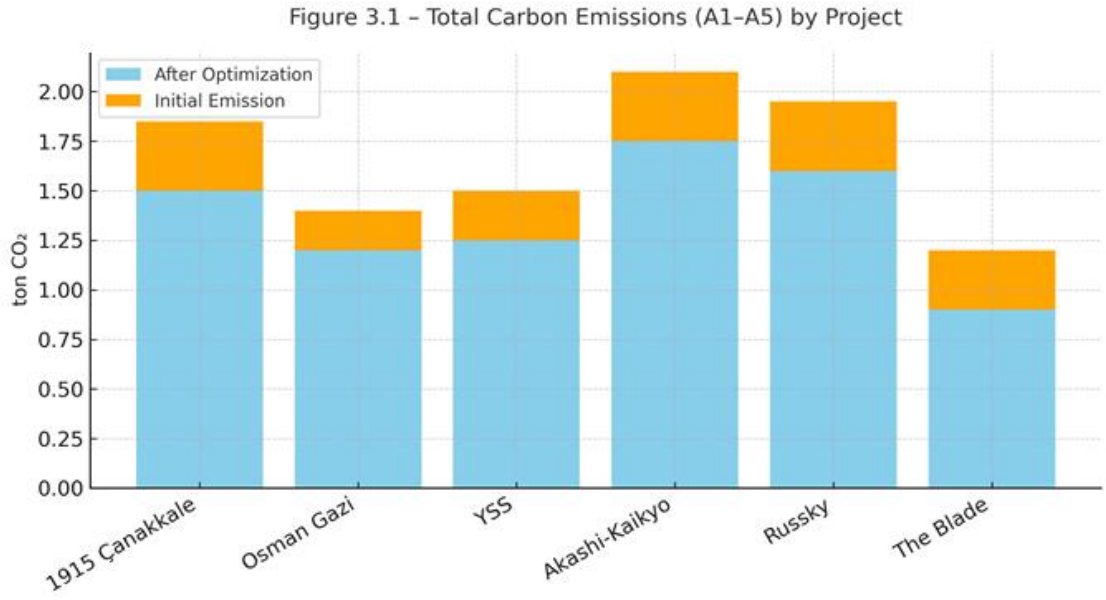


Figure 3.1. Total Carbon Emissions (A1–A5) by Project.
As indicated in Figure 3.1, the **largest post-optimization reduction—25%—was observed in *The Blade***, corroborating literature-reported ranges for large projects.

3.2. Recycling Rates

Steel's recyclability strongly supports circularity objectives. Across the analyzed projects, recycling rates ranged from 70% to 95%.

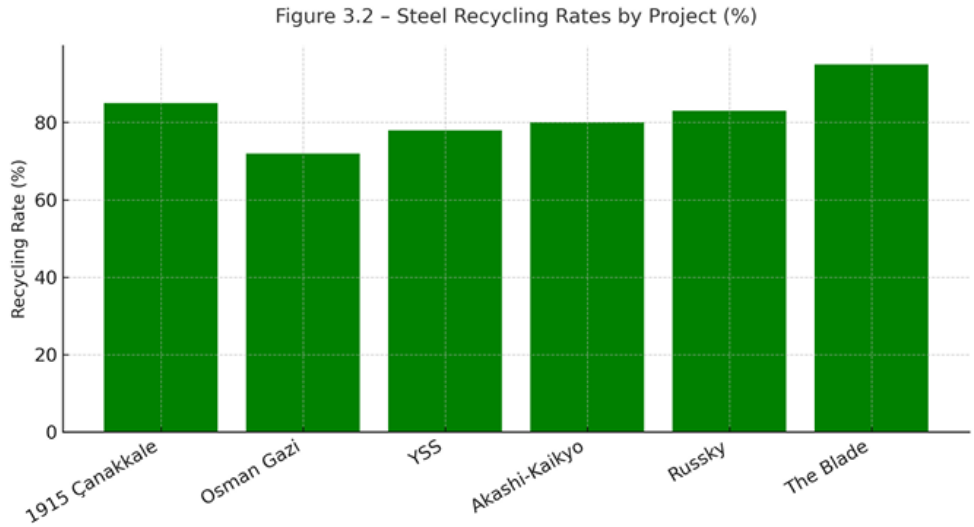


Figure 3.2. Steel Recycling Rates by Project (%)

Figure 3.2 shows that ***The Blade*** **achieved the highest recycling rate (95%)**, while **Osman Gazi** recorded the lowest (72%). Differences reflect procurement strategies, local recycling infrastructure, and specification requirements for recycled content.

3.3. Energy Efficiency Gains

Energy performance gains attributable to BIM-enabled optimization and, where applicable, digital twin operations varied across cases.

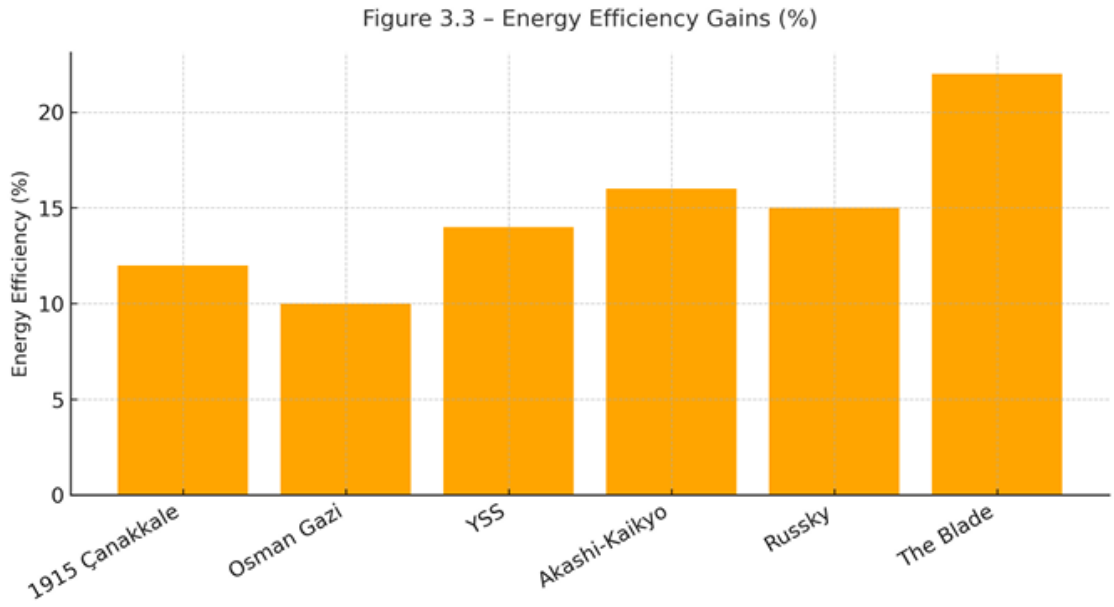


Figure 3.3. Energy Efficiency Gains (%)

As seen in Figure 3.3, ***The Blade*** **achieved the highest energy efficiency improvement (22%)**, whereas **Osman Gazi** registered approximately **10%**, pointing to divergent scopes of digitalization and operations-stage monitoring.

3.4 Discussion

The six case studies represent a spectrum of technological maturity and institutional contexts. In Türkiye, BIM is predominantly applied for coordination, clash detection, and construction planning—yielding time/cost benefits and improved constructability. In contrast, international cases—particularly *The Blade*—demonstrate extended digitalization, including digital twins, IoT integration, and AI-assisted energy monitoring, which translate to measurable operational sustainability gains.

When compared with literature, the observed carbon reduction levels (15–25%) align with Ding (2020) and Lu et al. (2021). Turkish bridges achieved ~15–20% reductions, whereas *The Blade* reached ~25%. This spread can be attributed to:

- **Regulatory frameworks and certification regimes** (e.g., LEED/BREEAM alignment driving documentation and continuous monitoring),
- **Supply chain capabilities** (availability of low-carbon steel, EPD coverage, and recycling infrastructure),

- **Digital maturity** (extent of BIM use beyond geometry—data standards, LCA mapping quality, and live operational feedback loops).

While Turkish mega bridges are remarkable engineering achievements, sustainability-focused data integration is still evolving. Consolidated national standards and public procurement incentives could accelerate practices such as low-carbon material selection, data-rich BIM execution plans, and mandatory lifecycle reporting.

4. Conclusion and Recommendations

4.1. Conclusion

This study confirms that BIM–LCA integration in steel structures can deliver substantial environmental and economic benefits. The case analyses indicate potential carbon reductions of 15–25%, recycling rates of 70–95%, and energy efficiency gains of 10–22%. Importantly, BIM–LCA proves valuable not only at the design stage but across construction and operations, functioning as a comprehensive sustainability management framework. Comparative results also reveal that performance is shaped by technology, institutional capacity, and regulatory context. While Turkish projects leverage BIM primarily for schedule and cost control, international exemplars show how standardized data protocols, certification alignment, and operations-driven digitalization can elevate environmental outcomes. Achieving the full potential of BIM–LCA will therefore require coordinated action across policy, finance, and education.

4.2. Recommendatıons

To mainstream BIM–LCA in steel projects, the following actions are recommended:

1. **Regulatory Integration:** Mandate BIM-based LCA in design submissions and align with **EN 15978** and recognized green certification systems (LEED, BREEAM). Require disclosure of embodied carbon (A1–A5) and, where feasible, end-of-life scenarios.

2. **Green Finance:** Deploy carbon credits, green bonds, and preferential financing to de-risk sustainability investments and prioritize low-carbon procurement.

3. **Technology Enablement:** Encourage digital twin deployment with IoT sensors and analytics/AI for continuous performance tracking (energy, condition, and carbon dashboards).

4. **Operational Circularity:** Require recycling and reuse plans in project execution, including targets for recycled content, take-back schemes, and traceable waste management.

5. **Capacity Building:** Establish BIM–LCA-focused university curricula and professional training; develop national BIM execution guidelines emphasizing LCA data structures, dataset mapping, and EPD usage.

Ultimately, BIM–LCA constitutes a powerful lever for achieving sustainability goals in steel structure projects. Realizing its benefits at scale depends on a holistic approach that couples digital technologies with policy instruments, financial incentives, and skills development.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Abanda, F. H., & Byers, L. (2016). An investigation of the impact of building information modelling on project performance. *Automation in Construction*, 69, 45–55.

Azhar, S. (2017). Building Information Modeling (BIM): Trends, benefits, risks, and challenges. *Leadership and Management in Engineering*, 11(3), 241–252.

Ding, Z. (2020). Integrating BIM and LCA for sustainable construction. *Journal of Cleaner Production,* 265, 121–125.

EN 15978. (2011). Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method. CEN.

Lu, Q., Xie, X., Parlikad, A. K., & Schooling, J. (2021). Digital twin-enabled sustainability in construction: Applications, challenges and future directions. *Automation in Construction,* 123, 103517.

UNEP. (2022). 2022 Global Status Report for Buildings and Construction.

Wang, J., & Chong, H. Y. (2022). BIM–LCA integration for sustainable infrastructure projects. *Sustainable Cities and Society,* 76, 103–128.

Ulaştırma ve Altyapı Bakanlığı. (2021). Türkiye'de mega köprü projeleri raporu.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Examination of Post-Disaster Housing Design in the Context of Regional and Climatic Adaptation

Emine Şeyma ERKAN [1*]

ORCID 1: 0000-0001-5034-0108
[1] Research Assistant, Istanbul Rumeli University, Faculty of Art, Design and Architecture, Department of Architecture, İstanbul-Türkiye
eseyma.erkan@rumeli.edu.tr **(**Responsible Author)

Nilay COŞGUN [2]

ORCID 2: 0000-0001-5874-3331
[2] Prof. Dr., Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
nilaycosgun@gtu.edu.tr

Elif ÖZER YÜKSEL [3]

ORCID 3: 0000-0002-1041-8748
[3]Assistant Professor, Gebze Technical University, Faculty of Architecture, Department of Architecture, Kocaeli-Türkiye
e.yuksel@gtu.edu.tr

Abstract

Disasters cause physical destruction, creating an urgent need for shelter. Meeting this need quickly and effectively in the post-disaster period and providing living comfort for disaster victims is of great importance. To this end, public institutions develop standardized housing projects to enable rapid post-disaster housing production. While these projects offer advantages in terms of speed and cost efficiency, they often overlook local climatic conditions, leading to long-term problems in environmental comfort. This study aims to evaluate the impact of climatic and regional differences on disaster housing design and the adequacy of standardized housing projects in this context. The research examines projects proposed for the provinces of Diyarbakır, Erzurum, Elazığ, Konya, Manisa, Adana, Bursa, and Ordu, located in different climate regions. Standard housing plans recommended by the Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change were assessed in terms of compact massing, spatial organization, facade orientation, natural ventilation, and energy efficiency, considering climate and geographic context. The results show that standardized projects are insufficient in terms of regional and climatic adaptation. In hot and dry climates, the lack of natural ventilation and shading strategies is notable, while in cold climates, facade designs increase heat loss. In conclusion, although standardized housing projects allow rapid and cost-effective responses to post-disaster shelter needs, neglecting climatic conditions reduces long-term quality of life for users. Therefore, post-disaster housing production should prioritize plan types that are sensitive to local climatic conditions and ensure sustainable environmental comfort, alongside speed and cost considerations.

Keywords: Disaster Housing, Standardized Projects, Regional Differences, Climatic Adaptation, Environmental Comfort

1. Introduction

Disasters are defined as natural, technological, or human-induced events that directly affect human life, settlement patterns, and social structures; cause physical, economic, and psychological losses; disrupt normal living conditions; and cannot be managed with local resources alone. Due to its geographical location, position on an active tectonic belt, diverse geological/topographical characteristics, and the coexistence of various climatic zones, Türkiye is exposed to multiple natural disasters, particularly earthquakes.

Disasters such as earthquakes, floods, landslides, and wildfires not only result in physical destruction but also generate profound social, economic, and psychological impacts (Limoncu

& Bayülgen, 2005; Yılmaz, 2021). In the post-disaster period, achieving both spatial and individual recovery is possible only through rapid, effective, and sustainable interventions by relevant state institutions. In this context, meeting shelter needs involves not merely providing a physical dwelling, but also re-establishing living quality, safety, and comfort conditions in a sustainable manner.

Standardized housing projects, commonly employed in post-disaster reconstruction, often lead to significant problems due to the neglect of climatic differences across regions. Owing to its latitudinal position, Türkiye accommodates multiple climatic zones. This climatic diversity requires parameters such as temperature, humidity, wind direction, precipitation, and solar exposure to be considered in spatial organization, material selection, and building form. Consequently, applying the same housing typology in different climatic regions may be unsuitable in terms of both energy efficiency and indoor comfort. The country's broad geographical characteristics therefore necessitate a design approach that responds to regional environmental conditions and is compatible with diverse climate types (Ç. B. Dikmen, 2011; Kısa Ovalı, 2019; Koca, 2006). For instance, in cold climates, compact layouts that minimize heat loss and orient toward the south are key design principles, whereas in hot-dry regions, courtyard-based, permeable, and shaded spatial arrangements are essential for balancing indoor temperatures. In highly humid areas such as the Black Sea Region, natural ventilation, facade openings, and breathable materials become crucial. However, when standard designs are implemented without considering such climatic requirements, users are forced to inhabit thermally and psychologically uncomfortable spaces, while energy consumption and maintenance costs increase (Ç. B. Dikmen, 2011; Kısa Ovalı, 2019; Koca, 2006).

Therefore, the main objective in post-disaster housing design should not be limited to ensuring structural safety; it should also focus on developing housing types that are compatible with local climatic data, adopt passive design strategies, offer high energy efficiency, and prioritize user comfort. An approach that does not overlook climatic differences will enable the reconstruction of post-disaster living environments in a sustainable and healthy manner (Ç. B. Dikmen, 2011).

In Türkiye, the production process of permanent post-disaster housing is carried out through an institutional division of responsibilities among the Disaster and Emergency Management Presidency (AFAD-Afet ve Acil Durum Yönetimi Başkanlığı), Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre ve Şehircilik İklim Değişikliği Bakanlığı), and the Housing Development Administration (TOKİ-Toplu Konut İdaresi). While AFAD is responsible for initial response, process coordination, and needs assessment, ÇŞİDB and TOKİ take part in the design and construction phases of the housing projects (Url-1; Url-2). In post-disaster housing production, TOKİ and ÇŞİDB employ standardized "type projects," which offer advantages in terms of cost and construction speed. However, these projects are often limited in their ability to reflect socio-cultural, geographical, and climatic differences. Although this approach accelerates the production process, it generates long-term disadvantages regarding climatic adaptability, comfort conditions, and the energy efficiency of the built environment (N. Dikmen, 2011; Kuz, 2021).

In this study, a literature review focusing on climate and energy-efficient design in post-disaster housing production was conducted in the Scopus, Web of Science (WoS), and ScienceDirect databases using the keyword "permanent post-disaster housing." Examination of the retrieved abstracts revealed that climatic assessments predominantly concentrate on temporary shelter

units, whereas studies on permanent housing largely remain limited to material- and heat-transmission-based analyses such as wall layers and building envelope properties. For this reason, studies addressing climatic performance aspects—such as daylighting, ventilation, and heating—in standard housing projects, even if not directly situated within the post-disaster context, were also included. This approach expanded the scope of the literature to enable the evaluation of climate-related design decisions in permanent post-disaster housing.

Bilgili (2023) selected a standard 2+1 housing project designed by TOKİ and analyzed its natural ventilation performance across five different climatic regions in Türkiye. The study assessed indoor airflow based on dominant wind direction and speed, comparing the effectiveness of natural ventilation across climates. The findings revealed that the same housing typology performs differently in terms of natural ventilation depending on the climatic context. While natural ventilation yielded favorable results in hot-dry, hot-humid, and temperate-humid climates, it was found to be insufficient in temperate-dry zones and problematic in cold-dry regions due to the necessity of wind-protected design. These results clearly indicate that implementing standardized projects without considering climatic conditions does not ensure equal efficiency across different regions (Bilgili, 2023).

Dikmen (2011) conducted an extensive survey with residents of mostly single-storey permanent houses built in rural areas through two different production models: state-led standardized projects after the 1995 Dinar (Afyonkarahisar) earthquake, and the participatory "Assistance to Those Who Build Their Own House" model after the 2000 Çankırı earthquake. The findings revealed that although users generally found the houses functionally adequate, they expressed significant dissatisfaction regarding thermal comfort and heating performance, which resulted in high energy/fuel consumption. The fact that user satisfaction with heating was higher in Dinar compared to Çankırı, despite both settlements being constructed without reference to climatic parameters, further demonstrates the lack of climate-responsive design in post-disaster housing (N. Dikmen, 2011)

Scientific studies consistently emphasize that climatic adaptation must not be overlooked in post-disaster housing production or in the implementation of standardized housing projects.

In Türkiye, the production of permanent post-disaster housing falls under the authority and responsibility of the central government. Within this framework, the state implements three primary methods for the construction of permanent housing: direct construction by ministries and government agencies, procurement of services from the private sector through tenders, and the "Assistance to Those Who Build Their Own House" (KEYY-Kendi Evini Yapana Yardım) model. In the first two methods, the constructed dwellings are allocated to disaster victims through low-interest loans or grants. In the KEYY model, users are encouraged to build their own houses, while the state provides financial assistance and technical support throughout the process. This approach aims to ensure the active participation of disaster-affected households in the reconstruction process (Savaşır, 2008). The central government may apply these methods individually or simultaneously in post-disaster housing delivery, and it adopts multiple production models such as mass housing, core housing, and user-participatory housing (AFAD, 2024; Savaşır, 2008).

The Disaster and Emergency Management Presidency (AFAD-Afet ve Acil Durum Yönetimi Başkanlığı) was established in 2009 under the Ministry of Interior. AFAD coordinates all phases of disaster management, including preparedness, emergency response, and post-disaster recovery. Its core responsibilities include the provision of temporary shelter, damage

assessment, determination of beneficiary eligibility, and planning of permanent housing production in disaster-affected areas (AFAD, 2024).

In 2011, the Ministry of Public Works and Settlement and the environmental units of the Ministry of Environment and Forestry were merged to form the Ministry of Environment and Urbanization. In 2021, its name was changed to Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre ve Şehircilik İklim Değişikliği Bakanlığı) (Url-3). The Ministry undertakes multi-dimensional roles in pre-disaster preparedness, response, and recovery phases, including damage assessment, debris removal, infrastructure restoration, and housing production. It directly participates in the process by providing technical guidance and coordination during site selection, planning, and design phases of housing projects. Additionally, it oversees regulatory compliance and coordinates housing production either through tenders or direct implementation in collaboration with TOKİ and AFAD. The Ministry also promotes community involvement through the KEYY model, enabling disaster victims to take an active role in constructing their own dwellings (ÇŞİDB, 2022; Url-1).

The Housing Development Administration of Türkiye (TOKİ-Toplu Konut İdaresi) was established in 1984 under the Mass Housing Law No. 2985 with the aim of planning and supporting housing production. Initially operating under the Prime Ministry, TOKİ was transferred to the Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre ve Şehircilik İklim Değişikliği Bakanlığı) by Presidential Decree No. 703 on 09.07.2018. TOKİ develops housing, infrastructure, and social facility projects both domestically and internationally, and undertakes the construction of housing and related infrastructure in disaster-affected areas. In cooperation with AFAD and the Ministry, it carries out large-scale housing production in a short time in accordance with approved projects, functioning as one of the key actors in post-disaster recovery. In addition, it plays an active role in housing finance, urban transformation, and the preservation of vernacular architecture(T.C. Resmi Gazete, 1984; Url-2).

Standardized “type project” applications, frequently preferred in post-disaster housing production, offer significant advantages in terms of accelerating construction and reducing costs. Particularly in large-scale interventions, standardized spatial solutions provide practicality for implementing institutions faced with the need for rapid production (Savaşır, 2008). However, this approach often fails to adequately consider climatic and regional differences and excludes user participation from the design process, which can lead to critical problems. Type projects are typically architectural schemes replicated nationwide without regard to geographical, climatic, or cultural context. As a result, the dwellings may not align with the climatic conditions, geography, socio-cultural structure, or household lifestyle patterns of the region in which they are built.

For instance, when identical window openings, facade orientations, or material selections are applied in regions with different climatic conditions, significant losses in both energy efficiency and spatial comfort may occur. Thus, in post-disaster planning processes, adopting design approaches that account not only for speed and cost efficiency but also for climatic characteristics plays a critical role in ensuring the sustainability of housing. This study aims to examine the extent to which regional climatic conditions are taken into consideration in the design of permanent post-disaster housing in Türkiye, and to evaluate the compatibility of province-specific prototype projects with the climatic and environmental characteristics of their respective regions.

2. Materials and Methods

The study initially intended to evaluate the housing projects of two main institutions responsible for post-disaster housing production in Türkiye: the Housing Development Administration (TOKİ-Toplu Konut İdaresi) and and the Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre ve Şehircilik İklim Değişikliği Bakanlığı). However, due to the lack of sufficient data on TOKİ projects, the analysis was limited to the post-disaster housing models proposed by the ÇŞİDB.Within the scope of the analysis, provinces representing different climatic regions of Türkiye were selected. Erzurum was chosen for the cold climate region; Diyarbakır for the hot-dry climate; Bursa and Ordu for the temperate-humid climate; Konya and Elazığ for the temperate-dry climate; and Adana and Manisa for the hot-humid climate.

The study first involved a literature review to establish the evaluation criteria, which were defined based on geographical region and climate type. In line with these criteria, pilot provinces representing different regional and climatic characteristics were selected, and the ÇŞİDB standard housing types in these provinces were examined in terms of building form, facade configuration, and plan layout.

The primary evaluation parameters, derived from the literature, are geographical regions and climate types. Türkiye's geographical regions were classified into seven main zones at the First Turkish Geography Congress held in 1941, as shown in Figure 1: Mediterranean Region, Eastern Anatolia Region, Aegean Region, Southeastern Anatolia Region, Central Anatolia Region, Black Sea Region, and Marmara Region (Url-4).



Figure 1. Geographical Regions of Türkiye (Url-5)

According to the classification proposed by Zeren (1959), the climate of Türkiye is divided into five regions: cold, temperate-humid, temperate-dry, hot-humid, and hot-dry (Figure 2). In establishing these climate categories, the seasonal and daily temperature patterns of the regions, as well as their year-round relationship with humidity, were taken as the primary criteria. For instance, although they differ in temperature characteristics, the Marmara Region, the Black Sea coast, and the coastal areas of the Aegean and Mediterranean exhibit humid climatic conditions due to the influence of maritime effects. In contrast, moving inland from the coastal zones, the increasing dominance of continentality—especially where mountain ranges block maritime influence—results in predominantly dry climatic conditions.

Another reason why climate regions do not fully overlap with the geographical regions of Türkiye is the variability in humidity levels shaped by the interaction of maritime and continental effects. Additionally, factors such as elevation differences, the orientation of mountain ranges, and the movement pathways of cold and warm air masses contribute to the

emergence of different temperature and climate classes even within the same geographical region (Kısa Ovalı, 2019; Koca, 2006).

In this study, the pilot provinces were selected based on the Sample Post-Disaster Housing Projects published on the official website of the Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre ve Şehircilik İklim Değişikliği Bakanlığı), taking both climate regions and geographical regions into account. The initial aim was to select two provinces from each climate region; each located in a different geographical region. However, all of the provinces listed under the hot-dry and cold climate regions on the Ministry's website (Url-6) are located within a single geographical region; therefore, only one province was selected from each of these two climate regions. On the other hand, since the temperate-humid, temperate-dry, and hot-humid climate regions include provinces distributed across different geographical regions, two provinces were selected from each of these categories.

The Ministry provides alternative architectural projects for different provinces, including single-storey, multi-storey, 2+1, and 3+1 housing types. For the purpose of ensuring a consistent and comparable analysis, only the 2+1 units within multi-storey buildings were included in the evaluation. As presented in Table 1 the selected provinces are: Erzurum representing the cold climate region, Diyarbakır representing the hot-dry climate region, Bursa and Ordu representing the temperate-humid climate region, Konya and Elazığ representing the temperate-dry climate region, and Adana and Manisa representing the hot-humid climate region. The locations of these selected provinces are marked on the climate regions map in Figure 2.

Table 1. Criteria for Selection and Pilot Provinces

	Marmara Region	**Black Sea Region**	**Aegean Region**	**Mediterranean Region**	**Central Anatolia Region**	**East Anatolia Region**	**Southeastern Anatolia Region**
Cold Climate Zone						Erzurum	
Temperate-Humid Climate Zone	Bursa	Ordu					
Temperate-Dry Climate Zone					Konya	Elazığ	
Hot-Humid Climate Zone			Manisa	Adana			
Hot-Dry Climate Zone							Diyarbakır

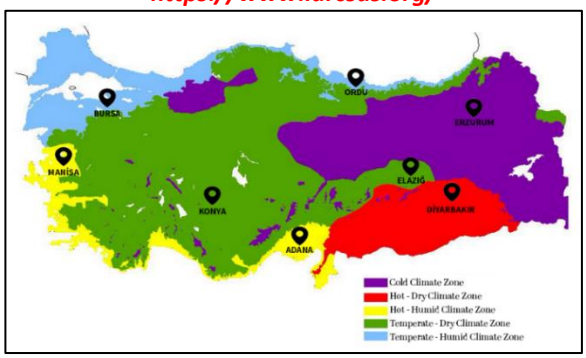


Figure 2. Climate Zones and Location of Pilot Provinces (Produced by the author using data from Koca, 2006)

3. Findings and Discussion

Under this heading, the design parameters according to climatic regions are first explained, and the standard floor plans of the multi-story 2+1 post-disaster housing units in the eight selected pilot cities are examined and evaluated within the climatic and geographical context. The assessment primarily focuses on building mass form, spatial organization, and facade orientation. Since none of the typified projects include an indication of facade orientation, it is not possible to make direction-based evaluations regarding facades or balconies. Therefore, facade orientation has been excluded from the scope of analysis, and the evaluation has been limited to mass form and spatial organization. The facade layout has been partially reviewed in a direction-independent manner.

In the hot-dry climate zone, the province of Diyarbakır experiences extremely hot and dry summers and cold winters. Daily and annual temperature differences, as well as solar radiation levels, are high throughout the year. The elevation of the provinces in the Southeastern Anatolia Region ranges between 500–1000 m, and the topography is generally flat or slightly undulating. In this region, the design strategy at the scale of building form and spatial organization should aim to reduce solar heat gains and enhance natural ventilation during the summer, while maximizing solar gains during the winter. The building form should be compact and preferably organized around an inner courtyard. In terms of spatial layout, to minimize heat exposure, facades should be narrow and spaces deeper in plan, while the transparency ratio on the west and south facades should be reduced (Ç. B. Dikmen, 2011; Dizdar, 2009; Kısa Ovalı, 2019).

In the hot-humid climate zone, represented by Manisa and Adana, summers are hot and highly humid. Therefore, the primary design objective is to reduce excessive heat gains in the summer while ensuring continuous air movement to improve indoor comfort. Since the south and west facades are exposed to the highest levels of solar radiation, the size of openings on these facades should be minimized, and effective shading devices should be used to control solar exposure. Planning interior spaces to remain open to prevailing winds increases cross-ventilation and prevents humidity buildup. Additionally, buildings should be positioned with sufficient spacing to avoid blocking natural airflow, enabling passive cooling at the settlement scale (Ç. B. Dikmen, 2011; Dizdar, 2009; Kısa Ovalı, 2019).

In the cold climate zone, represented by Erzurum, the long and severe winter conditions necessitate minimizing heat losses while maximizing solar heat gains. Accordingly, buildings should be designed in compact forms, with increased transparency on the south facade and buffer spaces such as storage rooms or stairwells located on the north side. Roofs should have

steep slopes to prevent snow accumulation, and the building envelope must be thick and well insulated. In the spatial organization, primary living spaces should be oriented to the south, whereas secondary functions should be located on the north to support energy-efficient use (Ç. B. Dikmen, 2011; Dizdar, 2009; Kısa Ovalı, 2019).

In the temperate-dry climate zone, represented by Elazığ and Konya, the diurnal temperature difference is high, with hot summers and cool winters. Summer design strategies should benefit from the cooling effect of prevailing winds, whereas in winter, the goal is to increase solar heat gains. Compact and attached building layouts help prevent heat loss while supporting solar exposure. Large transparent surfaces are not recommended, as they lead to excessive heat gain in summer and excessive heat loss in winter. Buildings should be oriented toward the south or southeast, and both roofs and exterior walls should be well insulated. Buffer spaces such as storage rooms or windbreaks should be placed on the north side to improve thermal comfort (Ç. B. Dikmen, 2011; Dizdar, 2009; Kısa Ovalı, 2019).

In the temperate-humid climate zone, represented by Bursa and Ordu, annual temperature fluctuations are low, yet humidity levels are high. This requires a design approach that promotes both ventilation for cooling and reduced humidity effects. Spatial organization should remain open, allowing continuous airflow through appropriately positioned openings. Shading devices and wide eaves should be integrated to protect facades. Window openings should be sufficiently large to benefit from summer breezes, and interior depth should be designed to balance solar gains (Dikmen, 2011; Dizdar, 2009; Kısa Ovalı, 2019).

3.1. Post-Disaster Housing Plans and Evaluation in the Cold Climate Region

The pilot province representing the cold climate region is Erzurum, located in the Eastern Anatolia Region of Türkiye. Figure 3 illustrates the standard floor plan of the post-disaster housing unit in Erzurum. The plan consists of two identical apartments symmetrically arranged around a central stair core. Overall, the layout is compact and linear; however, the living room facade is recessed slightly from the main building line, creating an indentation. The central core accommodates only the staircase, providing separate entrances to each unit.

An examination of the spatial organization reveals that each apartment includes an entrance hall, corridor, kitchen, living room, two bedrooms, a bathroom, a WC and one balcony. From the entrance hall, direct access is provided to the living room, kitchen and corridor; the corridor, in turn, distributes to the two bedrooms, bathroom and WC. The single balcony of the unit is connected to the kitchen.

With respect to facade organization, although each room contains more than one opening, all openings are positioned on a single facade, preventing cross-ventilation.

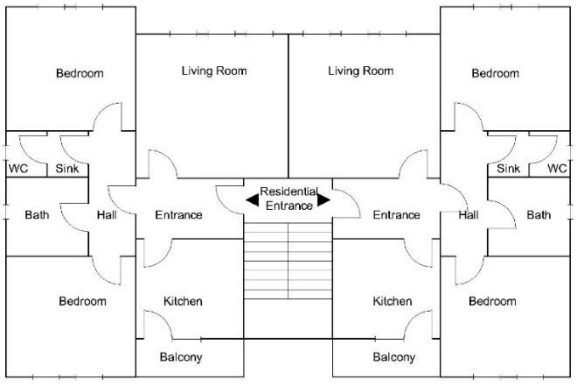


Figure 3. Erzurum Post-Disaster Housing Typical Floor Plan

Erzurum is located in Türkiye's cold climate zone, where compact building massing, southward orientation, buffer spaces on the northern facade, and high thermal insulation are considered key design strategies. The plan generally aligns with a compact, linear configuration; however, the recessed living room facade—while contributing to visual articulation—may increase heat loss. In addition, the stair core, entrance hall, and corridor lack access to natural ventilation. Since all windows face a single direction, cross-ventilation is not possible. Nevertheless, given the region's low humidity levels, this limitation may not constitute a critical drawback.

3.2. Post-Disaster Housing Plans and Evaluation in the Temperate-Humid Climate Region

The pilot provinces representing the temperate-humid climate region are Bursa, located in the Marmara Region, and Ordu, located in the Black Sea Region. The standard floor plan of the Bursa post-disaster housing unit, shown in Figure 4 consists of two apartments symmetrically arranged around a central core. A compact and linear configuration has been adopted, avoiding projections and recesses in the plan layout. The central core accommodates both the elevator and staircase, with the apartment entrances placed symmetrically and positioned opposite one another.

An analysis of the spatial configuration shows that each unit contains a living room, kitchen, two bedrooms, a bathroom, a WC, a hall, an entrance vestibule, and two balconies. The living room and kitchen are located on the front facade and are directly connected to the balcony on this side. The bedrooms are positioned at the rear of the apartment, ensuring privacy. The second balcony is associated with one of the bedrooms. With regard to facade organization, all spaces except the bedrooms have openings on two orientations.

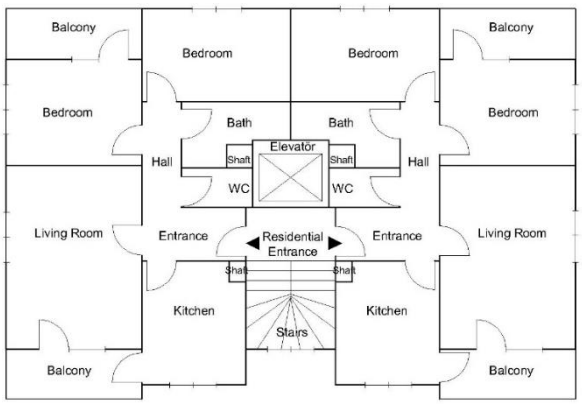


Figure 4. Bursa Post-Disaster Housing Typical Floor Plan

Bursa is located in the temperate-humid climate zone, where reducing indoor humidity and ensuring continuous air circulation are essential design considerations. The presence of two balconies in each unit, along with dual-aspect openings in all spaces except the bedrooms, enhances indoor air movement and enables cross-ventilation. This configuration also supports passive cooling through night ventilation. In particular, the dual-aspect layout of the living room and kitchen offers advantages in terms of natural ventilation and daylighting. However, the entrance vestibule, interior corridors, WC, and bathroom—being located adjacent to the central core—cannot benefit from natural ventilation; thus, cross-ventilation is limited to rooms facing the exterior facades.

The typical floor plan of the Ordu post-disaster housing unit is shown in Figure 5. The plan consists of two symmetrically arranged apartments organized around a central core. The building is formed by two compact masses connected through a smaller core volume, resulting in recessed areas on the front and rear facades at the core zone. At the center of the plan is a core containing a three-flight staircase and an elevator, with apartment entrances accessed from the floor hall connected to the core. Each apartment includes a living room, kitchen, bedroom, two additional bedrooms, WC, washbasin, bathroom, ventilation shaft, and two balconies.

From the perspective of spatial organization, common-use areas such as the entrance hall, kitchen, and living room are located near the entrance, while the bedrooms and children's rooms are placed further away. A night corridor separating these rooms from the living areas ensures privacy and acoustic comfort. The living room and kitchen are directly connected to the balconies. The placement of wet areas close to the core supports continuity of building services.

An examination of the facade organization shows that, except for the living room, all spaces are provided with a single-sided window opening. In the bedrooms and kitchen that open onto the balcony, an additional window on the same facade accompanies the balcony door.

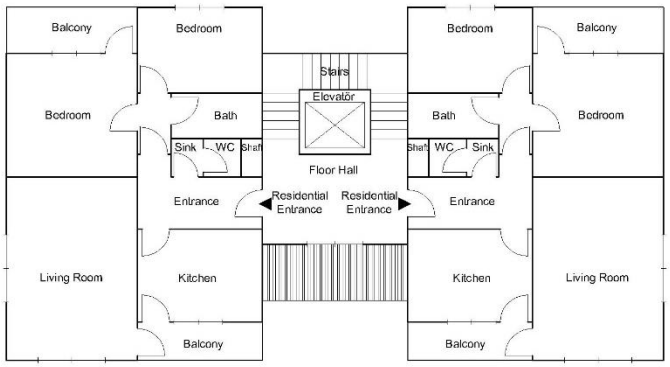


Figure 5. Ordu Post-Disaster Housing Typical Floor Plan

Ordu is located within a temperate and humid climatic zone, where moisture control and the provision of air circulation play a critical role in design. The placement of windows on two facades of the living room enables cross-ventilation. However, although the bedrooms could have been provided with openings on two facades, they are limited to single-sided windows, reducing the potential for cross-ventilation and creating a disadvantage in terms of indoor humidity distribution. The balconies on the front and rear facades contribute to the intake of prevailing winds at different times of the year, thereby enhancing natural ventilation efficiency. Since the bathroom, WC, and internal corridor are located away from the facade, they lack

natural lighting and ventilation. Conversely, the windowed facade of the floor hall allows the core area to benefit from natural daylight and air circulation.

3.3. Post-Disaster Housing Plans and Evaluation in the Temperate-Dry Climate Region

The pilot provinces representing the temperate-dry climate region are Konya, located in the Central Anatolia Region, and Elazığ, located in the Eastern Anatolia Region. Figure 6 illustrates the typical floor plan of the Konya post-disaster housing unit. The plan consists of two identical apartments symmetrically arranged around a central core. Overall, it features a compact and linear layout. The core accommodates the elevator, staircase, and atrium void, and is connected to each apartment via short and direct corridors.

An examination of the spatial organization reveals that each apartment includes a living room, kitchen, bedroom, children's room, bathroom, separate WC, washbasin area, entrance hall, and balcony. The living room and kitchen are positioned closer to the apartment entrance, while the bedroom and children's room are located further from it, enabling a functional separation between daytime living spaces and resting areas. The balcony is associated with the kitchen.

In terms of facade organization, all interior spaces receive light from a single direction, with openings located only on the front and rear facades; the side facades contain no openings.

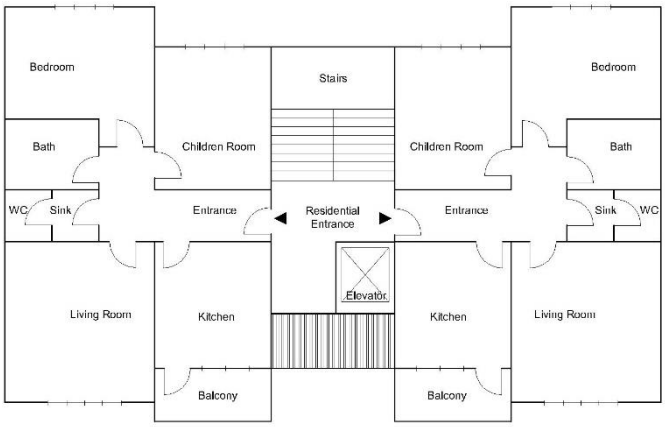


Figure 6. Konya Post-Disaster Housing Typical Floor Plan

Konya is located in a temperate–dry climate zone, characterized by high temperatures in summer, cold conditions in winter, and significant diurnal temperature variations. In such a climate, compact massing and appropriate solar orientation are of critical importance.

The Konya housing plan offers a linear and compact configuration, which is favorable in terms of energy efficiency. However, the presence of window openings solely on the front and rear facades, resulting in single-sided daylighting for all interior spaces, may lead to insufficient natural ventilation and daylight performance. The absence of openings on the side facades eliminates the possibility of cross ventilation, which may negatively affect indoor environmental comfort.

The floor plan of the Elazığ post-disaster housing unit is presented in Figure 7. The plan consists of two apartments symmetrically positioned around a central core. The layout is predominantly linear and compact, with no staggered or zigzag spatial arrangement.

At the center of the floor plan is a core containing the elevator, staircase, and service shafts. The entrances of both apartments open directly from this core into the entrance hall. Each

apartment includes a living room, kitchen, sitting room, bedroom, bathroom, washbasin area, WC, storage room, and entrance hall, as well as two balconies.

In terms of spatial configuration, the living room and kitchen are located on the front facade, near the entrance, together with the sitting room. The bedroom is positioned toward the rear of the plan, creating a functional separation between living and resting areas. Wet spaces are grouped adjacent to the service shafts. Additionally, small-scale storage spaces (pantries) are incorporated into the layout. The balconies are connected to the living room and bedrooms.

Window placement shows that openings exist on two facades. While the living room is served by windows on two adjacent facades, the remaining spaces receive daylight through a single window.

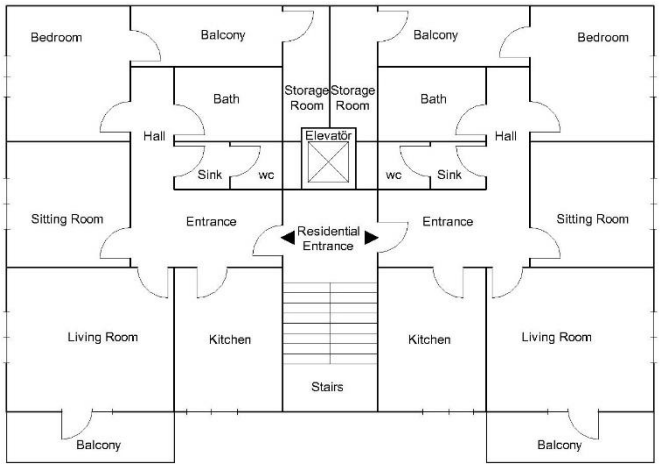


Figure 7. Elazığ Post-Disaster Housing Typical Floor Plan

Evaluation of the plan scheme indicates that the compact, linear, and symmetrical massing contributes to reduced heat loss, thereby improving thermal performance and lowering heating energy demand.

From the perspective of spatial organization, the central-core layout results in the bathroom and WC/washbasin areas lacking natural ventilation, whereas the storage room can be partially ventilated due to its direct connection to the balcony. The single-sided openings in most spaces limit cross ventilation. In a climate such as Elazığ—where night-time cooling enables natural ventilation and passive cooling—this restriction of cross ventilation may negatively affect user comfort.

3.4. Post-Disaster Housing Plans and Evaluation in the Hot-Humid Climate Region

The pilot provinces representing the hot-humid climate region are Manisa, located in the Aegean Region, and Adana, located in the Mediterranean Region. The typical floor plan of the Manisa post-disaster housing unit is presented in Figure 8. The plan consists of two apartments arranged symmetrically around a central core. Due to the projecting and recessed balcony forms, the overall plan geometry exhibits a partially indented–protruding massing. At the center of the plan is the core containing the elevator and staircase, from which the apartment entrances are accessed directly via short corridors. Each apartment includes a living room, kitchen, bedrooms, bathroom, WC, washbasin area, ventilation shaft, storage room, and two balconies.

Analysis of the spatial configuration shows that the living room is positioned on the front facade with a wide frontage and directly connected to the balcony, while the kitchen is placed closer to the entrance. The bedrooms and bathroom are located toward the rear of the plan to ensure privacy. The second room is designed to function as a sitting room, positioned to maintain a strong spatial relationship with the living room. One of the balconies is connected to the living room, while the other is associated with the bedroom. Furthermore, the storage space is accessed through the balcony adjacent to the bedroom.

Regarding window placement, it is observed that all spaces except the living room have single-sided openings; the living room, however, benefits from dual openings—one window and one door opening onto the balcony.

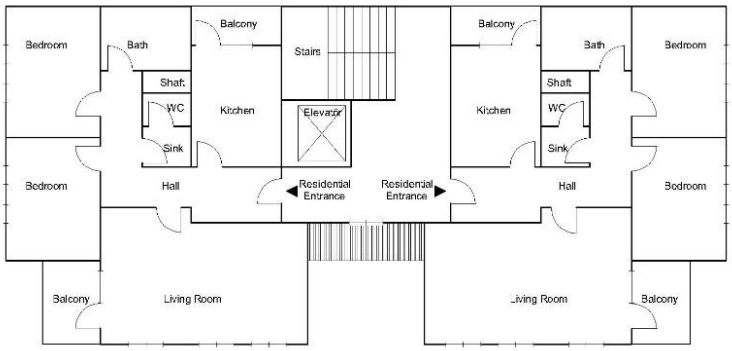


Figure 8. Manisa Post-Disaster Housing Typical Floor Plan

Manisa is characterized by hot and humid summers with limited annual temperature variation; therefore, reducing heat gain and ensuring natural ventilation are primary design goals. The recessed–projecting plan form contributes to passive cooling in summer by increasing exterior surface exposure and heat dissipation. Although this form may increase heat loss during winter, the cooling demand is more dominant in this climatic context, making the design strategy appropriate for summer conditions. The placement of openings on the front and side facades can help reduce solar heat gain when oriented effectively.

However, internal corridors and wet spaces are located away from the facade, preventing natural ventilation, and since most rooms are single-sided, cross-ventilation potential remains limited. In a city like Manisa—where night-time cooling can be used effectively—the lack of adequate ventilation strategies may negatively affect indoor comfort conditions.

The typical floor plan of the Adana post-disaster housing unit is presented in Figure 9. The plan consists of two apartments symmetrically arranged around a central core. In addition to the main core, there is a fire escape that is directly accessible from inside the apartment. Overall, the floor plan follows a compact layout; however, the recessed area created by the ground-floor entrance, which forms the outer facade of the corridor on the upper floors, partially deforms the compact form. The central core accommodates the staircase and elevator, while apartment entrances are accessed from the floor hall connected to this core. Each apartment includes a living room (combined with a dining area), kitchen, bedroom, children's room, bathroom, WC, two balconies, and a fire hall connected to the fire escape.

An analysis of the spatial configuration reveals that the entrance zone accommodates the foyer, kitchen, and living room—spaces associated with shared living and service functions. Private areas, such as the bedroom and children's room, are located farther from the entrance and

oriented toward the rear facades, ensuring functional separation between living and resting areas. Wet spaces are positioned near the central core to facilitate service shaft continuity and minimize plumbing runs.

Regarding facade organization, the kitchen on the front facade is almost entirely glazed, with the associated recessed balcony also enclosed by window surfaces. It is observed that all spaces except the children's room have single-sided window openings, while the children's room benefits from dual exposure through both a balcony door and an additional window on the adjacent facade.

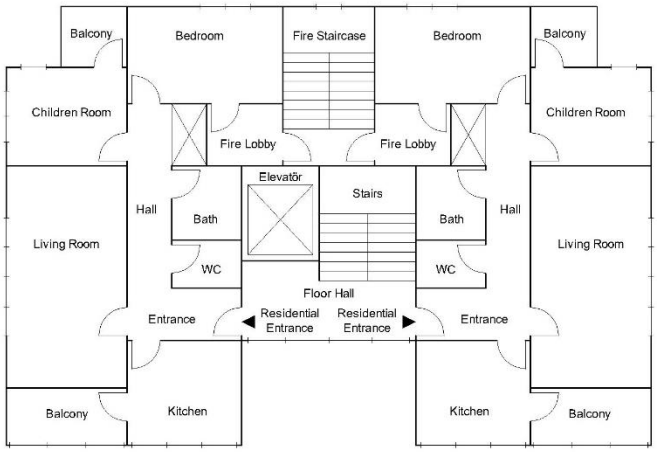


Figure 9. Adana Post-Disaster Housing Typical Floor Plan

Adana is located in the hot-humid climatic region, where minimizing solar heat gain and maximizing air circulation through cross-ventilation are key design priorities. Although the compact building form contributes to thermal gain, the relatively high window-to-wall ratio partially mitigates this effect. The recessed front facade and extensive glazing in the kitchen help reduce direct solar gain, while the overall compact massing of the building presents a disadvantage in other spaces by limiting heat dissipation. The dual-aspect openings in the children's room support cross-ventilation, whereas the single-aspect configuration of other rooms constrains airflow. Nevertheless, if internal doors are kept open, the potential for cross-ventilation throughout the dwelling can increase.

Because the bathroom, WC, and internal corridors are located away from exterior facades, these spaces lack natural lighting and ventilation. However, the presence of windows along one side of the floor hall provides daylight and ventilation to the core zone, enhancing its environmental performance.

3.5. Post-Disaster Housing Plans and Evaluation in the Hot-Dry Climate Region

The pilot province representing the hot-dry climate region is Diyarbakır, located in the Southeastern Anatolia Region of Türkiye. The typical floor plan of the Diyarbakır post-disaster housing block is illustrated in Figure 10. The plan is composed of four apartments symmetrically arranged around a central core. Unlike a linear layout, the spatial arrangement is formed by shifting the units relative to one another, generating recessed and protruding facades and interrupting the continuity of the building envelope.

The central core contains two elevators, a staircase, a refuse room, and service shafts, and provides access to each apartment through short distribution corridors. All four apartments on the floor follow the 2+1 typology, each comprising a living room, kitchen, bedroom, children's room, bathroom, separate WC, and entrance hall, along with two balconies. In the spatial configuration, the living room and kitchen are positioned closer to the entrance, while the bedroom and children's room are located farther away, ensuring a functional separation between living and resting zones. Wet spaces are organized close to the service shafts to facilitate plumbing efficiency. One balcony is connected to the kitchen, while the other is associated with the bedroom.

An examination of facade organization shows that each room contains only a single window opening, all oriented toward the same facade. Apart from the balcony attached to the bedroom, no openings are provided on the side facades, resulting in single-aspect apartments with limited daylight and ventilation potential.

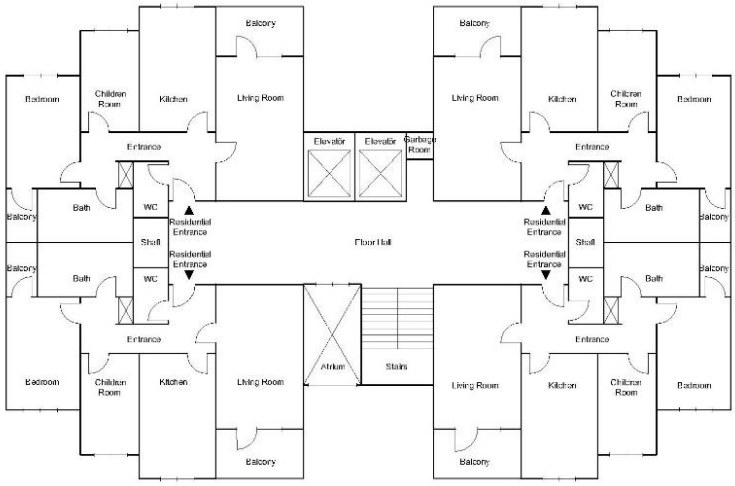


Figure 10. Diyarbakır Post-Disaster Housing Typical Floor Plan

From a massing perspective, the staggered positioning of the dwelling units is incompatible with a compact building form, leading to increased heat gain during summer and elevated heat loss in winter. This condition raises both heating and cooling loads, thereby increasing energy consumption, economic cost, and environmental impact. In terms of spatial organization, the centralized core and internal service zones—such as hallways, bathrooms, and WCs—lack direct access to exterior facades, making natural ventilation impossible. Furthermore, single-sided openings and single-orientation facade design severely restrict cross-ventilation throughout the apartments.

A climatic suitability assessment was conducted for the eight cities detailed above, and the results are summarized in Table 2 During the creation of the table and the evaluation process, housing designs in each city were analyzed according to climatic priorities. In cold climate regions, building mass and thermal retention were considered the primary design parameters, while other design criteria were of secondary importance. In contrast, in humid climates, ensuring cross-ventilation and even moisture distribution within interior spaces was evaluated as the determining criterion. The "suitability level" presented in Table 2 qualitatively classifies the performance of the designs in response to climatic conditions. Three categories were used in this classification. The term "partially suitable" indicates that the design meets certain climatic requirements but still contains some critical deficiencies. "Insufficient suitability"

denotes that the design partially responds to climatic conditions but performs poorly in key performance indicators. “Not suitable” indicates that the design conflicts with the recommended passive design principles for the respective climate zone. Based on the analyses conducted using this method, Erzurum, Elazığ, and Adana were determined to be partially suitable; Manisa and Konya were considered insufficiently suitable; and Ordu, Bursa, and Diyarbakır were found to be not suitable. Detailed explanations regarding the suitability levels presented in the table, as well as evaluations of the associated design parameters, are provided in the “3. Results and Evaluation” section of the study.

Table 2. Evaluation Findings of the Pilot Cities

	Erzurum	Ordu	Bursa	Elazığ	Konya	Manisa	Adana	Diyarbakır
Climate Zone	Cold	Temperate-Humid	Temperate-Humid	Temperate-Dry	Temperate-Dry	Hot-Humid	Hot-Humid	Hot-Dry
Plan / Mass Form	Central core, compact mass	Non-compact form	Linear compact mass	Predominantly compact mass	Predominantly compact mass	Non-compact linear form	Partially compact mass	Non-compact form
Positive Aspects	Compact form enhances heat retention	Living room cross ventilation	Compact mass and living room cross ventilation	Compact form provides energy efficiency; living room cross ventilation	Compact form provides energy efficiency	Indented form supports passive cooling	Compact form and some cross-ventilated spaces	Functional separation of spaces achieved
Negative Aspects	Recessed facades increase heat loss; single-aspect openings limit cross ventilation	Bedrooms single-aspect; limited cross ventilation and humidity control	Bedrooms single-aspect; limited cross ventilation and humidity control	Single-aspect spaces; passive cooling limited	Single-aspect openings in deep spaces limit daylight penetration and restrict cross ventilation	Single-aspect openings; cross ventilation and passive cooling limited	Compact form increases heat gain; single-aspect openings limit ventilation	Non-compact mass increases heat gain/loss; single-aspect openings limit ventilation; deep spaces reduce daylight
Climatic Suitability Level	Partially suitable	Not suitable	Insufficient suitability	Partially suitable	Insufficient suitability	Insufficient suitability	Partially suitable	Not suitable

Evaluation Note / Remarks	Focused on heat retention; cross ventilation limited	Humidity control and cross ventilation insufficient	Critical deficiency due to single-aspect openings; compact mass and living room cross ventilation present	Compact form advantageous; passive cooling limited but heating prioritized	Compact form advantageous; large spaces limited daylight	Passive cooling present; cross ventilation critically lacking	Positive and negative aspects balanced; moderately suitable	Non-compact form and facade openings inappropriate; deep spaces limit natural lighting

4. Conclusion and Recommendations

Disasters are phenomena that affect large populations and cause severe physical, social, and economic destruction within settlement systems. In a country like Türkiye, located on active fault lines and exposed to various climatic risks across its geographical regions, earthquakes in particular—along with floods, landslides, and wildfires—occur frequently and result in significant loss of life and property. One of the most urgent and fundamental needs that emerges in the aftermath of a disaster is shelter. Housing is not merely a physical necessity for protection; it also constitutes the primary space where social relations are established, daily life is sustained, and psychological recovery is supported. Therefore, ensuring the rapid, safe, and habitable provision of housing in post-disaster reconstruction processes is of vital importance. However, when post-disaster dwellings are produced rapidly without considering the climatic conditions, topography, or socio-cultural characteristics of the affected region, such housing often becomes dysfunctional over time and negatively affects users' quality of life. For this reason, the design of permanent post-disaster housing must be addressed not only through structural and engineering considerations, but through a multi-layered approach that incorporates spatial, geographical, and climatic suitability.

Post-disaster permanent housing should not only meet the physical needs of its occupants but also be compatible with the climatic conditions of its geographical location. Within the scope of this study, multi-storey 2+1 post-disaster housing typologies proposed by the Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change were evaluated based on climatic data across different geographical regions of Türkiye. The aim of this study is to evaluate the suitability of standardized housing prototypes, frequently employed in post-disaster housing production, across different climatic regions, and to determine the extent to which these prototypes adapt to regional variations. Accordingly, eight provinces representing five major climatic zones of Türkiye were selected: Erzurum (Cold Climate Zone), Diyarbakır (Hot-Dry Climate Zone), Bursa and Ordu (Temperate-Humid Climate Zone), Konya and Elazığ (Temperate-Dry Climate Zone), and Adana and Manisa (Hot-Humid Climate Zone). The spatial plans were assessed by considering the climatic and geographical characteristics of each province, and the resulting findings were analysed. In the context of climate and geography, the plan analyses demonstrate that the standardized post-disaster housing prototypes predominantly follow compact and linear planning principles; however, they remain insufficient in offering spatial organizations optimized for climatic needs.

In cold-climate cities such as Erzurum, certain design decisions intended to reduce heat loss are partially observed; however, in Diyarbakır, which is located in a hot-dry climate zone, strategies that could mitigate excessive solar heat gain have not been sufficiently implemented. In Elazığ

and Konya, situated in a temperate-dry climate, the use of compact planning can be regarded as a positive step. Nevertheless, the placement of openings on a single facade restricts cross-ventilation and daylight penetration, thereby reducing indoor environmental comfort. In hot-humid regions such as Adana and Manisa, both the orientation of openings and the overall ventilation potential remain weak, while in temperate-humid cities such as Bursa and Ordu, partial improvements are observed in terms of shading and natural air circulation to counteract high humidity levels. However, the absence of facade orientation information in the project documentation raises questions regarding whether the design decisions are grounded in climate-responsive strategies.

Based on these findings, the general conclusion is that while standardized prototypes offer a practical solution for rapid and cost-effective post-disaster housing production, they do not incorporate passive design strategies compatible with local climatic conditions, resulting in low energy efficiency. Therefore, prioritizing speed of construction and economic feasibility alone is insufficient in the production of permanent post-disaster housing. Ensuring climatic responsiveness in design is of fundamental importance. Achieving this, however, requires addressing several technical and structural issues present in current practice. First, the prototype housing plans provided by the Ministry do not explicitly indicate building orientation, despite the fact that orientation is a primary parameter for assessing solar exposure, natural ventilation, and heat gain/loss. The absence of this information makes it difficult to evaluate whether the designs are genuinely climate-adaptive. Thus, clearly defining building orientation in the drawings and associating it with design decisions is essential for ensuring sustainability. Moreover, the presentation of standardized prototypes made available on the Ministry's online platforms varies in terms of language, scaling methods, and level of detail. This variation complicates both the analyses conducted in scientific studies and the decision-making processes of practitioners in the field. Adopting a unified presentation standard for these prototypes—defining clear criteria regarding drawing conventions, expression methods, and content depth—could effectively address this issue.

In conclusion, initiating a comprehensive standardization process for prototype housing within the Ministry would enhance both comparability and regional adaptability in post-disaster housing production. Developing alternative housing plans for each region that adhere to established standards and account for local climatic and geographical conditions not only streamlines the production process but also helps establish the foundations for a sustainable housing policy that is both livable and responsive to the local climate.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. 1st Author %50, 2nd Author %25 and 3th Author %25 contributed.

References

Afet ve Acil Durum Yönetim Başkanlığı. (2024). *2024 Yılı İdare Faaliyet Raporu. (13.05.2025):* https://www.afad.gov.tr/kurumsal-raporlar

Afet ve Acil Durum Müdahale Hizmetleri Yönetmeliği. (2022, January 24). Resmi Gazette *(*No: 31760). *(13.05.2025): https://www.resmigazete.gov.tr/eskiler/2022/02/20220224-31.pdf*

Dikmen, Ç. B. (2011). Enerji etkin yapı tasarım ölçütlerinin örneklenmesi. *Politeknik Dergisi*, *14*(2), 121–134. Access Address (28.05.2025) https://dergipark.org.tr/en/pub/politeknik/issue/33057/367908

Dikmen, N. (2011). Comparative analysis of permanent post-disaster houses constructed in Çankırı and Dinar. *Disasters*, *35*(2), 404–416. Access Address (28.10.2025) https://doi.org/10.1111/J.1467-7717.2010.01220.X

Dizdar, H. (2009). *İklimsel Tasarım Parametreleri Açısından Geleneksel Ve Yeni Konutların Değerlendirilmesi: Diyarbakır Örneği (Yüksek Lisans Tezi). İstanbul Teknik Üniveristesi. İstanbul.*

Kısa Ovalı, P. (2019). Biyoklimatik Tasarim Matrisi (Türkiye). *Trakya Üniversitesi Mühendislik Bilimleri Dergisi*, *20*(2), 51–66. Access Address (03.04.2025) https://dergipark.org.tr/tr/pub/tujes/issue/52129/575617

Koca, Ö. (2006). *Sıcak kuru ve sıcak nemli iklim bölgelerinde enerji etkin yerleşme ve bina tasarım ilkelerinin belirlenmesine yönelik yaklaşım (Yüksek Lisans Tezi). İstanbul Teknik Üniveristesi. İstanbul.*

Kuz, E. N. (2021). *Afet sonrası kalıcı konut uygulamalarına yönelik kullanıcı memnuniyeti araştırması: Çankırı-Merkez-İnandık Köyü örneği (Yüksek Lisans Tezi). Konya Teknik Üniversitesi. Konya.*

Limoncu, S., & Bayülgen, C. (2005). Türkiye'de afet sonrası yaşanan barınma sorunları. *Megaron*, *3*(1). Access Address (05.04.2019) https://megaronjournal.com/jvi.aspx?un=MEGARON-97720&volume=1&issue=1

Savaşır, K. (2008). *Afet Sonrasi Uygulanacak Ve Geçiciden Kaliciya Dönüştürülecek Konutlar İçin Türkiye Koşullarina Uygun Planlarin Geliştirilmesi Ve Yapim Sistemlerinin Araştirilmasi (Doktora Tezi). Dokuz Eylül Üniversitesi. İzmir.*

T.C. Resmi Gazete. (1984). *Toplu Konut Kanunu (Kanun No: 2985, Kabul Tarihi: 17.03.1984)*.

Toplu Konut Kanunu. Kanun No: 2985. (1984, March 17). Official Gazette (No: 18344). (13.05.2025):https://www5.tbmm.gov.tr/tutanaklar/KANUNLAR_KARARLAR/kanuntbmmc067/kanuntbmmc067/kanuntbmmc06702985.pdf

Yılmaz, S. (2021). *Afet sonrası geçici barınmanın çevresel ekonomik ve sosyal sürdürülebilirliğinin değerlendirilmesi (Yüksek Lisans Tezi). Uludağ Üniversitesi. Bursa.*

URL-1: https://yapiisleri.csb.gov.tr/afet-koordinasyon-hizmetleri-i-88552 (13.05.2025)

URL-2: https://www.toki.gov.tr/kurulus-ve-tarihce (13.05.2025)

URL-3: https://www.csb.gov.tr/tarihcemiz-i-7012 (13.05.2025)

URL-4: https://www.tck.org.tr/tr/makaleler/fiziki-cografya/turkiyenin-cografi-bolgeleri (01.05.2025)

URL-5: https://www.harbiforum.net/konu/ingilizce-turkiye-haritasi-bolgeler.126822/ (25.10.2025)

URL-6: https://yapiisleri.csb.gov.tr/ornek-afet-konutlari-projeleri-i-99167 (21.04.2025)

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Analysis of the Impact of Urban Design on Social Inequalities and Mental Health: A Case Study of Isfahan, Iran

Parsa BARAHOUEİ [1]*

ORCID 1: 0009-0004-4258-833X
[1] Ph.D. Candidate, Eastern Mediterranean University, Faculty of Architecture, Department of Architecture, Famagusta- Northern Cyprus
24600779@emu.edu.tr **(**Responsible Author)

Çilen ERÇİN [2]

ORCID 2: 0000-0002-9799-1810
[2] Assoc. Prof. Dr, European University of Lefke, Faculty of Architecture and Design, Department of Architecture, Lefke- Northern Cyprus
cercin@eul.edu.tr

Abstract

This study focuses on the city of Isfahan and examines the interrelation between urban design, social inequality, and mental health by combining secondary evidence, official statistics, and public-health findings within the frameworks of social determinants of health, environmental stress, and salutogenic design. The research adopts a descriptive–correlational case-study approach; evidence was gathered using a PRISMA-based literature review from both international and Iranian databases, and analysis was completed through GIS and spatial statistical methods. Key limitations include reliance on secondary data and the absence of standardized neighborhood-level indicators. The findings indicate that the gradual erosion of the city's green heritage and human-scale structure has generated spatial inequalities in access to shelter, services, and restorative environments—approximately 55 % of the city's area falls into "deprived" or "highly deprived" categories. Public-health data reveal high levels of mental-disorder prevalence among target groups (44 % depression among university students; 28 % depression and 14 % anxiety among staff of Isfahan University of Medical Sciences). Satisfaction with urban green spaces shows a significant negative correlation with anxiety and depression levels ($\beta = -0.24$ and $\beta = -0.69$). Policy implications include integrating health equity into urban-planning frameworks, expanding community-based mental-health services, and applying green-justice criteria such as the 3–30–300 rule in underprivileged districts.

Keywords: Urban health equity, social determinants of mental health, salutogenic and restorative urban design, socio-spatial ınequality

1. Introduction

The WHO emphasizes that cities being the foremost health determinants, have a direct influence on health outcomes. Corburn & Cohen (2012) draw attention to the role of urban ecosystems like street networks, open areas, and the standard of housing. On the other hand, Ghaedrahmati et al. (2018) point at the unequal resource distribution and social segregation within cities as main factors causing health disparities and the increasing global population. This research takes a deep dive into the interconnections among urban design, social inequity, and mental health in Isfahan, Iran. The study underlines the role of environmental stressors, among which are noise, air pollution, overcrowding, and neighborhood safety, as major determinants of mental health and increasing in anxiety, depression, and other mental disorders as a result (Sarkar & Pujara, 2025). Though this connection has been widely investigated in the Global North cities, there is still a lack of understanding regarding the portrayal of these processes in non-Western urban areas. Isfahan's diverse history of urbanism and swift expansion give a good premise for research of the past and present urban development patterns. Meanwhile, one of the existing literature represents the deep spatial injustices in the access to urban facilities, and the other one the abnormal high mental health burden among the population

(Saraei, Ghafarian, & Dasta, 2020). In this context, the study aims to deliver place-specific knowledge, thus contributing to the enhancement of urban health equity. The research goal, which is an objective one, is to investigate how the features and characteristics of urban design contribute to the final stages of social inequalities and mental health in the urban area of Isfahan, Iran. In order to conduct the study properly and to achieve the above-mentioned research aim, the following questions have been formulated:

1. How could one characterize the major historical and contemporary, urban design elements and patterns that these neighborhoods or districts in Esfahan uniquely embody?

2. How are social differences especially with regard to accessibility to services, housing conditions, and income fairly spread spatially through Isfahan?

3. Could you kindly inform him/her about the prevalence of other chief mental health issues like anxiety and depression as well as the accessibility of services in Isfahan?

4. In principle, considering the outcome of any secondary data analyses, what connections could be drawn between specific urban design characteristics and the social inequality patterns and mental health results in micro-areal scales (for instance, neighborhoods and districts, and particularly in Isfahan)?

Besides involving urban planning, architecture, and landscape architecture, it also deals with the overall arrangement of space, aesthetic character, and performance of the structures, public places, transportation, and facilities (NYC DCP, 2024). The main principles of the design department are development that keeps people in mind; this means to create places for humans, the elderly, and children; the inclusion of green areas for parks and urban gardens that offer us nature in the city and habitat for wildlife, thus reducing carbon footprints, among others (Vaia, 2025; NYC DCP, 2024). Public spaces like the streets, the squares, and the parks are main areas where the civic life and social interaction take place. Their qualities are Accessibility, Safety, Inclusiveness, and Aesthetic. Urban design and architecture have a direct influence on the visual character of cities, while the public transport systems and facilities for walking, cycling, and using public transport that are equitably distributed enhance the mobility and come with the advantage of the lower carbon emissions. The provision of basic utilities such as water, energy, and communication networks forms the backbone of urban life and sustainability. According to the NYC Department of City Planning (2024), the mixed land-use neighborhoods that have good design, are walkable, and are located close to each other support people’s health through physical activity and social interaction.

Social Inequality in the Urban Fabric

Such divisions have their roots in fixed social structures that are based on class, race, gender, ethnicity, or other social categories (CUNY, 2021). In layman's terms, inequality is a disparity in a distribution while inequity is a disparity that is considered wrong, which is mostly the outcome of systemic hurdles or bias. Systemic and structural factors, such as educational levels, wealth distribution, types of occupations, and power relations, keep the differences going. Ideological supports, such as laws, policies, and cultural narratives, legitimize and reinforce the differences (CUNY, 2021). In cities, the inequalities are often seen through the lens of hidden structures that make up the social and economic landscape of the city. Such structures create neighborhoods with concentrated poverty and disadvantage. This unfair division of the city limits poor people's access to essential services and amenities while rich areas receive greater investment, thereby perpetuating their advantage. The Gini coefficient for income distribution,

the Index of Dissimilarity for residential segregation, concentration indices for health outcomes, and Geographic Information Systems (GIS) for mapping spatial patterns are among the tools used to measure urban inequalities (Ghanbari et al., 2013; Pourreza et al., 2018). With the help of these methods, one can have a glimpse of the uneven distribution of resources, opportunities, and health services among urban populations.

Urban Minds, Mental Health in the Built Environment

Mental health is the most important aspect of human well-being, which includes a variety of mental, emotional, social, and behavioral functions that vary throughout a person's life (Bitsko et al., 2022). Mental disorders are disruptions in cognition, emotion, or behavior that are so severe as to be each of the factors mentioned above, namely, psychological, biological, or developmental, being the underlying cause (CDC, 2022). Urban environments can be a double-edged sword for mental health. Urban areas have been found to have more people with mood, anxiety, and psychotic disorders than rural ones (Sarkar & Pujara, 2025). One of the major factors behind this scenario are psychosocial stressors such as social isolation, high perceived stress, and the fast pace of life along with environmental stressors like noise, air pollution, overcrowding, limited access to nature, and perceived lack of safety (WHO, 2025; CDC, 2022). Besides these, lifestyle factors like inactive lifestyle, poor diet, and sleeplessness also play an important role in determining the mental health outcomes (Sarkar & Pujara, 2025). The most common signs of mental health issues in cities include the number of people suffering from depression and anxiety, the levels of psychological stress, and the rates of suicides (Alijanvand et al., 2022; Nouhi Siahroudi et al., 2025). The main barriers preventing people from accessing and using mental health services are the high cost, distance, stigma, and lack of awareness (CDC, 2022). Urban challenges notwithstanding, the city can still be a safe haven, offering social connectivity, specialized medical care, culture, and job and education opportunities as advantages (Sarkar & Pujara, 2025). In line with the salutogenesis strategy, planning of the cities should lead the situation towards the areas rich in coherence, manageability, and meaningfulness, while also including ecological areas as support for stress reduction and psychological healing (Müller et al., 2023; Sarkar & Pujara, 2025).

Bridging the Concepts

Numerous theoretical frameworks present different views on the complicated interaction among urban planning, social inequalities, and mental health. One such framework is the Social Determinants of Health (SDOH), which stresses that health variations are determined by the environments where people are born, brought up, living, working, and eventually dying (Corburn & Cohen, 2012). Mental health inequality is largely impacted by urban design factors (like housing quality, walkability, and amenities) and social inequalities (such as income, education, and exclusion), and policies in other sectors also play a major role in shaping these determinants (Smith et al., 2024). Intersectionality theory sheds light on the interaction of overlapping social identities, like race, gender, and class, with the system of power that creates compounded disempowerment and health inequality (Iyer et al., 2022). The frameworks of environmental stress spotlights urban environmental features that are stressors—noise, pollution, overcrowding, traffic, unsafe areas and lack of green spaces—which have a greater impact on the poorer neighborhoods and thus raise the risks of anxiety, depression and psychological distress (Sarkar & Pujara, 2025). In contrast, autogenic and restorative environment frameworks examine urban design as a promoter of mental health and well-being. Salutogenesis emphasizes the creation of environments that are comprehensible, manageable,

and meaningful, while restorative design highlights the role of green spaces, safe public areas, aesthetically pleasing settings, and social interaction in alleviating stress and mental fatigue (Müller et al., 2023; Sarkar & Pujara, 2025). The THRIVES framework which stands for Towards Healthy Urbanism: Inclusive, Equitable, and Sustainable, is a new and unique approach that interweaves the above ideas and advocates the urban development of such that the whole human population would have their well-being improved while the environment and the social injustices entailed would be less (Pineo, 2020).

Various studies confirm that the way cities are designed determines, among other things, the level of stress and the availability of places for relaxation, the exposure to these factors being spatially mediated by social inequalities and the mental health of the population being influenced by this interplay. However, there are still some gaps that need to be filled: the majority of studies done so far are cross-sectional, thus cannot determine causality, and the evidence from non-Western contexts, particularly that of Isfahan, ~which is a city with a rich history and culture, is meager (Sui, Ettema & Helbich, 2022; Mahani et al., 2024). Future studies need to apply mixed methods and longitudinal designs, incorporate various data sources (qualitative experiences, socio-economic statistics, environmental metrics, and detailed mental health data), and aim at facilitating the evidence-to-action in urban policy (Pineo, 2020; Sui, Ettema & Helbich, 2022).

2. Methodology

This study takes a practical and integrative viewpoint to analyze the interaction of urban design, social inequality, and mental health in Isfahan, Iran. ~Due to the contextual complexity of these relationships, an in-depth case study method was selected to facilitate a complete understanding.~ The research uses a descriptive-correlational design, depending on secondary data synthesis instead of primary fieldwork, to create a multi-level picture of Isfahan's socio-spatial and health conditions.

The researchers employed the PRISMA method to gather secondary data from various international and Iranian databases (Scopus, Web of Science, PubMed, SID.ir, Magiran), which was a major step in assuring transparency and reliability.The search terms used were "urban design", "social inequality", "spatial justice", and "mental health". The analysis was also supported by official statistics from the Iranian Statistical Center and the Ministry of Health, as well as the review of urban master plans. The urban disparities were visualized and measured quantitatively by using Geographic Information Systems (GIS) along with the support of spatial statistical tools (e.g., Moran's I). Then these results were combined with the thematic qualitative synthesis of previous studies to interpret how the built environment influences the perceptions of inequality and well-being. The findings were examined through the theoretical perspectives of, for instance, the Social Determinants of Health, environmental stress, and salutogenic design. The major restrictions concern the secondary character of the data and the absence of uniform neighborhood-level indicators that would connect the design, socio-economic status, and mental health. The immobile nature of the official maps impedes the understanding of the residents' lived dynamics, while the differences in index definitions and time periods make it hard to compare studies. Such limitations make the results to be correlational instead of causal; however, they still reveal the existence of urban disparities in a systemic way.

3. Findings and Discussion

Isfahan comes with a rich history and a great reputation for the development of not only Iran but also world urbanism. It is a perfect place to study the relations among spatial form, social organization, and lived experience. The change of Isfahan from an early settlement to the present-day city has demonstrated how urban design has simultaneously supported and obstructed social justice and people's happiness. Isfahan situated on the central plateau of Iran and fed by the Zayandeh Roud River; its development reached the climax during the Seljuk era (11th-12th centuries CE) when it turned into the capital and gradually changed into a living urban core around Masjed-e Jame' Atiq and its adjacent bazaar. This urban structure, with its narrow streets, inward-looking courtyard houses, and harmonious public-private spatial distribution, was indicative of the sustainable and socially supportive model of Persian urbanism. The city had its peak during Shah Abbas I rule in 1598 when the Safavid planning formed the heart of a new urban structure via Naqsh-e Jahan Square, which was a representation of cultural richness, civic activities, and architectural harmony. Naqsh-e Jahan Square, containing the government (Ali Qapu Palace), religious (Sheikh Lotfollah and Imam Mosques), and commercial (Qeisarieh Bazaar) complexes, is a clear-cut synthesis of civic, spiritual, and economic functions. Official documents mark it out as a ceremonial as well as a leisure center and a mainstay of Safavid cultural and political identity. The square's orientation towards the historic bazaar points to a deliberate incorporation of the new royal order into the city's traditional urban heart.

Chaharbagh Avenue was one more major undertaking during this time, a linear boulevard that united the royal areas with the Zayandeh Roud River. This avenue was a mix of transportation, landscape, and social activities, which mirrored the Safavid concept of urban spaces that were both organized and pleasant. As shown in Figure 1, the historical urban layout of Isfahan illustrates the integration of civic, religious, and commercial functions. The demolitions of older buildings that often accompanied the urban expansion in the following centuries, were very different from the planning that characterized the Safavid period, which was based on addition and cohesion.

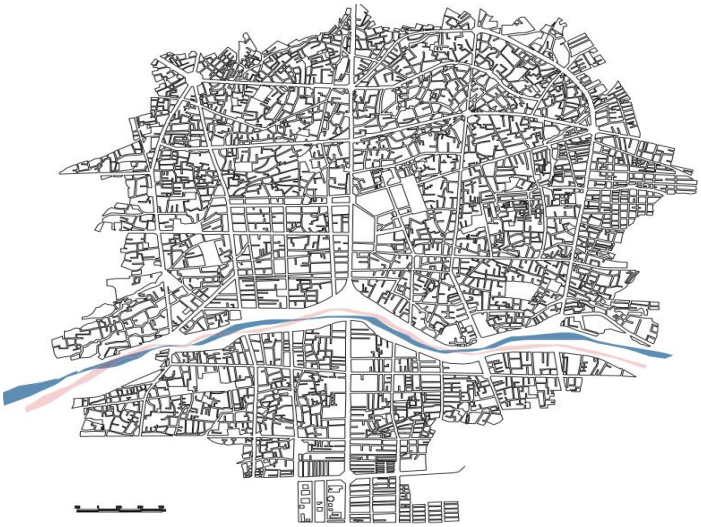


Figure 1. Urban Layout of Isfahan: A Historical City Map (Massachusetts Institute of Technology, n.d.)

Isfahan's traditional urbanism grandly displaying courtyard houses, breezy alleys, and marketplaces and squares as public spaces these concepts are usually overlooked in

contemporary design. The periodic difference in public space quality, accessibility to urban nature, walkability, and social interaction in between the old and newly developed areas is very important to understand the facts of spatial inequality. The city's planning throughout Isfahan's urban evolution highlighted the power plays of each period, determined the people's social structure and resource distribution. The city's transformation has undergone several phases Seljuk's organic centrality, Safavid's magnificence, Pahlavi's modernization, and today's urban sprawl creating a very complex and varied city in terms of both its physical and social systems. This historical flow sets up a basis to look at how the differences in density, housing types, proximity to services, and the quality of open and green spaces relate to the indicators of inequality (income, education, housing) and to the psychological issues of stress, anxiety, and depression. Thus, Isfahan's urban heritage that has been standing the test of time is a source of inspiration in making cities more sustainable and equitable through their development. Table 1, the highest residential density of 450 persons/ha, an 80/20 historic–modern fabric, and very little green space of only 5.2 m²/person are features of historic districts. The longest road network of 15.8 km and the largest green space of 8.0 m²/person are the characteristics of modern districts which still provide an environment that is less automobile-oriented. Peripheral districts have the lowest density of 150 persons/ha, the shortest road network of 9.3 km and the smallest provision of green space of only 2.5 m²/person. They also have a 90/10 modern fabric ratio. All these contrasts together point to the need for capacity and conservation challenges in the historic cores, modernization opportunities in the modern districts, and the periphery's amenity/connectivity deficits, targeted open-space provision, and transit-oriented development.

Table 1. Key Urban Design Features Across Different Districts of Isfahan (Author, 2025)

Urban Form Indicator	Historic District	Modern District		Peripheral District	
Residential Density (persons/hectare)	450	320	150	**Population**	**%**
Green Space per Capita (m²/person)	5.2	8.0	2.5	10.342.391	75.8
Road Network Length (km)	12.5	15.8	9.3	13.474.701	75.6
Historic/Modern Fabric Ratio (%)	80/20	30/70	10/90	15.702.851	75.0
Urban Form Indicator	Historic District	Modern District	Peripheral District	18.895.089	68.1

The Safavid legacy of urban planning which relied on the strategic utilization of the Zayandeh Roud River along with its “madi” channels provided Isfahan with a well-organized layout. On the other hand, urban sprawl, high-density population, and inadequate infrastructure are some of the problems the city is facing today, particularly in the areas outside and around the old city. Researches pointed out that the provision of public amenities like sports facilities is unequal across regions, which is a clear indication of injustice in this matter. Besides, the difference in

income levels makes it even harder to afford housing, thus the low-income people are being pushed into the areas where the houses are substandard and the services are poor Quantitative analyses have demonstrated very strong correlations between urban morphology, social inequality, and well-being. Research done in Isfahan in 2022 revealed that the more people were satisfied with the urban green spaces, the less anxious ($\beta = -0.24$, $p < 0.01$) and depressed ($\beta = -0.69$) they were. This protective connection survived the COVID-19 crisis, thereby highlighting the psychological advantages of green areas that are easy to access. In the United Kingdom the Persian Cohort Study provided national-level evidence, which confirmed that the mental health issues of low-income groups are more pronounced (concentration index = –0.012) and that gender and age are the major factors influencing this situation. In Isfahan, mental health problems are still a major issue, and the rate of depression among students has reached 44%. Furthermore, a study conducted in 2017 showed that around 60% of adults had experienced mental distress. The conditions of depression–stress (16.5%) and depression–anxiety (12%) are examples of how the vulnerabilities overlap. Suicide trends are one of the indicators of the mental health crisis: the ages 15-29 recorded the highest rates, and the methods of hanging and self-immolation were the most common respectively for men and women The distribution of suicide methods by gender is summarized (See Figure 2).

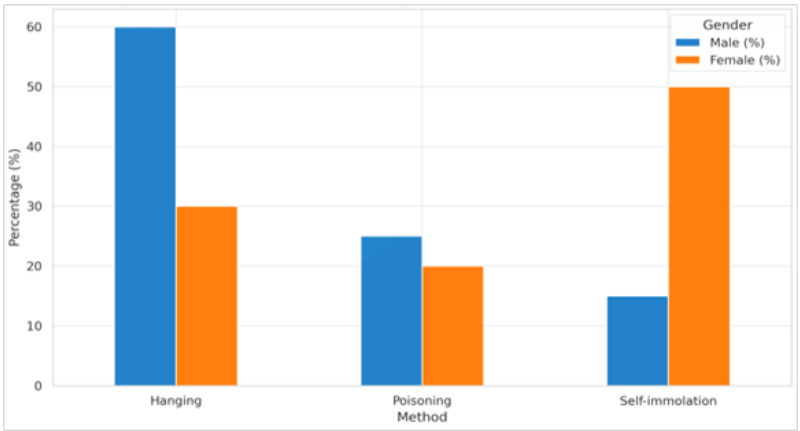


Figure 2. Common Suicide Methods by Gender in Isfahan Province (2013–2015) (Author, 2025)

According to national records, the period from 2010 to 2021 saw an average suicide rate of 8.14 per 100,000 people in Iran, where around 131 attempts occurred per 100,000. About 76% of the respondents stated the need for mental health assistance, but only 50% of them tried to consult a professional, mainly because of financial issues, lack of access to services, mistrust, and social stigma (Mohammadi et al., 2008). Urban planning factors in Isfahan only make matters worse. Areas with little greenery and no facilities for leisure, poor housing, and the residents' feelings of being polluted and slow public transport are the main causes of mental suffering, especially in low-income neighborhoods (Sui et al., 2022; Saraei et al., 2020; Asgari & Gholi Zadeh, 2020). Major barriers to mental health service utilization are illustrated, As shown in Figure 3, cost of services is the most frequently reported barrier, followed by access/distance and stigma (See Figure 3).

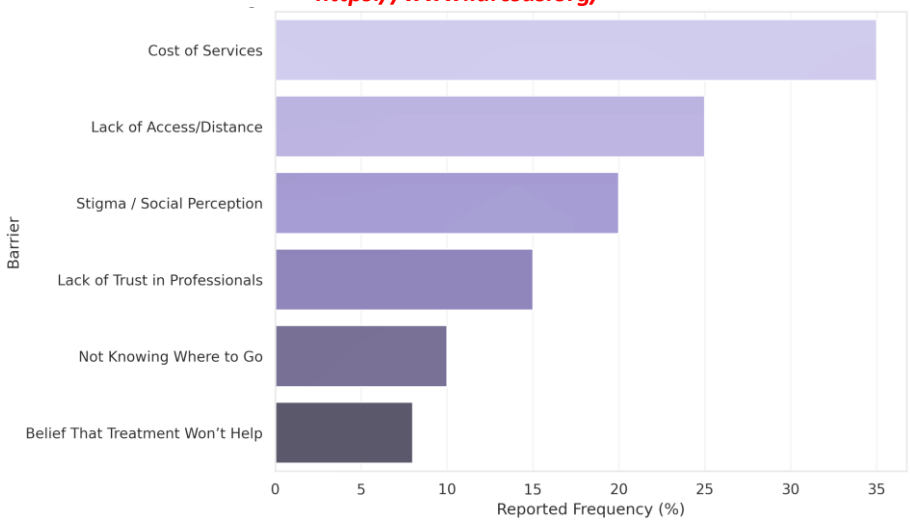


Figure 3. Barriers to Mental Health Service Utilization in Isfahan (Author, 2025)

The socio-economic inequalities which are geographically located within Isfahan's urban fabric, have a great impact on mental health disparities (Mahani et al., 2024). Urban design that promotes equity, such as easy access to parks, increased housing quality, and mental health services that cater to all, can alleviate these disparities and enhance the wellbeing of the whole community (Sarkar & Pujara, 2025; Asgari & Gholi Zadeh, 2020). There is a need for further detailed, neighborhood-level studies utilizing GIS tools to identify the complex spatial patterns of inequality and the effects on public health (Martens, 2017). In Figure 4, the highest prevalence is observed among IUMS students (≈45%), followed by IUMS employees (≈28–29%) and secondary school students (≈21–22%). Lower levels are seen in general adults with depression + stress (≈15–16%) and general adults with depression + anxiety (≈10–11%).

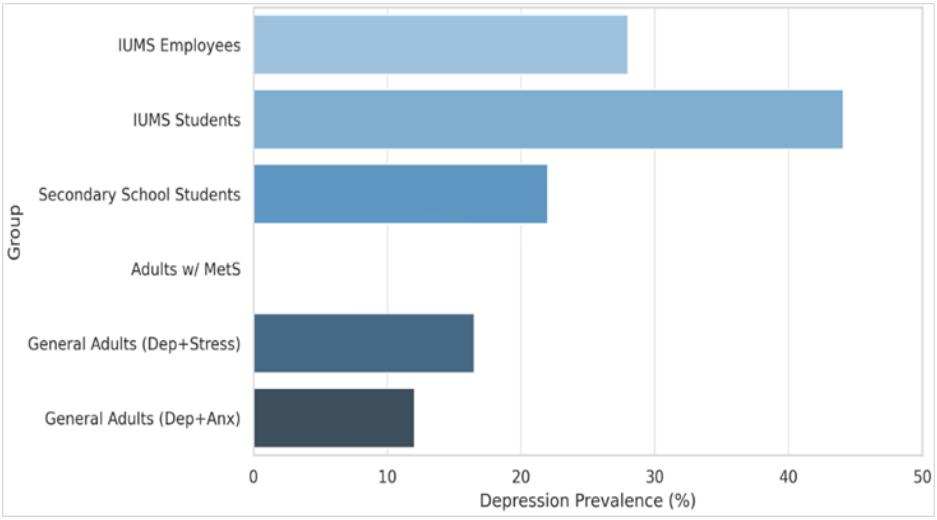


Figure 4. Depression Prevalence Among Different Population Groups in Isfahan (Author, 2025)

The HADS (Hospital Anxiety and Depression Scale) showed a 28% depression rate among the IUMS staff (Najafi, Rezaei, & Hashemi, 2022). Students at university had a 44.1% prevalence

based on the BDI (Ahmadi & Rezai, 2024), while high school students came up with a figure of 22% through the use of the CDI (Bazargan & Dehghani, 2023). Furthermore, the adult population with metabolic syndrome exhibited depression and anxiety levels that were higher than the ones recorded for the non-metabolic group (Shahrestanaki et al., 2012). The anxiety rate that was among the IUMS personnel was about 14% (Najafi, Rezaei, & Hashemi, 2022).Suicide, which is the most drastic expression of mental health issues, has raised a worrying issue in Isfahan. In the years 2013–2015, the most common methods of suicide were hanging, poisoning, and self-immolation, with men opting for hanging and women for self-immolation; it was mainly 15–29-year-olds who made up the majority of cases (Sharifi et al., 2024). Some places like Najafabad have been singled out for having particularly high mortality rates (Sharifi et al., 2023). The accessibility of mental health care is still very limited in some regions. Even though a large portion of the population, 76%, indicated that they required professional help for their mental health problems, the demand was not met as only 50% of the individuals opted for the treatment; similarly, among parents with mental disordered children, 81.3% were ready to seek help but only 55.4% opted for it (Mohammadi, Naghavi, & Zarafshan, 2008). The main obstacles consist of various issues related to logistics (high cost, distanced location, long waiting time, lack of information), people's perception of the situation (e.g. stigma, distrust of the professionals, doubts about the effectiveness of the treatment), and the unavailability of professionals in psychiatry and the high prices of mental health services (Mohammadi et al., 2008; Hosseini et al., 2023; Shakeri et al., 2022). All in all, these data suggest that there is a huge unmet demand for mental health services in Isfahan, including depressive disorders, anxiety, stress, and suicides, with cost, accessibility, and stigma comprising the main barriers. This underscores a critical gap between population needs and available mental health services (Alijanvand et al., 2022; Mohammadi, Naghavi, & Zarafshan, 2008). In the Table 2 Prevalence estimates are derived from different screening instruments (HADS, BDI, CDI) applied to distinct sub-populations (employees, university students, adolescents), and are therefore not directly comparable across rows (Afshar et al., n.d.; Karimi et al., 2021). Provincial suicide data refer to 2013–2015, whereas national suicide/attempt rates are aggregated for 2010–2021; temporal comparisons should be interpreted cautiously (Brief Lands, n.d.; Ahmadi et al., 2023). Barriers to care and service utilization figures are based on Iranian and Isfahan samples and document persistent cost, access, stigma, and trust constraints within the mental healthcare pathway (Mohammadi, Naghavi, & Zarafshan, 2008).

Table 2. Health Outcome Improvements by Building Type (Author, 2025)

Indicator	Finding / Data Point (Prevalence % or Rate)	Population Group / Context	Location	Source(s)
Depression Prevalence	28% (HADS)	IUMS Employees	Isfahan Province	(Afshar et al., n.d.)
	44.1% (BDI)	IUMS Students	Isfahan	("Prevalence of Depression in Iranian College Students," n.d.)
	22% (CDI)	Secondary School Students	Isfahan	(Karimi et al., 2021)
	Higher mean score in	Adults with/without	Isfahan	(Hosseini et al., 2012)

	adults with Metabolic Syndrome (HADS)	MetS		
	Pair-comorbidity with Stress: 16.5% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
	Pair-comorbidity with Anxiety: 12.04% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
Anxiety Prevalence	14% (HADS)	IUMS Employees	Isfahan Province	(Afshar et al., n.d.)
	Higher mean score in adults with Metabolic Syndrome (HADS)	Adults with/without MetS	Isfahan	(Hosseini et al., 2012)
	Pair-comorbidity with Stress: 10.23% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
	Pair-comorbidity with Depression: 12.04% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
Stress Prevalence	Pair-comorbidity with Depression: 16.5% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
	Pair-comorbidity with Anxiety: 10.23% (HADS)	General Adults	Isfahan Province	(Alijanvand et al., 2022)
Completed Suicide Rate	Methods: Hanging (esp. males), Burning (esp. females), Poisoning. Age: Peak 15-29 yrs.	General Population (2013-2015)	Isfahan Province	(Brief Lands, n.d.)
	Iran overall: 8.14 per 100k (9.1 M, 5.0 F)	National (2010-2021)	Iran	(Ahmadi et al., 2023)
Suicide Attempt Rate	Iran overall: 131 per 100k (128 M, 152 F)	National (2010-2021)	Iran	(Ahmadi et al., 2023)
Barriers to MH Service Use	Cost, inconvenient access, stigma, lack of trust are major barriers.	General Population / Patients (incl. Isfahan sample)	Iran / Isfahan	(Mohammadi, Naghavi, & Zarafshan, 2008)
MH Service Utilization	Low utilization despite need (e.g., only 50% of those wanting help sought it; 15.6% ever saw	General Population / Specific samples	Iran / Isfahan	(Mohammadi, Naghavi, & Zarafshan, 2008)

	psychologist/psychiatrist in another study).			
Mental Health Burden (DALYs)	Significant & increasing burden nationally from mental disorders (Depression, Anxiety highest).	National (1990-2019)	Iran	(National and subnational burden of mental disorders in Iran (1990–2019), 2020)
MH Professionals per capital	Data specifically for Isfahan not found in reviewed sources.	-	Isfahan	-

Sharifi et al. (2023) mention that some areas with higher localized suicide death rates in the Isfahan province, like Najafabad, have been reported. Overall, Ilam, Hamadan, and Kermanshah have the highest suicide rates, yet the problem continues to be serious all over the country (Sharifi et al., 2023). Access to mental health services is restricted. A national study indicated that 76% of the participants considered themselves in need of psychological support, but only 50% actually took the step to contact the help (Mohammadi, Naghavi, & Zarafshan, 2008). The same gap was observed among parents of children with mental health disorders—over 81% were ready to seek assistance, while just about 55% did. Finance, distance, time for processing, and lack of information about services were mentioned as the major barriers. Participants pointed out among other reasons that there was low trust in professionals, there was stigma, and there were doubts about the efficacy of treatment (Mohammadi, Naghavi, & Zarafshan, 2008). There were also structural difficulties, such as services not being affordable, side effects of medication, and stigma, which were mentioned in the context of qualitative research that was conducted among patients suffering from bipolar disorder in Isfahan (Hosseini et al., 2023). There is limited information available concerning the number of mental health professionals per capita in Isfahan (Shakeri et al., 2022). Philanthropy density was taken into account, though, in other provinces like Lorestan, while similar information for Isfahan was not accessible (Shakeri et al., 2022). National DALYs data reveal a huge increase in the mental disorder burden, particularly depression, anxiety, schizophrenia, and bipolar disorders, from 1990 to 2019 (Tehrani-Banihashemi et al., 2022). Also, one of the main reasons for this is the low mental health literacy (MHL) which is shown by the fact that the correlation of higher MHL with better life outcomes is strong (Sheikhi et al., 2022). However, merely 15.6% of the study participants ever went to see a mental health professional. Likewise, only a third of medical interns at Tehran during the pandemic resorted to psychological help (Khafri et al., 2022). Figure 5 Anxiety prevalence (%) across population subgroups. Bars display the point estimates of reported anxiety by group. The highest prevalence is observed among IUMS employees (≈14–15%), followed by general adults with comorbid anxiety–depression (≈11–12%) and general adults with anxiety plus stress (≈10–11%). Taken together, this evidence clearly indicates that there are considerable unmet mental health needs in the Isfahan area where depression, anxiety, stress, and suicide exist at high rates and are further intensified by barriers like cost, access, and stigma (Alijanvand et al., 2022; Mohammadi, Naghavi, & Zarafshan, 2008).

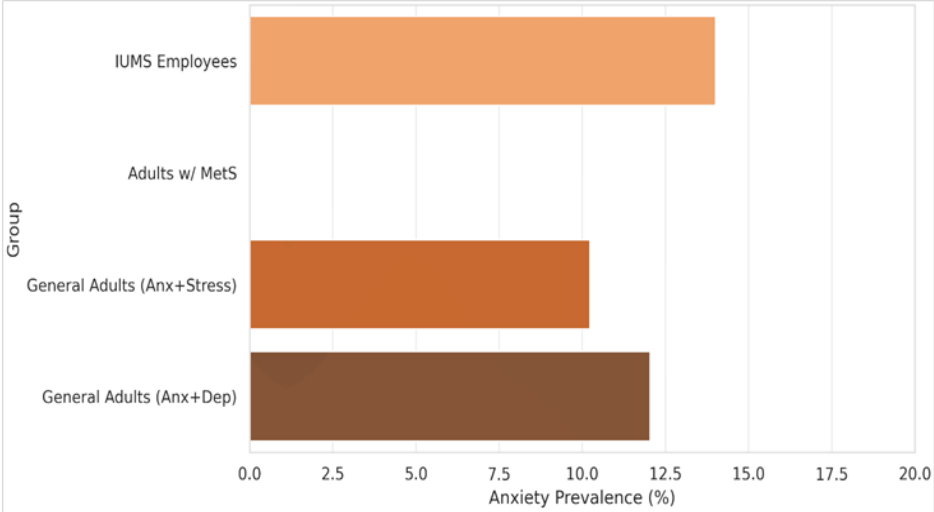


Figure 5. Anxiety Rates Across Socio-Demographic Groups in Isfahan and Comorbid Conditions (Author, 2025)

The negative impact on mental health in Isfahan is increased due to the geographical distribution of socioeconomic inequalities (Parrish et al., 2024). A significant part of the population suffers from poor mental health with high prevalence of depression, anxiety and suicide (Karimi et al., 2021), and at the same time, persistent barriers that make access difficult such as high cost, inaccessibility and stigma (Mohammadi, Naghavi, & Zarafshan, 2008) represent a critical public health issue. No public or green spaces may lead to less social interaction and thus less time for individuals to build social support, which could further raise the risk of people becoming isolated—a factor affecting mental health (Sarkar & Pujara, 2025). Isfahan's contemporary urban layout manifests inequality in resources and opportunities distribution (Martens, 2017). Such disparities might be the reason behind the mental health problems in the community and less use of mental health services (Karimi et al., 2021; Mohammadi et al., 2008). Therefore, the urban context of the city could be considered both a potential resource and a source of stress for the inhabitants (Chitsazzadeh & Farahani, 2021; Sarkar & Pujara, 2025). The mentioned conclusions are consistent with the Social Determinants of Health framework (Corburn & Cohen, 2012), the Environmental Stress Model, and the Salutogenesis concept which all point to the direction that built environments and social disadvantage affect people's well-being (Sarkar & Pujara, 2025; Müller et al., 2023). It is still so important to make mental health services more available by providing investment, financial support, primary-care integration, and running awareness campaigns (Mohammadi et al., 2008). This lack of data, which is related to the neighborhood level, connecting environmental design with socioeconomic and mental health outcomes has prevented a full causal analysis (Kiadaliri et al., 2013). One way to approach this issue would be through GIS-based spatial analyses that might reveal a connection between certain urban design features and health outcomes (Martens, 2017). Table 3, Social discrimination indicators by district in Isfahan (Ghaedrahmati et al., 2018). Values report unemployment rate (Historic 9.8%; Modern 7.5%; Peripheral 14.3%), income inequality via the Gini coefficient (0.32; 0.28; 0.41), healthcare service coverage (88%; 92%; 76%), and housing affordability rate (65%; 78%; 50%) across historic, modern, and peripheral districts, respectively. Note: higher Gini indicates greater inequality; for percentages, higher is better except for unemployment.

Table 3. Social discrimination Indicators by District (Ghaedrahmati et al. 2018)

Social Indicator	Historic District	Modern District	Peripheral District
Unemployment Rate (%)	9.8	7.5	14.3
Income Gini Coefficient	0.32	0.28	0.41
Healthcare Service Coverage (%)	88	92	76
Housing Affordability Rate (%)	65	78	50

Minor and inconclusive evidence that can be found in the current literature, however, indicate a pattern of spatial inequity that is very strong and well defined in Isfahan. In addition, the analysis of the urban fabric has uncovered differences that are present in the distribution of basic amenities and services. As an example, the public sports facilities are very unevenly distributed in favor of the central districts, whereas the urban peripheries suffer from a lack of such facilities (Saraei, Ghafarian, & Dasta, 2020). Because of the income gap that makes it difficult for people to afford housing, the poorest families are perforcedly segregated into neighborhoods with poor-quality housing and little resources. The injustice is aggravated by the socioeconomic factors. (Asgari & Gholi Zadeh, 2020) GIS research indicates that injustice in space is not evenly distributed among the municipal districts of Isfahan. The ideal method for spatially unjust situations to be represented would be one that includes both visual and quantitative characteristics. A good example is the research of Ghaedrahmati et al. (2018) showing the whole country mapped very clearly regarding social justice levels according to access to basic urban services fivefold combined indicator. The best usufruct areas, as depicted in the image, Indeed, urban resources are allocated extremely unevenly, judging by the areas that receive good and poor living conditions. The city is divided into neighbourhoods where the poor are concentrated, and in large parts of the city, especially in the outer and older, worn-out districts, people are being classified as impoverished or totally impoverished. This visual evidence makes the inequity distribution of urban resources very clear. In Figure 6, depression prevalence (%) across population subgroups. Bars indicate point estimates for each group. The highest prevalence is observed in IUMS students (≈45%), followed by IUMS employees (≈28–30%) and secondary school students (≈22–23%). Lower levels are seen in adults with metabolic syndrome (MetS) (≈14–15%), general adults with depression plus stress (≈12–13%), and general adults with depression plus anxiety (≈8–9%).

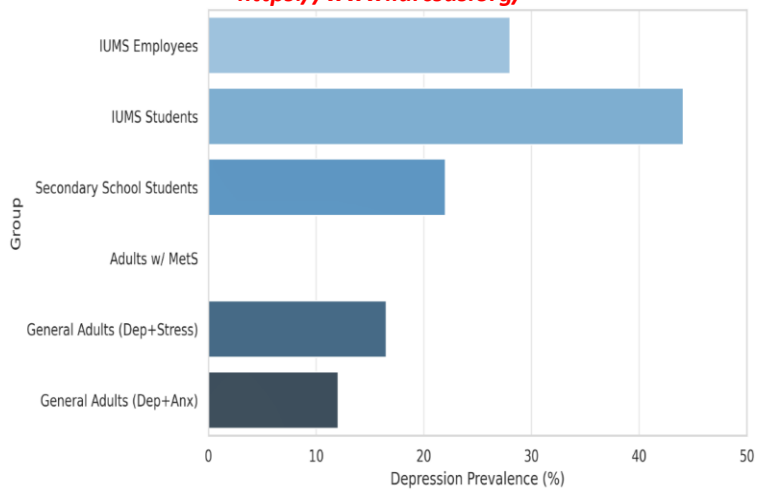


Figure 6. Equity in Space of Isfahan (Ghaedrahmati et al., 2018)

The areas where the dark color is present have a high level of enjoyment while the regions with lighter colors such as yellow and orange are the ones with less people having access to basic needs and thus the dark color is in the center of the city and the yellow and orange colors are in the outskirts. Source: Adapted from Ghaedrahmati et al. (2018). The spatial analysis is being expressed quantitatively through the summary in (Ghaedrahmati et al., 2018). Table 4 shows, area shares across four social-justice tiers are reported with defining characteristics: Enjoyment (5.3%): high access to health, education, recreation, and green space; Semi-Enjoyment (39.6%): moderate/good access with some gaps; Deprived (36.2%): limited access to multiple essential services; Fully Deprived (18.9%): critically low access to basic urban infrastructure and amenities.

Table 4. Levels of Spatial Inequality in Isfahan: The Opportunity Structure of its Municipal Districts (Ghaedrahmati et al. 2018).

Level of Social Justice	Area Percentage	Key Characteristics
Enjoyment	5.3%	High access to all services (health, education, recreation, green space).
Semi-Enjoyment	39.6%	Moderate or good access to most services, but with some deficiencies.
Deprived	36.2%	Limited access to multiple essential services.
Fully Deprived	18.9%	Critically low access to basic urban infrastructure and amenities.

When taking a closer look at the quantitative results, it comes to light that urban setting, inequality, and mental health are linked by statistically significant correlations. The less the positive views of urban green space (UGS) the more the anxiety ($\beta = -0.24$, $p < .01$) (Sarkar &

Pujara, 2025). Besides, the application of Global Moran's I in spatial analysis was a further step that confirmed the non-random distribution of social justice, as the Moran's Index of 0.515 ($z = 57.27$, $p < 0.001$) showed this with high- and low-inequality areas being clustered (Ghaedrahmati et al., 2018). The present-day urban environment divides people regarding access to services, sports facilities, and housing prices (Martens, 2017; Saraei et al., 2020; Asgari & Gholi Zadeh, 2020). Isfahan mental health studies have revealed high rates of gloom and anxiety (Alijanvand et al., 2022) among people who also face the barriers to care like cost, logistics, and stigma (Mohammadi et al., 2008). The scarcity of recreational areas and their unequal distribution signal a lost opportunity for the enhancement of well-being and equality (Müller et al., 2023). The case in Isfahan reveals that disparity in the availability of services, infrastructure, and health impacts are signs that health equity need be a fundamental part of urban planning. Besides, development projects and zoning laws should always be reviewed for their impact on social inequity and mental health. Policies that favor human-scale design, connectivity, mixed land use, and public amenities distribution among areas most in need will be the ones to make it certain that all communities draw benefits from urban growth (Higgins et al., 2020; New York City Department of City Planning, 2024).

The authors suggest that the access to greenery and public spaces should be given priority in the neighborhoods that are in most need in order to lower the risk for mental health (Sarkar & Pujara, 2025). The money must be spent on parks and plazas and areas for recreation that are either within walking distance or very close to public transit, thus making sure that the urban amenities are distributed equitably. Mental health care access equity can be achieved through the increase of community-based services, the incorporation of care into primary health systems, the reduction of fees, and the organization of stigma-reducing awareness campaigns (Mohammadi et al., 2008). Well-positioned services and interdisciplinary teams across urban planning, housing, transport, public health, and social services are crucial, with the help of the participatory planning process that involves local people (Chitsazzadeh & Farahani, 2021; Inclusive aspects of urban design, 2017). Isfahan does not consist of reliable datasets at neighborhood level which are already combined urban design, socioeconomic indicators, and mental health outcomes, and data at provincial level hides intra-city variability (Kiadaliri et al., 2013). Differences in survey methods and timelines continue to pose problems to comparisons and synthesis (Kiadaliri et al., 2013). GIS-based spatial analyses can link outside form (green place, street connectivity, building typologies) with inequality and health outcomes (Martens, 2017). Lastly, the analysis of the past infrastructure, for example, the mâdi water-distribution system, could unearth not only the cultural and practical aspects of social cohesion and well-being but also the needs of the people in that area (Chitsazzadeh & Farahani, 2021). Table 5 shows, health care and mental health as stakeholders in the relationship between common mental disorders and sources of health data (Author, 2025). Values report anxiety prevalence (Historic 22.4%; Modern 18.6%; Peripheral 29.1%),depression prevalence (14.7%; 12.0%; 21.5%), and suicide rate (per 100,000 population: 6.2; 4.5; 8.7). Main access barriers are qualitative summaries by district: Historic cost, stigma; Modern accessibility, cost; Peripheral cost, distance.

Table 5. Health care, and mental health sit as stakeholders of the operations of the Relationship of Common Mental Disorders and Sources of Health Data (Author, 2025).

Variable	Historic District	Modern District	Peripheral District
Anxiety Prevalence (%)	22.4	18.6	29.1
Depression Prevalence (%)	14.7	12.0	21.5
Suicide Rate (per 100,000 population)	6.2	4.5	8.7
Main Access Barriers	Cost, Stigma	Accessibility, Cost	Cost, Distance

4. Conclusion and Recommendations

The sketched out scenario portrays the said researchers opposing each other and working with different pieces of evidence to conclude that in Isfahan the urban amenities and Society opportunities have a spatial structure rather than a random placement which eventually generates separate zones of both risk and advantage. By trying to connect one of the geographical patterns of Society injustice (Ghaedrahmati et al., 2018) with a major mental health crisis on the population (Alijanvand et al., 2022), this research identifies the built environment as an important factor that plays a role in the health disparities. The study confirms that innocent urban design depicts various environmental and social stressors that are unequally distributed among the sensitive communities and the systemic barriers that limit their access to the services (Mohammadi, Naghavi, & Zarafshan, 2008). The main scholarly contribution of this research is the transformation of already recognized models for urban health to the specific, complex historical situation of a huge non-Western metropolis that offers an unavoidable location-based empirical basis for further investigations and ultimately informed policy. The instance of Isfahan strongly supports the view that the creation of genuinely healthy and sustainable urban environments in the future requires a change in the way urban planning is done retaining the concern for aesthetics and functional efficiencies but at the same time giving priority to social equity and mental health as the core of the planners' agenda. Based on the findings, the following policy actions are recommended for municipal authorities and Society health officials in Isfahan: Spatially goal Health Investments: Make use of GIS data pertaining to social equity for directing the distribution of resources. Set up (for instance, in areas 7, 8, 11, and 12) new inexpensive community mental health clinics in underprivileged regions and alongside public facilities like libraries or community centers in order to facilitate access and eliminate stigma (Ghaedrahmati et al., 2018).

1. Promulgate Quantitative Green place Equity Standards: The deficiency of restorative environments should be tackled via the adoption of urban green space standards that are quantifiable and citywide. The criteria of "3-30-300" may be taken as a guideline where one can put it this way: at least three trees should be visible from the house, the neighborhood should have a 30% tree cover, and the residence should not be more than 300 meters away from a good park. It is these outer and disadvantaged districts that must receive the first attention.

2. Health Equity Impact Assessments (HEIA) should be mandated: All major urban submitted for approval need to go through a formal evaluation process assessing the negative or positive

impacts on health equity, access to services and quality of environment. Such assessments are to be done by the developers at the make stage so that the new buildings or enhancement will not increase the existing inequalities but will actually decrease them.

3. Foster Inter-Sectoral Collaboration: Create a formal task force that will include representatives from urban municipal planning, regional health ministry, and academic institutions. The taskforce will synchronize data exchanging, joint planning, and monitoring of health equity objectives thus clearing the way for breaking down institutional barriers and advancing urban health governance through efficiency.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. No financial support, sponsorship, or external funding was received for the preparation of this article. All authors contributed equally to the conception, analysis, and writing of the manuscript and approved the final version. AI-assisted tools (Ask PDF for document structuring and QuillBot for limited paraphrasing) were used solely to enhance clarity and linguistic quality; these tools were not credited as authors and had no role in the study design, analysis, interpretation, or conclusions. The authors retain full responsibility for the scientific accuracy and originality of the work and for compliance with ethical principles. No plagiarism or rights infringement occurred, and all sources have been properly cited in accordance with academic integrity and publication ethics.

References

Ahmadi, M., & Rezai, N. (2024). Prevalence of depression in Iranian college students: A systematic review and meta-analysis. *International Journal of Psychology and Behavioral Sciences*. Retrieved from https://brieflands.com/articles/ijpbs-101524

Alijanvand, M. H., Feizi, A., Afshar, H., Roohafza, H., Keshteli, A. H., & Adibi, P. (2022). Depression, anxiety and stress, comorbidity evaluation among a large sample of general adults: results from SEPAHAN study. *Acta Scientiarum. Health Sciences, 44*(1), e59224. https://doi.org/10.4025/actascihealthsci.v44i1.59224

An Analysis of Disparities in Access to Health Care in Iran: Evidence from Lorestan Province, accessed May 1, 2025, https://www.researchgate.net/publication/265175616_An_Analysis_of_Disparities_in_Access_to_Health_Care_in_Iran_Evidence_from_Lorestan_Province

Asgari, M., & Gholi Zadeh, A. A. (2020). Impact of income inequality on low-income housing affordability in selected metropolises of Iran. *The Journal of Economic Policy, 12*(23), 33–63. https://doi.org/10.22034/epj.2020.10644.1854

Assessment the Trend of Inequality in the Distribution of Intensive Care Beds in Iran: Using GINI Index - ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/267754866_Assessment_the_Trend_of_Inequality_in_the_Distribution_of_Intensive_Care_Beds_in_Iran_Using_GINI_Index

Assessing the inequality of health distribution among the provinces of Iran during the Fifth Development Plan (2011-2015), accessed May 1, 2025, https://jhr.ssu.ac.ir/browse.php?a_id=750&sid=1&slc_lang=en&html=1

Assessing the inequality of health distribution among the provinces of Iran during the Fifth Development Plan (2011-2015) - KnE Publishing, accessed May 1, 2025, https://publish.kne-publishing.com/index.php/JCHR/article/download/11643/11403/

Centers for Disease Control and Prevention. (2022). *Mental health surveillance among*

Children - United States, 2013–2019. *MMWR, 71*(Suppl-2), 1–42. https://www.cdc.gov/mmwr/volumes/71/su/su7102a1.htm

Chitsazzadeh, E., & Farahani, P. (2021). Paradisiacal streams: Water the historic urban landscape of Isfahan. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 14*(3), 1–20. https://doi.org/10.1080/17549175.2021.1880353

Clinical Study *Psychological Status and Quality of Life in relation to the Metabolic Syndrome: Isfahan Cohort Study* - Semantic Scholar, accessed May 1, 2025, https://pdfs.semanticscholar.org/1813/46037cbbd14fdfa985797471253187840bb9.pdf

Corburn, J., & Cohen, A. K. (2012). Why we need urban health equity indicators: Integrating science, policy, and community. *PLOS Medicine, 9*(8), e1001285. https://doi.org/10.1371/journal.pmed.1001285

Correlation between the Built Environment and Sociology: A critical review of Residential Segregation and Social Housing Policy in Iran - Preprints.org, accessed May 1, 2025, https://www.preprints.org/manuscript/202404.0622/v1

Correlation between the built environment and sociology: A critical review of residential segregation and social housing policy in Iran. (n.d.). ResearchGate. Retrieved May 1, 2025, from https://www.researchgate.net/publication/388155248_Correlation_between_the_built_environment_and_sociology_A_critical_review_of_residential_segregation_and_social_housing_policy_in_Iran

Custom Writings. (2025, May 1). *Urban studies research paper: Basic recommendations on how you can cope with one*. https://www.customwritings.com/howtowrite/post/urban-studies-research-paper-guide/

Depression, anxiety and stress, comorbidity evaluation among a large sample of general adults: results from SEPAHAN study - ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/360077413_Depression_anxiety_and_stress_comorbidity_evaluation_among_a_large_sample_of_general_adults_results_from_SEPAHAN_study

Eliminating Health Disparities Call to Action in Iran, accessed May 1, 2025, https://scialert.net/fulltext/?doi=ijaef.2009.22.34

Epidemiology of Major Depressive Disorder in Iran: a Systematic Review and Meta-Analysis - PMC, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC3075476/

Epidemiology of major depressive disorder in Iran: a systematic review and meta-analysis, accessed May 1, 2025, https://www.academia.edu/25268035/Epidemiology_of_major_depressive_disorder_in_iran_a_systematic_review_and_meta_analysis

Equity in the geographical distribution of general practitioners in Iran - PMC, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC11421784/

Evaluation and Ranking of Influencing Factors in Citizen Participation in Urban Management (Case Study: Region 2 of Municipality), accessed May 1, 2025, https://jurbangeo.ut.ac.ir/article_66901_00a550fab30c05419e9d7ff52ffb388b.pdf

Explaining Socioeconomic Inequality Differences in Catastrophic Health Expenditure Between Urban and Rural Areas of Iran After H - Dove Medical Press, accessed May 1, 2025, https://www.dovepress.com/article/download/59194

Exploring the relationship between urban green infrastructure connectivity, size and multifunctionality: a systematic review - PubMed Central, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC11893650/

Firts Page-final - *International Journal of Body, Mind and Culture*, accessed May 1, 2025, https://ijbmc.org/index.php/ijbmc/article/download/66/55/130

Full article: Adaptation and psychometric properties of the Head-Toes-Knees-Shoulders task in young Iranian children - Taylor & Francis Online, accessed May 1, 2025, https://www.tandfonline.com/doi/full/10.1080/09297049.2025.2481951?src=

Ghaedrahmati, S., Khademalhoosini, A., & Tahmasebi, F. (2018). Spatial analysis of social justice in city of Isfahan, Iran. *Annals of GIS, 24*(1), 59–69. https://doi.org/10.1080/19475683.2018.1424732

Ghanbari et al. (2013). (If you keep this, ensure full citation; otherwise remove.)

Hashemi, M., Ranjbaran, M., & Sarokhani, D. (2022). The prevalence of depression, anxiety, and sleep disturbances among medical students and resident physicians in Iran: A systematic review and meta-analysis. *PLOS ONE, 17*(3), e0307117. https://doi.org/10.1371/journal.pone.0307117

Health equity in Iran: A systematic review - ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/352168143_Health_equity_in_Iran_A_systematic_review

Hosseini, S. M., Mohammadi, S., & Khosravi, M. (2023). Help-seeking strategies and treatment experiences among individuals diagnosed with bipolar spectrum disorder in Iran: A qualitative study. *Archives of Psychiatry and Psychotherapy, 25*(1), 15–27. Retrieved from https://www.researchgate.net/publication/364353354_Help-seeking_strategies_and_treatment_experiences_among_individuals_diagnosed_with_Bipolar_Spectrum_Disorder_in_Iran_A_qualitative_study

Inclusive Aspects of Urban Design: Sociability, Walkability and Overall Ambiance, accessed May 1, 2025, https://ideas.repec.org/a/wsi/cjuesx/v05y2017i01ns2345748117500014.html

Inequality in dental care expenditure in Iranian households: analysis of income quintiles and educational levels - NET, accessed May 1, 2025, https://rcastoragev2.blob.core.windows.net/ea42886b7945e7d8988c68b56f5bf98f/PMC8549140.pdf

Inequality in distribution of burn facilities in Iran - PMC, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC6946933/

Instructions for Authors | Urban Planning - Cogitatio Press, accessed May 1, 2025, https://www.cogitatiopress.com/urbanplanning/pages/view/forauthors

irep.ntu.ac.uk, accessed May 1, 2025, https://irep.ntu.ac.uk/id/eprint/30380/1/Maryam.Ahmadi-2016.pdf

Iran - GHS Index, accessed May 1, 2025, https://ghsindex.org/wp-content/uploads/2021/12/Iran.pdf

Iyer, P., Sen, S., & Rodríguez, D. A. (2022). Urban planning for health equity must employ an intersectionality framework. *Journal of the American Planning Association, 89*(2), 167–174. https://doi.org/10.1080/01944363.2022.2079550

Journal of Education and Health Promotion, accessed May 1, 2025, https://jehp.mui.ac.ir/

Karimi, A., Hosseini, S. H., Alavi, S. S., Amini-Tehrani, M., & Mehran, G. (2021). Prevalence of depression in Iranian school students: A systematic review and meta-analysis. *International Journal of Preventive Medicine, 12*, 150. https://doi.org/10.4103/ijpvm.IJPVM_697_20

Khafri, S., Hosseini, S., & Bahrami, M. (2022). Factors associated with suicidal ideation among medical residents in Tehran during the COVID-19 pandemic: A multicentric cross-sectional survey. *PLOS ONE, 17*(2), e0300394. https://doi.org/10.1371/journal.pone.0300394

Kiadaliri, A. A., Hosseinpour, R., Haghparast-Bidgoli, H., & Gerdtham, U.-G. (2013). Pure and social disparities in distribution of dentists: A cross-sectional province-based study in Iran. *International Journal of Environmental Research and Public Health, 10*(5), 1882–1894. https://doi.org/10.3390/ijerph10051882

Martens, K. (2017). *Evaluating justice in accessibility to urban opportunities: Introducing justice analysis frameworks*. Retrieved May 1, 2025, from https://www.scribd.com/document/812155005/Evaluating-justice-in-accessibility-to-urban-opportunities-Introducing-justice-analysis-frameworks

Measuring Socioeconomic Inequality Changes in Child Mortality in Iran - SID, accessed May 1, 2025, https://www.sid.ir/FileServer/JE/86320180917

Mental health in the Eastern Mediterranean Region: *Reaching the unreached*, accessed May 1, 2025, https://applications.emro.who.int/dsaf/dsa702.pdf

Mohammadpour, A., & Ghaffarianhoseini, A. (2015). Isfahan School of urban design: A morphological perspective. *Frontiers of Architectural Research, 4*(1), 67–77. https://doi.org/10.1016/j.foar.2014.12.003 Retrieved from https://www.researchgate.net/publication/272790847_Isfahan_School_of_urban_design_a_morphological_perspective

Mohammadi, M. R., Naghavi, H. R., & Zarafshan, H. (2008). Frequency of and barriers to utilization of mental health services in an Iranian population. *Iranian Journal of Psychiatry and Clinical Psychology, 14*(2), 152–158. Retrieved from

https://www.researchgate.net/publication/5294459_Frequency_of_and_barriers_to_utilization_of_mental_health_services_in_an_Iranian_population

Müller, H., Rehn-Groenendijk, J., & Wasmer, A. (2023). Small-scale urban design interventions: A framework for deploying cities as resource for mental health and mental health literacy. *Frontiers in Psychology, 14*, 1112209. https://doi.org/10.3389/fpsyg.2023.1112209

Najafi, M., Rezaei, M., & Hashemi, H. (2022). Psychological profile in a general population in Central Iran. *International Journal of Body, Mind and Culture, 9*(1), 45–55. Retrieved from https://ijbmc.org/index.php/ijbmc/article/download/59/47/119

Nasehi, H., Saberi, H., Ghaedrahmati, S., & Khademolhoosini, A. (2023). Social sustainability and urban third places: The case of the city of Isfahan in Iran. *GeoJournal, 88*, 4873–4885. https://doi.org/10.1007/s10708-023-10839-0

Nouhi Siahroudi, A., Hashemi Nazari, S. S., Namdari, M., Panahi, M. H., Mahdavi, S. A., & Khademi, A. (2025). The effect of COVID-19 on completed suicide rate in Iran: An interrupted time series study. *Frontiers in Public Health, 13*, 1387213. https://doi.org/10.3389/fpubh.2025.1387213

Parrish, J., Johnson, S. A., Lee, M., & Thompson, D. (2024). Barriers to integration of health and equity into urban design policies in Regina, Saskatchewan. *International Journal of Environmental Research and Public Health, 21*(1), Article 11630771. https://doi.org/10.3390/ijerph211011630771

Investigating the Development and Access to Healthcare Services across Iranian Provinces - ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/366526319_Investigating_the_Development_and_Access_to_Healthcare_Services_across_Iranian_Provinces

Principles of Good Urban Design for New York City 2024 — NYC.gov, accessed May 1, 2025, https://www.nyc.gov/assets/planning/download/pdf/planning-level/urban-design/principles-of-good-urban-design-nyc-022024.pdf

Psychological Status and Quality of Life in relation to the Metabolic Syndrome: *Isfahan Cohort Study* — PubMed Central, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC3363984/

Quality of life, anxiety and mindfulness during the prevalence of COVID-19: A comparison between medical and non-medical students - PMC, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC11514895/

Redemption from plight: A qualitative study on reasons behind treatment decisions among Iranian male opioid users, accessed May 1, 2025, https://d-nb.info/1218895268/34

Reference List: Articles in Periodicals - Purdue OWL, accessed May 1, 2025, https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/reference_list_articles_in_periodicals.html

Books - Purdue OWL, accessed May 1, 2025, https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/reference_list_books.html

Electronic Sources - Purdue OWL, accessed May 1, 2025, https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/reference_list_electronic_sources.html

Saraei, M. H., Ghafarian, H. R., & Dasta, F. (2020). Analysis of justice in distribution of sport services in spatial (Case study: Isfahan city). *Yazd University*. Retrieved from https://sid.ir/paper/1361119/en

Sarkar, A., & Pujara, T. (2025). Perceptions of urban environment indicators associated with mental well-being: A stakeholder investigation. *Cities & Health, 9*(2), 273–297. https://doi.org/10.1080/23748834.2025.2480480

Shafaghi, S., Tazik, M. E., & Kazemi, S. M. (2021). Measurement and spatial analysis of internal development zones in Isfahan metropolitan area 3. *International Journal of Engineering and Technology, 13*(2), 157–166. https://www.sciencepubco.com/index.php/ijet/article/download/29470/15868/60554

Shakeri, M., Farhadi, P., & Rahimi, M. (2022). An analysis of disparities in access to health care in Iran: Evidence from Lorestan Province. *Journal of Health Economics and Management, 10*(3), 45–60. Retrieved from https://pdfs.semanticscholar.org/81f7/9a0a99440e50c8ce03160e378b0347722479.pdf

Shahr-e Forudgahi Emam Khomeini. (2016). *Shahr-e forudgahi Emam Khomeini [Imam Khomeini Airport City]*. Retrieved May 1, 2025, from https://www.sid.ir/FileServer/JE/1036020161902.pdf

Sharifi, V., Hosseini, M. J., Khademi, N., & Karami, M. (2023). Suicide attempt and suicide death in Iran: A systematic review and meta-analysis study. *BMC Psychiatry, 23*, Article 100. https://doi.org/10.1186/s12888-023-04897-1 Retrieved from https://pmc.ncbi.nlm.nih.gov/articles/PMC10293692/

Sharifi, V., Hosseini, M. J., Salehi, M., & Karami, M. (2023). High prevalence of mental disorders: A population-based cross-sectional study in the city of Ilam, Iran. *Frontiers in Psychiatry, 14*, 1166692. https://doi.org/10.3389/fpsyt.2023.1166692

Sharifi, V., Hosseini, M. J., Khademi, N., & Karami, M. (2024). A forensic epidemiological investigation of the characteristics of completed suicide cases in Iran. *International Journal of Psychology and Behavioral Sciences*. Retrieved from https://brieflands.com/articles/ijpbs-8035

Sheikhi, M., Ahmadi, S., & Eslami, A. (2022). Mental health literacy and quality of life in Iran: A cross-sectional study. *Journal of Public Health Research, 11*(3), 257–265. Retrieved from https://www.researchgate.net/publication/355191410_Mental_health_literacy_and_quality_of_life_in_Iran_a_cross-sectional_study

Tehrani-Banihashemi, A., Jahanmehr, N., Pourmalek, F., & Mokdad, A. H. (2022). National and subnational burden of mental disorders in Iran (1990–2019): A systematic analysis for the Global Burden of Disease Study 2019. *BMC Psychiatry, 22*, Article 147. https://doi.org/10.1186/s12888-022-03887-3

The effects of urban expansion on spatial and socioeconomic patterns of the peri-urban areas: A case study of Isfahan city - Eldorado (TU Dortmund), accessed May 1, 2025,

https://eldorado.tu-dortmund.de/bitstream/2003/37804/1/Dissertation%20Text-orginal.pdf

Tourism Management Studies, accessed May 1, 2025, https://tms.atu.ac.ir/?lang=en

Towards healthy urbanism: inclusive, equitable and sustainable (THRIVES) – an urban design and planning framework from theory to praxis - Taylor & Francis Online, accessed May 1, 2025, https://www.tandfonline.com/doi/full/10.1080/23748834.2020.1769527

Unhealthy Neighbourhood "Syndrome": A Useful Label for Analysing and Providing Advice on Urban Design Decision-Making? - MDPI, accessed May 1, 2025, https://www.mdpi.com/2071-1050/13/11/6232

Urban Design Principles — Los Angeles City Planning, accessed May 1, 2025, https://planning.lacity.gov/odocument/3198c428-4cba-49eb-8155-c302d12b177a/UrbanDesignPrinciples.pdf

Urban Disparity Analytics Using GIS: A Systematic Review — MDPI, accessed May 1, 2025, https://www.mdpi.com/2071-1050/16/14/5956

Urban Disparity Analytics Using GIS: A Systematic Review — OUCI, accessed May 1, 2025, https://ouci.dntb.gov.ua/en/works/7BdmXj3l/

Urban Disparity Analytics Using GIS: A Systematic Review — ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/382224376_Urban_Disparity_Analytics_Using_GIS_A_Systematic_Review

Urban Inequities; Urban Rights: A Conceptual Analysis and Review of Impacts on Children, and Policies to Address Them, accessed May 1, 2025, https://pmc.ncbi.nlm.nih.gov/articles/PMC3368043/

Urban sustainability assessment at the neighborhood scale: Integrating spatial modellings and multi-criteria decision making approaches — ResearchGate, accessed May 1, 2025, https://www.researchgate.net/publication/371610340_Urban_sustainability_assessment_at_the_neighborhood_scale_Integrating_spatial_modellings_and_multi-criteria_decision_making_approaches

Vaia. (n.d.). *Urban design: Definition & principles*. Retrieved May 1, 2025, from https://www.vaia.com/en-us/explanations/architecture/architecture-theory/urban-design/

Vaughan, L., Clark, D. L. C., Sahbaz, O., & Haklay, M. (2005). Space and exclusion: Does urban morphology play a part in social deprivation? *Area, 37*(4), 402–412. https://doi.org/10.1111/j.1475-4762.2005.00651.x

World Health Organization. (2025). *Urban health*. https://www.who.int/news-room/fact-sheets/detail/urban-health

Writing a Formal Research Paper in the Social Sciences — Germanna Community College, accessed May 1, 2025, https://germanna.edu/sites/default/files/2022-03/Writing%20a%20Formal%20Research%20Paper%20in%20the%20Social%20Sciences.pdf

Yeager, R. A., Smith, L. M., Thayer, W. M., & Whitaker, K. M. (2022). Longitudinal associations between the neighborhood social, natural, and built environment and mental

health: A systematic review with meta-analyses. *Health & Place, 75*, 102768. https://doi.org/10.1016/j.healthplace.2022.102768

Yu, S., Li, X., & Zhang, J. (2015). Path analysis of relationship among personality, perceived stress, coping, social support, and psychological outcomes. *World Journal of Psychiatry, 6*(2), 248–255. https://doi.org/10.5498/wjp.v6.i2.248

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Nature-Based Open Space Approaches for Sustainable Campus Life

Emirhan AKSU[1*]

ORCID 1: 0009-0000-7349-2016
[1] Çanakkale Onsekiz Mart University, Graduate Education Institute, Department of Landscape Architecture. Çanakkale-Türkiye
emirhanaksu435@gmail.com **(**Responsible Author)

Alper SAĞLIK[2]

ORCID 2: 0000-0003-1156-1201
[2] Prof. Dr., Çanakkale Onsekiz Mart University, Faculty of Architecture and Design, Department of Landscape Architecture, Çanakkale-Türkiye
alpersaglik@gmail.com

Abstract

Today, university campuses are often perceived primarily as places dedicated to education and research activities. However, campuses also have the potential to become vibrant social, cultural, and aesthetic environments for students, academics, and visitors. This study explores the role of nature-based open space approaches in campus life. Taking the Terzioğlu Campus of Çanakkale Onsekiz Mart University as a case study, the research focuses on workshops organized with natural materials and the exhibition of the produced works in an open-air museum format. Findings indicate that nature-based workshops enhance participants' environmental awareness, provide aesthetic contributions, and strengthen the social functions of the campus. Moreover, this approach supports university-community interaction and contributes to transforming campuses into sustainable cultural hubs. The study emphasizes the importance of considering campus models integrated with nature in future planning and design processes. In conclusion, nature-based open space arrangements help redefine university campuses not only as academic centers but also as social, cultural, and aesthetic environments. By integrating sustainability, environmental awareness, and creativity, this approach offers an innovative model for contemporary campus life.

Keywords: Nature-based campus, Sustainability, Open-air museum, Campus design

1. Introduction

University campuses are multidimensional living environments that extend beyond being mere physical settings where academic education takes place. They are spaces where individuals gain social, cultural, and environmental experiences. Today, campus design is being reinterpreted through comprehensive approaches that prioritize concepts such as sustainability, ecological sensitivity, user needs, accessibility, and integration with nature. These approaches have become decisive in the spatial planning policies of higher education institutions, as they influence not only students' academic performance but also their social and psychological development processes. The positive impacts of nature-integrated campus environments on individuals reveal that university campuses should transcend their traditional role as solely educational spaces. Studies addressing the effects of the natural environment on individuals demonstrate that contact with nature has a restorative and regulating effect on human psychology. Özdemir (2010) notes that natural landscapes contribute to reducing stress, enhancing mental restoration, and strengthening the sense of place attachment. When university campuses are examined from this perspective, it becomes evident that campuses featuring expansive open spaces, natural vegetation, shade-providing trees, recreational zones, and topographical diversity create more favorable outcomes for students. Thus, adopting a nature-integrated approach in campus design not only enriches the physical environment but also generates pedagogical value that directly shapes student experience.

Nature-based practices have become increasingly significant in higher education institutions in recent years. These practices enable the use of natural materials (such as wood, stone, and plant-based elements) in production processes, facilitate direct interaction between students and their natural surroundings, and support creative thinking through hands-on experiential settings. Chawla (1999) emphasizes that active engagement with nature plays a critical role in fostering environmental responsibility. Accordingly, nature-based activities organized on campuses provide effective learning environments that support both the cognitive and emotional development of students. Open space use—an essential component of campus life—constitutes a key factor shaping students' relationship with their campus environment. Aslanboğa (2018) highlights that students' satisfaction with open spaces directly influences their overall perception of campus quality of life. Students particularly prefer shaded areas under trees, lawn surfaces, recreational arrangements, and semi-open seating units. The common characteristics of these preferred spaces include the comfort, tranquility, and opportunities for social interaction offered by natural landscape elements. Therefore, preserving the natural environment and utilizing it functionally are crucial considerations in the design and planning of campus open spaces. Supporting open spaces with social and cultural functions transforms campus life into a more dynamic and participatory structure. In this context, nature-based workshops provide opportunities for students to take part in production processes while simultaneously engaging directly with natural settings. These workshops offer significant potential for transforming natural materials into creative outputs, enabling students to make constructive interventions in their surroundings and experience a design process that is integrated with nature.

The open-air museum approach, on the other hand, stands out as a unique spatial model that enables the integrated exhibition of natural and cultural elements. Open-air museums are defined as environments that make cultural production visible within natural landscapes, directly interact with visitors, and transform space into a learning environment. Acar (2019) states that open-air museums play an important role in preserving and communicating cultural heritage. Implementing such an approach on university campuses allows student productions to become visible and strengthens the cultural identity of the campus, thereby offering an original design model. University campuses are also regarded as significant components of urban systems. In today's context—where densely populated city centers are expanding and natural areas are increasingly diminishing—campuses may serve as valuable recreational and ecological spaces for urban residents as well. Supporting campuses with nature-based practices provides positive contributions not only to the university community but also to the surrounding urban fabric. The preservation of natural spaces within campuses, the reorganization of open areas for multifunctional uses, and the integration of cultural activities contribute to establishing a sustainable campus–city relationship. In conclusion, nature-based open space approaches present a significant design framework that enhances the social, cultural, and ecological qualities of university campuses. The positive influence of nature contact on student life, the creativity stimulated through production processes involving natural materials, and the increased cultural interaction facilitated by the open-air museum model all demonstrate the need for a holistic design approach in university campuses. This study aims to reveal the existing open space potential of the campus, evaluate nature-based workshop and open-air exhibition approaches, and develop recommendations that contribute to sustainable campus life.

2. Literature Review

This section examines four main themes: open space use on university campuses, the effects of campus design on user experience, the concept of nature-based workshops, and the open-air museum approach. The literature review demonstrates that campuses are not merely educational spaces but large-scale living environments in which social, cultural, and ecological experiences are produced.

2.1. Campus Life

Campus life consists of multidimensional social and environmental interactions experienced simultaneously with the educational process by students, academics, and various user groups. University campuses serve as places not only for academic activities but also for socialization, rest, cultural participation, and creative production. For this reason, the quality of campus spaces directly affects students' academic performance, psychological well-being, and sense of spatial belonging.

The integration of natural environments into campus life creates positive effects on students' mental and emotional processes. Hartig, Kaiser, and Bowler (1997) emphasize that time spent in natural areas has a strong restorative impact on mental renewal. This finding reveals that natural landscapes serve not merely as aesthetic components but also as functional elements that support mental restoration, stress reduction, and motivation.

Today, many campuses aim to provide green spaces, recreational arrangements, and natural landscape elements that enhance students' social life. Increasing the time spent in open spaces contributes to stronger student relationships, higher levels of social interaction, and the adoption of the campus as a living environment. As a result, the quality of campus life has become as important as the quality of education itself.

Another significant feature of campus life is spatial diversity. Quiet study zones, active social areas, walking routes, rest areas, semi-open spaces, and outdoor recreational surfaces offer a multifaceted structure that accommodates the needs of different user groups. This variety helps users perceive the campus not merely as a place of obligation but as an active component of their daily routines. Therefore, the quality of open spaces is regarded as a key determinant of overall campus life quality.

2.2. Campus Uses, Campus Design, and the Campus for All Approach

Adopting a user-centered, inclusive, and accessible approach in campus design is a fundamental principle of contemporary planning. Since university campuses host users with diverse physical and social needs, their design must encompass a wide range of requirements. In this context, the "campus for all" approach prioritizes equitable access and usage rights for diverse user groups, including individuals with disabilities, children, older adults, and students from various socio-cultural backgrounds.

Korkut and Karahan (2022) emphasize that open space design principles on campuses should be reconsidered according to user needs. In this regard, accessibility, safety, wayfinding, seating areas, lighting, continuity of green texture, and pedestrian connections constitute essential components of the design process. Additionally, socially interactive campus environments help students embrace the campus as a space of daily life.

Sustainability is another critical principle in campus design. Practices such as preserving natural landscapes, using native plant species, maintaining ecological connections, and selecting

materials with a low carbon footprint support long-term spatial sustainability. These practices ensure that campuses provide a high-quality environmental infrastructure not only for current users but also for future generations.

Open space arrangements on campuses are also valuable in terms of spatial continuity and functional diversity. Shade-providing trees, permeable surfaces, natural ground textures, open lawn areas, and semi-open spaces encourage users to spend more time outdoors. Aslanboğa (2018) indicates that open spaces are significant determinants of students' campus satisfaction. Therefore, open space design must be approached as a multifaceted framework that responds to both natural and social needs.

In conclusion, contemporary campus design goes beyond spatial organization; it represents an inclusive, sustainable, socially interactive, and nature-integrated approach shaped around the needs of users.

2.3. The Concept of Nature-Based Workshops

Nature-based workshops are participatory, experience-oriented activities that involve the use of natural materials in creative processes. These workshops contribute to learning and environmental awareness by enabling individuals to engage directly with the natural environment. Widely used across disciplines such as education, art, design, and landscape architecture, this method is an effective tool for fostering sustainability awareness.

In nature-based workshops, natural materials such as wood, stone, clay, and plant-based elements are utilized in various production processes. These activities allow students to explore the physical properties of natural materials, develop skills related to material transformation, and strengthen creative thinking practices. Highlight that production processes involving natural materials enhance sustainable design awareness. Therefore, nature-based workshops hold significant educational and experiential potential in university campuses.

Another important characteristic of nature-based workshops is their contribution to community-building processes. These activities bring together students from different disciplines, foster collaboration toward common goals, and encourage active participation in production. Thus, students not only create tangible outputs but also strengthen their social interaction, communication, and teamwork skills.

Conducting workshops in outdoor environments integrates the natural landscape into the production process. This provides participants with an immersive learning experience embedded in the natural context. Topographical diversity, various types of vegetation, open lawn surfaces, and semi-natural spaces offer a rich spatial infrastructure for workshops. Since most university campuses include such areas, the applicability of nature-based workshops is considerably high.

2.4. The Concept of Open-Air Museums

Open-air museums are spatial organizations that enable the exhibition of cultural, artistic, and natural elements in open environments. These museums contribute to the preservation of cultural heritage while offering visitors a display experience integrated with the natural environment. Unlike indoor museums, open-air museums incorporate the natural texture of the landscape into the exhibition and promote a more immersive engagement between visitors and the space.

Acar (2019) emphasizes that open-air museums make cultural heritage visible, accessible, and participatory. This approach also provides a relevant model for university campuses. Exhibiting artworks produced in nature-based workshops within open spaces not only increases the visibility of student productions but also enriches the cultural identity of the campus.

Open-air museums also represent a sustainable exhibition model. Low energy consumption, the use of natural landscapes as protective mediums, and the integration of exhibition areas with open spaces constitute environmentally friendly practices. For this reason, the open-air museum model can be considered compatible with sustainable campus design.

Another important advantage of outdoor exhibition areas is their continuous interaction with campus users. Exhibits placed along main pedestrian routes, in lawn areas, or within natural clearings allow students to encounter cultural elements during their daily activities. In this way, the campus becomes not only a space of education and circulation but also a living cultural environment.

3. Materials And Methods

The materials and methods used in this research consist of two main stages designed to evaluate the applicability of nature-based open space approaches on university campuses: a literature review and field observation. These two stages were addressed in a complementary manner to obtain both theoretical and practical data.

3.1. Materials

The materials of the study include the open spaces of the university campus, its natural landscape characteristics, potential workshop areas, and possible open-air exhibition sites. Within the scope of the research, the following components of the campus were examined in detail:

- topographic structure,
- diversity of vegetation,
- pedestrian circulation networks,
- shading opportunities,
- recreational surfaces,
- natural material potential (wood, stone, plant-based elements, etc.).

In addition to these physical components, the theoretical materials of the study were obtained from academic literature related to nature-based design, campus open spaces, nature-based educational approaches, and the concept of open-air museums. Thus, a holistic material structure was established by integrating both spatial observations and scientific resources.

3.2. Method

The research method consists of two main stages: a literature review and field observation.

3.2.1. Literature review

In the first stage of the study, a comprehensive literature review was conducted. This review included national and international academic publications on nature-based workshops, open

space design principles, campus open space use, cultural display practices, and open-air museum approaches.

The literature review formed the conceptual framework of the research and served as a key reference point for interpreting the findings obtained through field observation. In this way, the theoretical foundations of nature-based campus approaches were clarified, and their connection to field data was strengthened.

3.2.2. Field observation

The second stage of the research consisted of field observation. In this stage, campus open spaces were examined on-site along routes determined by the researcher. During the field observations, the following aspects were assessed:

- user density,
- types of open space use,
- resting and socialization areas,
- potential accumulation areas for natural materials,
- possible workshop activity sites,
- open-air exhibition potential,
- landscape continuity and accessibility.

Throughout the observation process, methods such as photography, field note-taking, spatial analysis, and on-site evaluation were used. The collected data were then evaluated by establishing a relationship between the physical and natural characteristics of the campus and user behaviors.

4. FINDINGS

The findings of this research were evaluated in relation to the current characteristics of campus open space use, user behaviors, natural material potential, and open-air exhibition capacity. When the results of the literature review and field observations are considered together, it becomes evident that the campus possesses strong ecological and social potentials. The findings are presented under three main categories: open space use characteristics, natural material potential and workshop areas, and open-air exhibition potential.

4.1. Open Space Use Characteristics

Field observations indicate that open spaces on the campus are among the most frequently used areas by students. These areas are particularly preferred for resting, socializing, spending short periods of time, working outdoors, or waiting between classes. Three primary types of spaces were found to be especially prominent:

1. **Shaded Areas Beneath Trees -** A majority of students prefer shaded spaces. Tree canopies provide both protection from sunlight and a natural microclimate, ensuring comfortable outdoor use, especially during warm weather.

2. **Semi-Open and Open Seating Units** - Benches, pergolas, and semi-open seating structures located throughout the campus are among the most intensively used spaces. These areas support a wide range of activities, from individual sitting to group interactions.

3. **Large Lawn Surfaces** - Lawn areas are especially preferred in favorable weather conditions for socializing, resting, lying down, or reading. Their flexible usage potential is one of their main advantages.

These usage patterns align with findings in the literature on the positive effects of natural environments on individuals. Hartig, Kaiser, and Bowler (1997) indicate that natural settings contribute to mental restoration and psychological relief. The tendency of campus users to gravitate toward such natural spaces confirms the consistency between the observed findings and real spatial practices.

4.2. Natural Material Potential and Workshop Areas

The natural structure of the campus provides rich material resources that can be utilized in various production processes. Observations at different points of the campus identified the presence of materials suitable for nature-based workshops, including:

- wooden pieces of various sizes,
- natural stones,
- plant-based materials (dried branches, leaves, cones, etc.),
- soil textures,
- natural ground elements.

The natural availability of these materials on campus enables cost-effective and easily accessible nature-based production activities. Jones and Snow (2020) note that using natural materials in educational processes enhances sustainable design awareness and improves participants' material recognition skills. Accordingly, the campus provides favorable conditions for workshop activities to generate both pedagogical and ecological value.

Potential Workshop Areas

Field observations identified several areas suitable for nature-based workshops. These spaces share common characteristics:

- close proximity to natural textures,
- relatively quiet locations away from noise,
- wide and flexible surfaces suitable for various activities,
- opportunities for uninterrupted interaction with the natural environment.

These characteristics provide a supportive physical infrastructure for both individual and group work, making the areas suitable for creative production with natural materials.

4.3. Open-Air Exhibition Potential

One of the most notable findings of the research is the substantial potential of the campus for open-air exhibitions. Main pedestrian routes, large open clearings, terraced surfaces, and natural transition areas offer spatial opportunities for displaying student productions.

These exhibition areas provide significant aesthetic and functional advantages:

1. Visibility Along Pedestrian Routes

Exhibitions placed along heavily used pedestrian paths ensure continuous interaction between the displayed works and campus users. This allows the works to become part of the general circulation rather than remaining confined to designated exhibition zones.

2. Landscape-Integrated Display

Exhibition elements integrated with the natural landscape are perceived as extensions of the surrounding environment, contributing to the aesthetic unity of the space. Franz (2018) highlights that open-air museums enrich spatial experience by merging cultural production with public space (DOI: 10.1080/13527258.2017.1422578). Field observations support this perspective.

3. Spatial Diversity

Terraced levels, large lawn surfaces, wall edges, natural clearings, and semi-open courtyards offer various spatial typologies for exhibition. This diversity provides a wide range of display options compatible with different scales of production.

4. Enhancement of Social Interaction

Open-air exhibitions increase interaction among students, academics, and visitors, strengthening the social dynamism of the campus. They also contribute to the campus's cultural identity and enrich the learning environment.

5. Discussion and Conclusion

The findings obtained in this study reveal that nature-based open space approaches provide significant social, cultural, and spatial contributions to university campuses. The literature review and field observations conducted in line with the main aim of the research demonstrate that the natural potential of campuses is not merely an aesthetic resource but also a fundamental component that directly supports processes such as learning, socialization, production, and cultural interaction. A primary topic highlighted in the discussion is the active use of campus open spaces by students. Observations indicate that shaded areas beneath trees, lawn surfaces, and semi-open seating units are key spaces shaping campus life. The preference for these areas underscores the critical role natural landscapes play in students' everyday practices. Students' strong relationship with the natural environment underscores the need for nature-centered approaches in campus open space planning. The psychological relief, spatial comfort, and social interaction opportunities provided by natural settings contribute to the prominent role of open spaces within the culture of the university.

Another significant finding is the natural material potential present on the campus. Natural wood fragments, stones, plant materials, and other natural elements are easily accessible across many parts of the campus, increasing the feasibility of nature-based workshops. Considering the well-established benefits of using natural materials in educational and creative processes—such as enhancing creativity and increasing environmental awareness—the natural material potential of the campus stands out as an important advantage. Workshop activities enable campus users to experience their environment not merely as consumers but as active producers, thereby introducing a new dimension to learning processes. In addition to nature-based workshops, the open-air exhibition potential of the campus is another noteworthy aspect of this study. Pedestrian routes, natural clearings, terraced surfaces, and wide lawn areas offer spatial qualities suitable for exhibiting student works. The placement of open-air exhibitions within the campus not only makes student productions visible but also enriches campus culture and

enhances social interaction. Moreover, open-air exhibitions elevate the aesthetic value of the campus, providing a more engaging spatial experience for students, academics, and visitors alike.

Another issue emphasized in the discussion is the role of open space arrangements in supporting the cultural and social structure of the campus and in strengthening campus identity. Nature-based productions, exhibitions, and workshop activities conducted in outdoor areas function as vital dynamics that help transform the campus into a living environment. Such activities have been observed to increase students' sense of belonging and reinforce a culture of encounter and interaction within the campus. An additional point to consider in the conclusion is the contribution of nature-based approaches to the principle of sustainability in campus design. The preservation of natural environments, the support of on-site production processes, the multifunctional use of open spaces, and the preference for nature-compatible materials enhance the ecological sustainability of campuses. These approaches contribute to ensuring that both current and future generations experience a high-quality educational and living environment.

Overall, the study demonstrates that nature-based open space arrangements have strong potential to create user-centered, culturally enriched, and ecologically sustainable living environments on university campuses. Workshop processes involving natural materials, open-air exhibitions, and spatial arrangements integrated with natural landscapes are essential practices that improve the quality of campus life. Therefore, incorporating nature-based approaches more prominently into campus planning and design processes can be considered a significant requirement in terms of educational quality, cultural enrichment, and overall quality of life.

Thanks And Informatıon Note

This paper was developed based on insights derived from the researcher's master's thesis titled *"A Nature-Based Museum Campus Approach in the Terzioğlu Campus of Çanakkale Onsekiz Mart University."*

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Acar, H. (2019). Açık hava müzelerinin kültürel mirasın korunmasındaki yeri. *Milli Folklor, 31*(123), 47–58.

Aslanboğa, İ. (2018). Üniversite kampüs açık alanlarının öğrenci memnuniyeti üzerine etkisi. *Megaron, 13*(3), 356–369. https://doi.org/10.14744/megaron.2018.43775

Chawla, L. (1999). Life paths into effective environmental action. *The Journal of Environmental Education, 31*(1), 15–26. https://doi.org/10.1080/00958969909598628

Franz, K. (2018). Open-air museums and heritage interpretation: Creating meaningful visitor experiences. *International Journal of Heritage Studies, 24*(5), 537–552. https://doi.org/10.1080/13527258.2017.1422578

Hartig, T., Kaiser, F. G., & Bowler, P. A. (1997). Further development of a measure of perceived environmental restorativeness. *Journal of Environmental Psychology, 17*(2), 145–161. https://doi.org/10.1006/jevp.1997.0058

Korkut, A. B., & Karahan, F. (2022). Üniversite kampüslerinde açık alan tasarım ilkeleri üzerine bir değerlendirme. *Bartın Orman Fakültesi Dergisi, 24*(1), 86–95. https://doi.org/10.24011/barofd.1057943

Özdemir, A. (2010). Doğal çevrenin birey psikolojisi üzerine etkileri. *İstanbul Üniversitesi Orman Fakültesi Dergisi, 60*(1), 15–28.

Sanoff, H. (2000). *Community participation methods in design and planning*. John Wiley & Sons.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 224*(4647), 420–421. https://doi.org/10.1126/science.6143402

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Social Dimension of the Climate Crisis

Hatice Gözde ÖZKARAKAYA [1]

ORCID 1: 0000-0002-5535-6210
[1] Master's Student, Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, Isparta-Türkiye
ozkarakaya.hg@gmail.com

Murat AKTEN [2*]

ORCID 2: 0000-0003-4255-926X
[2] Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
muratakten@sdu.edu.tr (Responsible Author)

Abstract

The climate crisis has become one of the most urgent global issues of our time, not only as an environmental threat but also as a multidimensional problem affecting the whole of social life. Especially in geographies sensitive to climate change such as Turkey, the crisis directly transforms not only the ecological balance, but also the social structure, social relations and daily life practices. In this study, the social effects of the climate crisis are examined; how different socio-demographic groups were affected by the crisis, how social inequalities deepened and what adaptation and solidarity mechanisms emerged in this process are discussed. Research findings based on literature review show that the climate crisis has more devastating effects, especially on low-income groups, women, children, the elderly and individuals with disabilities. While the dependence of agriculture and livestock activities on climatic conditions in rural areas increases economic vulnerability, infrastructure deficiencies, water crisis and extreme heat in cities cause serious health and quality of life problems, especially in disadvantaged neighborhoods. In addition, it has been determined that climate change triggers migration dynamics, increases seasonal labor and raises new social adaptation problems in cities. The findings also reveal that local communities develop their own resilience mechanisms through traditional knowledge systems and solidarity networks. As a result, it is emphasized that the policies to be developed against the climate crisis should not be limited to technical solutions, but should also include social vulnerabilities and social justice dimensions. The study recommends strengthening the competencies of local governments, adopting participatory planning processes, and implementing climate justice-oriented social policies for an effective and fair fight against the climate crisis. At the same time, it opens up new areas of discussion at the theoretical and practical level for a just, inclusive and sustainable climate struggle by making visible the vulnerabilities between different socio-demographic groups. In this context, the disciplines of landscape architecture and urban planning should be repositioned not only as spatial arrangements but also as tools that support social transformation.

Keywords: Climate crisis, social impacts, climate justice, environmental inequality

1. Introductıon

One of the biggest and most urgent problems facing humanity on a global scale today is the climate crisis, the effects of which are increasing **.** Increasing fossil fuel use and anthropogenic activities in line with the rising production approach with the industrialization period have pushed the ecological limits of the world and led to climate change. This situation is defined as a new social issue full of uncertainties, threatening prosperity with both global and intergenerational consequences. The fact that the climate crisis has gained a global identity as a threat shows that it has become an undeniable fact that directly affects all humanity and the world.

When examining the conceptual framework of climate change, the expression defined in the United Nations Framework Convention on Climate Change (UNFCCC) is of central importance. According to the United Nations Framework Convention on Climate Change,

climate change; It is defined as "the change in climate that occurs as a result of human activities that directly or indirectly disrupt the composition of the global atmosphere, in addition to the natural climate variability observed over comparable time periods" (UNFCCC, art:1. 1992; iklim.csb.gov). There is a consensus in the scientific community that the climate change experienced today is largely caused by human activities rather than natural causes that are part of the cycle, such as volcanic eruptions. The increase in greenhouse gas emissions disrupts the climate system by causing global warming, and the urgency and possible irreversible consequences of this situation encourage the use of the concept of "climate crisis" (Corbett, 2021: 4; Birpınar, 2022: 19).

The main indicators of the global climate crisis include temperature increases, increase in the frequency and severity of extreme weather events (droughts, floods, storms, forest fires), melting glaciers, rising sea levels and decreasing agricultural productivity. Beyond this environmental destruction, the climate crisis closely affects economic, social and political life, causing serious problems in a wide range of areas from agriculture to food security, from diseases to migration. Especially countries in the Mediterranean Basin, such as Turkey, are among the geographies that will be most affected by drought and extreme weather events.

1.1. Social Dimension and Importance of the Climate Crisis

The importance of the climate crisis stems not only from its devastating effects on ecological balances, but also from the deep inequalities these effects create between layers of society. The consequences of climate change do not affect every region, country or social group equally; on the contrary, it deepens existing personal, social and economic inequalities (Preston et al., 2014: 2-3). In the literature, underdeveloped countries, poor segments and disadvantaged groups (elderly, children, women, migrants), which have the least impact on the occurrence of carbon emissions, are disproportionately more affected by this situation, leading to a climate inequality. For example, people living in highly fragile areas are 15 times more likely to die from floods, storms, and droughts compared to those living in low-vulnerability areas (IPCC, 2023).

These unbalanced effects of climate change; It creates the necessity of millions of people to dislose, face unemployment, face poverty and struggle with a series of problems that increase due to lack of social support. For this reason, it is vital that comprehensive solution plans to be developed for the climate crisis focus on rights-based social policy measures that establish social justice and focus on the human factor, as well as technical solutions such as reducing greenhouse gas emissions. The struggle should be built in a framework that integrates economic, social and environmental goals.

In this context, this study aims to examine the social dimension of the climate crisis in detail, going beyond the environmental and economic destruction caused by the global climate crisis. Within the scope of the study, it is aimed to address the social inequality caused by the climate crisis, the pressures on social protection systems and forced climate migration, and to offer social policy recommendations for the solution of these problems.

2. Method

The collected data were examined and interpreted by literature review method in order to determine the general trends, main debates and arguments regarding the social consequences of the climate crisis. This method has enabled the selected studies to be brought together and reorganized within the framework of certain themes (social inequality, social protection and migration) and to associate the literature with current/potential developments. Thus, from the

perspective of climate justice, it is aimed to provide a holistic assessment in the light of current debates by analyzing the multidimensional, intersectional and relational interactions of the crisis on social actors, structures and processes in depth.

3. Findings and Discussion

3.1. Causes, Indicators and Basic Social Dimensions of the Climate Crisis

The current state of the climate crisis has emerged largely as a result of anthropogenic (human-caused) activities. There is a consensus in scientific circles that today's climate change is caused by human activities rather than natural cyclical causes such as volcanic eruptions. The climate crisis itself is not only an environmental change, but also an economic, social, global, political and social phenomenon.

3.1.1. Causes of the climate crisis

The most negative intervention of humans towards the ecological balance became evident with the Industrial Revolution, and the increasing greenhouse gas emissions with this process led to the climate crisis. Climate-changing human activities can be classified in different ways.

a. Fossil Fuel Consumption

With the onset of industrialization, the use of fossil fuels such as oil, natural gas, and coal has increased and continues. This use increases the concentration of greenhouse gases such as carbon dioxide, carbon monoxide and methane in the atmosphere, creating a greenhouse effect and raising the earth's temperature. A large portion of Turkey's energy consumption consists of fossil fuels, representing 88% of the total primary energy supply as of 2017 (OECD, 2019).

b. City Activities

Urbanization and industrialization increase energy expenditure and fossil fuel consumption in the long run, increasing carbon dioxide emissions and affecting the climate. Cities are at the center of climate change-generating activities, including the buildings sector, which is responsible for 30% of global energy expenditure and 28% of carbon emissions related to energy use. Urbanization plays an important role in the increase in global average temperature observed since the 1950s by directly affecting the local climate. Furthermore, impermeable surfaces in cities (such as asphalt and concrete) have a high capacity to absorb, store, and dissipate heat, while their evaporation capacity is low, amplifying the urban heat island effect.

c. Land Use

Differentiation in land use on a global scale directly affects the climate crisis. The allocation of forest areas for agriculture or settlement purposes is among the factors affecting climate change by leading to deforestation. Forests, as carbon sink areas, function to preserve excess greenhouse gases in the atmosphere and regulate the climate; Narrowing these areas causes more carbon emissions into the atmosphere. In addition, while soil has a climate-regulating effect due to its carbon sink area, the increase in urbanization, concreting and the misuse of agricultural lands contribute to the global temperature increase by reducing the carbon sequestration rate of the soil.

d. Other Socio-economic Impacts

Human-induced causes of climate change include rapid population growth, change in consumption habits, moral decay, market economy, agricultural activities, fertilizer use and

animal husbandry activities. In particular, 18% of greenhouse gas emissions and 9% of carbon dioxide emissions in the world are expressed as carbon dioxide equivalent (Köknaroğlu and Akünal, 2010).

3.1.2. Indicators of the climate crisis

The climate crisis has gone beyond scientific warnings and has turned into concrete disasters that become noticeable in daily life.

a. Global Temperature Rise

Temperature rises documented on a global scale are one of the most obvious signs of climate change. An increase in global average surface temperatures between 2-4.5 °C is expected for the 1990-2100 period. Rising air temperatures; It leads to desertification, forest fires, decreased rainfall and drought. In Turkey, the aridification trend has been effective in the Mediterranean basin since the 1970s, and the Aegean, Mediterranean, Marmara and Southeastern Anatolia Regions have been among the most affected geographies.

b. Extreme Weather Events

Unusual weather events (floods, landslides, storms, droughts and forest fires) have been more frequent and intense in the last decade. These events, intensified by climate change, cause serious loss of life and property in cities. For example, floods, as the most common type of disaster worldwide, caused approximately $46 billion in economic damage and 4,500 deaths globally in 2019. According to IPCC reports, global warming has led to an increase in the frequency and intensity of heavy rainfall events around the world.

c. Ecological Change

Among the indicators of the climate crisis; melting of glaciers, rising sea levels, increasing the amount of carbon dioxide, seasonal changes, decrease in plant and animal populations and decrease in water resources (Demircan, 2022). Sea level rise directly affects island states and human life living in coastal areas, leading to migrations. In addition, changes in climatic conditions can cause an increase in infectious diseases by changing the distribution of vectors and disease agents (Kiraz, 2019). Agricultural production and productivity are also negatively affected by these ecological changes.

3.1.3. Main social dimensions of the climate crisis

The social repercussions of the climate crisis lead to consequences such as loss of livelihoods, increase in unemployment rates, lack of clean water and food, difficulties in accessing basic services, and the spread of poverty. Climate change is considered one of the most difficult collective issues in the history of humanity because it poses economic and social threats in the long term.

a. Social Inequality (Climate Injustice)

The effects of climate change do not affect every region, country or social group equally; deepens existing personal, environmental, social and economic inequalities. Climate injustice occurs as a result of underdeveloped countries, the poor and disadvantaged groups, which have the least share in the emergence of carbon emissions, being disproportionately affected by this process.

1. **Vulnerable Groups: Socially** and economically disadvantaged groups (including people who face discrimination based on gender, age, ethnicity, class, disability and immigration) are disproportionately adversely affected by climate change.
2. **Vulnerability and Risk: Approximately** 3.5 billion people live in areas that are highly vulnerable to climate change, and they are 15 times more likely to die from floods, droughts, and storms than those living in low-vulnerability areas (IPCC, 2023).
3. **Deepening of Inequality:** Low-income individuals, who are most affected by the problems caused by climate change, are more vulnerable to future climate catastrophe due to the increasing poverty spiral. Especially elderly and disabled individuals experience more disadvantages in coping with heat stress and disasters due to their physical condition and low income levels.

b. Social Protection

The dangers posed by climate change make disadvantaged groups quite vulnerable in terms of social support. Negative reflections of climate change; increases life cycle threats such as unemployment, illness, work accidents, disability, death and old age, and the importance of social support is emphasized in this context (ILO, 2019).

1. **Importance of Social Protection:** Social protection has key objectives aimed at reducing poverty and inequality; protecting people in the face of shocks and life changes and ensuring adequate living standards; and improving opportunities by providing employment, business, and livelihoods (Costella et al., 2021).
2. **Adaptive Social Protection: Social** protection in the context of climate change is addressed through the Adaptive Social Protection approach, which combines social protection, natural disaster risk management and climate change adjustment. This approach aims to integrate climate-related risks into social protection programs and ensure that climate-related adverse impacts are managed.
3. **Effects:** Social security measures reduce poverty and susceptibility to shocks by increasing incomes and food expenditures, encourage human development and include interventions to compensate for the losses caused by climate change.

c. Immigration

Another important social consequence of the climate crisis is related to migration. Climate change; threatens food security, reduces water resources, leads to malnutrition and famine, significantly shrinks living spaces, and renders individuals unable to sustain their basic vital activities. This situation causes people to leave their current places, causing population movements called ecological migration.

1. **Dimensions of Migration: Climate** change can be a direct cause of migration, or it can be considered as a threat multiplier by interacting with political, demographic, economic, social and environmental push factors. According to World Bank data, it has been stated that 143 million people in Sub-Saharan Africa, South Asia and Latin America may be forced to migrate internally due to climate change by 2050 (Rigaud et al., 2018). In Turkey, 275,313 people have migrated in the last 10 years due to climate and disasters (UNDP Turkey, 2019).
2. **Causes of Migration: Climate** refugee is mainly; It occurs due to factors such as the intensity of greenhouse gases, extreme climatic events, temperature fluctuations, air pollution, heavy rainfall, floods, drought, desertification, sea level rise and food crises.

3. **Legal Status Problem: The** concept of "climate refugee" used for those displaced due to climate change does not have a clear definition in the legal regulation, which creates loss of rights and uncertainty.

4. **Fragility:** The migration movement that will occur as a result of the migration movement due to the rise in sea level and the negative impact on agricultural activities, especially in coastal regions, are important reasons affecting the quantity of the population to migrate. Migration waves caused by the climate crisis cause an increase in social and economic problems and a weakening of the resilience of cities, especially in the cities of fragile countries.

3.2. Vulnerable Groups Affected by the Crisis

One of the most prominent features of the climate crisis as a social problem is that its effects are characterized by different and unequal societal outcomes. The effects of climate change are intensified according to the existing personal, environmental, social and economic inequalities of individuals and groups, and deepen these inequalities. Underdeveloped countries, poor segments and disadvantaged groups, which play the least role in the formation of carbon emissions, are disproportionately affected by this situation and face many life-threatening risks. This situation also leads to climate injustice.

Individuals who are socially, economically and geographically disadvantaged (including those who experience discrimination based on gender, age, ethnicity, class, disability and immigration) and neglected individuals are extremely adversely affected by climate change.

3.2.1. Women, children, elderly

Personal factors such as age and gender constitute the main areas of inequality affected by the climate crisis. Vulnerable groups such as the elderly and children are among the groups that will be most affected by the consequences of the climate crisis, such as disasters and extreme weather events.

a. Women

Women are exposed to significant inequalities that exist independently of the climate crisis, and this situation is deepening with climate change. Women are expected to be more affected than men. Among the reasons behind this sensitivity; gender-related social and economic duties and responsibilities, their situation in the labor market, disadvantaged positions in the fields of education and social security.

- Economic Vulnerability: Women are intensively employed, especially in sectors directly related to agroecosystem services. The decrease in jobs in agriculture may lead to unemployment and poverty for women. In addition, new green occupations such as construction, manufacturing and engineering are also observed, where women are relatively unemployed.

- Migration and Violence: Women and girls may be more vulnerable to a number of impacts due to migration due to climate change. During and after natural disasters, women and girls become more vulnerable to sexual exploitation and gender-based violence.

b. Kids

Children are more sensitive to the effects of climatic changes than adults. Their physical weaker nature and less ability to radiate heat make children more vulnerable to environmental elements such as heat, pollution or scarcity. They may also be exposed to poor living conditions resulting from job and income losses faced by their families; They may have difficulty accessing food

and water. Exposure to environmental factors in early childhood and pregnancy also causes children to be negatively affected.

c. Elderly

Elderly individuals are among the groups most affected by extreme weather events and natural disasters caused by climate change. The World Health Organization (WHO) has defined the elderly as a vulnerable group that is likely to be at risk in the event of a disaster.

- Physical and Health Issues: Physical and cognitive limitations that increase with age affect seniors' ability to act quickly in the face of disasters or emergencies. This situation causes them to face more disease and mortality rates in the event of a disaster. For example, heat waves (such as the one seen in Europe in 2003) have killed large numbers of people, the majority of whom are elderly. A significant relationship was found between temperature increase and mortality rates in Turkey.

- Social and Economic Challenges: Elderly individuals need medical and psychological support, assistance in daily activities, resources, and protective measures during and after disasters. Elderly people who live alone and have insufficient economic status are more vulnerable to heat waves. The difficulties of elderly and disabled individuals in finding a job and changing professions in the labor market may cause them to be adversely affected by the occupational transformation caused by the climate crisis and to experience severe poverty.

3.2.2. Migrants and disabled people

a. Immigrants

Forced displacement and migration status are social factors that weaken individuals' social networks and cause them to live a life that excludes them economically, socially, politically and culturally. Climate change will trigger irregular and mass migrations by creating economic and social insecurities that will endanger life in some regions or countries.

- *Disadvantaged Position*: People who have to change countries due to climate change; They are disadvantaged in terms of being accepted to another nation, gaining a political identity, language skills, finding a job and being deprived of social security systems. This situation causes them to be deprived of the opportunity to change their current conditions in the context of the climate crisis.
- *Legal Uncertainty*: The lack of a clear definition of the concept of "climate refugee" in the legal regulation, which is used for those who are displaced due to climate change, makes it difficult to determine the protection status of these people and leads to loss of rights.
- *Groups at Risk*: Refugees coming to Turkey and living in camps in Southeastern Anatolia are vulnerable groups to climate change and epidemics. An increase in cases such as tuberculosis and measles has been observed in these camps. Migrants and asylum seekers, who are considered vulnerable groups, should be followed up with a good monitoring program.

b. Engelliler

Engelli bireyler, bedensel durumları dolayısıyla iklim değişikliğinin yol açacağı felaketler ve aşırı hava koşullarından birincil olarak etkilenecek sosyal kesimlere dahildirler. Afetler ile yüzleştiklerinde, fiziksel durumları felaketten kurtulma ve bununla başa çıkma yeteneklerini olumsuz bir şekilde etkilemektedir. Engelliler, düşük gelir düzeyleri ve hareket kabiliyetlerinin sınırlı olması nedeniyle ısı stresi ve afetlerle baş etme konusunda daha fazla dezavantaj yaşamaktadır.

3.2.3. Low income groups/poor

Low-income groups and the poor are at the heart of the climate crisis's deepening of social inequalities. This segment, which has the least share in the emergence of the climate crisis, is disproportionately more affected by the process.

- *Increased Vulnerability*: Individuals with low income levels are more sensitive to the effects of climate change and more vulnerable to risks; they are also inadequate in terms of their ability to recover from and cope with the damages they have been exposed to.
- *High Risk*: Individuals living in low-income areas lack sufficient skills and resources to adapt and respond to the effects of climate change. It is stated that the poor are becoming more vulnerable to future climate crises due to the increasing poverty spiral.
- *Disaster Exposure*: Approximately 3.5 billion people living in highly vulnerable areas are 15 times more likely to die due to floods, droughts and storms in the 2010-2020 period than those living in regions with very low vulnerability.
- *Food and Shelter*: Poor individuals face difficulties in obtaining adequate drinking water and food, and are disproportionately more affected by drought, food shortages and rising food prices. In addition, low-income household groups are estimated to be disproportionately affected by climatic threats.

3.2.4. Rural communities

Communities living in rural areas and earning their living from agricultural activities are also heavily affected by the effects of the climate crisis.

- *Dependence on Agriculture*: Climate change poses a threat to agricultural production and productivity, which is dependent on factors such as soil, water, sunlight, and temperature. Countries and rural communities that develop their economies based on agriculture will be more affected by this negativity.
- *Migration and Loss of Livelihood*: The negative impact of the climate crisis on the feasibility of agriculture and animal husbandry is an important reason triggering migration movements in these communities. It can be argued that social actors such as rural households and farmers predominantly experience the form of forced mobility.
- *Farmers at Risk*: It has been stated that deaths in cases of Crimean-Congo Hemorrhagic Fever (CCHF), a fatal tick-borne infection, are mostly seen in those engaged in farming and animal husbandry. This is associated with the spread of disease vectors due to climate change. Those who make their living from farming, such as those living in coastal areas, are particularly at risk.

3.2.5. Peoples of underdeveloped countries

The biggest injustice of the climate crisis on a global scale is that underdeveloped countries (or regions located in the global south) are the hardest hit by the crisis, but historically the least responsible.

- *High Vulnerability and Low Capacity*: Societies in underdeveloped countries are both greatly affected by climate change and show serious sensitivity due to their sensitivity. These countries are less vulnerable to the devastating effects of the climate crisis.

- *Economic Impacts*: The negative health effects of climate change are expected to be most intense in low-income countries. Residents in these countries have the fewest resources to adapt to rising temperatures and extreme weather events.

- *Migration Pressure: The* biggest threat of migration movements caused by the climate crisis is on the cities of fragile countries. For example, it is estimated that by 2050, 143 million people in Sub-Saharan Africa, South Asia and Latin America could be forced into internal migration due to climate change.

These findings clearly demonstrate that policies to combat the climate crisis necessitate rights-based approaches to meet the social justice and social protection needs of these groups.

3.3. Grievances of Vulnerable Groups

The social consequences of the climate crisis negatively affect the most vulnerable segments of society in economic, social, environmental and legal terms. Existing socio-economic inequalities increase the risk and susceptibility of disadvantaged groups to climate hazards, while also reducing their ability to cope with and recover from these damages, creating a vicious cycle. People living in highly fragile areas are 15 times more likely to die from disasters such as floods, droughts and storms than those living in low-vulnerability areas.

3.3.1. Economic and social grievances

The climate crisis creates serious economic and social destruction, especially on vulnerable groups, leading to direct loss of livelihoods, unemployment and deepening poverty.

- **Loss of Livelihoods and Poverty:** Sudden and extreme weather events due to climate change cause loss of livelihoods, unemployment, poverty, and cultural losses. For example, as a result of the storms that affect the Philippines every year, 7000 people lost their lives in Storm Haiyan in 2013 and the livelihoods of 5.9 million people were adversely affected. Women, who are heavily employed, especially in sectors that are closely dependent on ecosystem services, such as agriculture, are expected to become unemployed and poor with the loss of jobs in agriculture.
- **Social Insecurity: The** negative effects of the climate crisis exacerbate traditional life cycle risks such as unemployment, disease, work accidents, disability, death and old age, and make disadvantaged groups vulnerable to social protection. This situation weakens the ability of low-income individuals and the poor to cope with the damages they suffer due to their lack of sufficient capacity and resources to withstand climatic disasters.
- **Food and Water Insecurity:** Poor individuals have difficulties in accessing sufficient water and nutrients, and they are disproportionately more affected by drought, famine and rising food costs caused by the climate crisis. Declining water resources cause food insecurity, malnutrition and famine, which leads to the migration of people who are unable to continue vital activities. Drought increases the risk of nutritional deficiencies by reducing food diversity and food consumption.
- **Exclusion from New Job Opportunities:** Disadvantaged groups such as the elderly and disabled individuals experience difficulties in the labor market as they cannot easily find jobs and change professions. It is possible for these groups to experience severe poverty by being adversely affected by the occupational transformation necessitated by climate change. In addition, it is observed that women are already excluded from newly formed "green business" branches (such as construction, manufacturing, engineering).

3.3.2. Human rights and health grievances

Climate change causes multi-layered problems that directly threaten basic human rights and public health. This situation brings with it grievances that have not only environmental but also ethical and legal dimensions.

- **Violation of Fundamental Human Rights:** Climate change poses various threats and social inequalities in terms of fundamental human rights such as the right to life, the right to a healthy environment, the right to food and the right to water. The effects of climate change jeopardize the enjoyment of these universal, inalienable and interdependent rights.

- **Health and Mortality Risk:** Events such as extreme temperatures, floods, and storms due to climate change directly negatively affect human health and can lead to loss of life.

- **Heat Wave Victims:** The elderly react faster to the effects of hot weather due to reduced fluid intake, thinned subcutaneous fat layer and chronic diseases. The heat waves in Europe in the summer of 2003 caused the death of 70,000 people, most of whom were elderly. It has been observed that the elderly who live alone and have insufficient economic status are more vulnerable to heat waves.

- **Infectious Diseases:** Changes in climatic conditions cause an increase in infectious diseases by changing the distribution of vectors (disease carriers) and disease agents. The incidence of waterborne and foodborne diseases such as cholera and rotavirus is increasing. Refugees living in camps in Southeastern Anatolia in Turkey are vulnerable to climate change and epidemics, and an increase in cases such as tuberculosis and measles has been observed in these camps.

- **Mental Health Traumas:** People who lose their homes, jobs, and relatives after climatic disasters (floods, forest fires, etc.) experience traumatic effects and face mental health problems (stress, chronic anxiety, depression, anger management problems). A direct link has been found between high temperatures and poor mental health; Women and low-income individuals in particular are the most affected by this connection.

- **Occupational Risks:** High temperatures and humidity increase the effects of toxic substances on the body; for example, it has been reported that the frequency of pesticide poisoning increases as the temperature rises in farmers. In addition, outdoor workers are at increased risk of increased biological hazards, vector-borne diseases, pollen, and mold-related allergies. Workers working under the sun are at risk of skin cancer due to exposure to UV rays.

- **Gender-Based Violence: During** and after climate change-related disasters, women and girls become more vulnerable to sexual abuse and gender-based violence. Access to critical health services and education rights are also disrupted due to migration due to the climate crisis, and problems such as early marriage of girls increase the number of child brides.

3.3.3. Legal and spatial grievances (climate refugees)

One of the most profound and complex social consequences of the climate crisis is forced displacement and the legal vacuum caused by this mobility.

a. Spatial Grievances

Climate change significantly narrows living spaces and makes people unable to continue their basic vital activities.

- **Forced Displacement:** Environmental factors such as sudden onset floods and hurricanes or long-range sea level rise, drought and land degradation force people to relocate. According to the World Bank (WB) report, without a concrete action plan, more than 216 million people in six regions will be forced to migrate due to climate change by 2050. In Turkey, 275,313 people have migrated in the last 10 years due to climate and disasters.

- **Coastal and Island Losses: Sea** level rise as a result of increasing air temperatures and melting glaciers directly affects island states and human life living in coastal areas, causing these people to leave their places permanently or indefinitely. Many regions of Southern Iraq and almost all of the Nile Delta are expressed as regions that will migrate due to sea level rise.

b. Legal Grievances (Climate Refugees)

The concept of "climate refugee", which is used for those who are displaced due to climate change, does not have a clear definition in international legal regulations. This conceptual and legal gap creates uncertainty about the status and rights of these individuals.

- **Lack of Status: The** 1951 Convention on the Determination of Refugee Status shapes the definition of refugee based on persecution-based elements such as race, religion, citizenship or political opinion, and does not contain any explanation or definition of climate events. This situation leaves the legal status problem of individuals known as climate refugees unresolved on an international scale and leads to loss of rights.
- **Lack of Legal Protection: The** United Nations Human Rights Council (2018) states that the legal system and regulations to protect the human rights of migrants due to the climate crisis are inadequate. However, the United Nations Human Rights Committee has taken a decision that can be a "gateway" for asylum claims of people whose lives are threatened by global warming and that governments cannot force people who have to migrate due to the climate crisis to be sent back.
- **Disadvantage in the New Environment:** Individuals who have to migrate are disadvantaged in terms of acceptance in the new country, acquiring a political identity, and lack of employment and social protection mechanisms. It is also stated that the uncertainty in the legal status may cause social tensions and indirectly security problems due to resource shortages of climate refugees. These people are also expected to have problems with acceptance due to the thought that it will create significant economic and social cost burdens to the country of immigration.

3.4. Concrete Examples by Country and Region

Although the effects of the climate crisis are global, the severity and consequences of these effects vary significantly across regions, countries and geographies. This situation reveals the social injustice that arises due to the problems and inequalities caused by climate change. Because underdeveloped countries, which have the least share in the formation of greenhouse gas emissions, are disproportionately the most affected by the process.

3.4.1. Examples of climate-induced migration and displacement

One of the most prominent social consequences of the climate crisis is forced displacement and migration movements due to the shrinkage of living spaces and the loss of livelihoods. These movements are triggered not only by sudden disasters, but also by slow and gradual environmental disruptions such as droughts.

Most Affected Countries

According to climate change projections, underdeveloped and developing countries are among the nations that will be most affected by the crisis. These groups are greatly affected by climate change and show significant sensitivity due to their vulnerability.

- **Economic Capacity Gap:** As the level of economic development increases, the likelihood of exposure to the harmful effects of climate change decreases, indicating that underdeveloped countries have the fewest resources to adapt.

- **Turkey's Sensitivity:** Turkey is located in the Mediterranean Basin, which is an area that is extremely sensitive to the effects of climate change due to its geographical location. Turkey is expected to be among the countries that will suffer the most from extreme weather conditions. It is estimated that Turkey will be the third country that will be most affected by extreme weather conditions in Eastern Europe, the Balkans, Eurasia and the Turkic States by the end of the 21st century.

- **The Case of the Philippines:** One of the most striking examples of the destruction caused by sudden disasters occurred in the Philippines. Typhoon Haiyan (hurricane) in 2013 caused the death of approximately 7,000 people and negatively affected the livelihoods of 5.9 million people. This situation shows the magnitude of the economic and social destruction of climatic disasters.

Regional Relocation

The effects of the climate crisis permanently change the natural balances in certain geographical regions, pushing local settlements into forced mobility.

- **Sea Level Rise:** The thawing of glaciers and the increase in sea levels due to global warming directly affect island countries and individuals living in coastal areas, causing these people to leave their places temporarily or permanently.

- **Endangered Coastal Areas:** 3% of Turkey's coasts have low altitudes, and according to sea level rise projections, cities connected to the sea are estimated to be endangered.

- **Drought and Agricultural Areas:** In the Mediterranean Basin, where Turkey is located, temperature increases, up to 20% decrease in precipitation and decrease in soil moisture are expected. Especially the Southeastern and Central Anatolia regions are described as arid and semi-arid, which pushes communities dependent on agricultural activities such as rural households and farmers to compulsory mobility.

Migration Due to Extreme Heat

Extreme temperatures accelerate migration movements by directly affecting both human health and livelihoods.

- **Loss of Health and Habitat:** High temperatures and associated drought lead **to food and water insecurity**, which makes people unable to continue their vital activities. It has been stated that due to the increase in temperature, animals also turn to cooler places to get out of hot regions, and this creates an opportunity for the spread of pathogens.

- **Regional Agricultural Losses: Estimates** predict that a 2 °C temperature increase worldwide will cause a 5% decrease in grain yield, while it is reported that the decrease in this yield will reach 25-35% in the Mediterranean region. The negative impact on agricultural

production constitutes a basic economic reason that forces rural communities, especially those whose economic welfare is based on agriculture, to relocate.

Large-Scale Internal Migration Projections

An examination of population mobility due to the climate crisis shows that large-scale displacements within countries come to the fore rather than international cross-border migrations.

- **143 Million Internal Migrants Prediction:** According to a report prepared by the World Bank Group in 2018, it is emphasized that 143 million people in three developing regions, Sub-Saharan Africa, South Asia and Latin America, may be forced to migrate within the country by 2050 due to climate change.

- **200 Million Global Prediction:** In another study, it is estimated that approximately 200 million people will migrate in 2050 due to adverse climate-related conditions, and it is calculated that 140 million of this number will occur in the form of internal migration due to reasons such as water scarcity, storms, floods and sea level rise.

3.4.2. Historical drought examples

Drought is a climatic phenomenon that occurs as a result of global climate change, with a lack of rainfall that occurs due to unusually high temperatures. Drought is considered one of the most threatening climate events due to its slow onset and spread over large geographical areas. When the historical process is examined, it is an indisputable fact that drought is one of the main environmental factors that force societies to relocate through agricultural collapse and food shortage.

Ireland:

The great famine period in Ireland is one of the most striking global examples of the devastating effects of climatic stress leading to social migration. Sources state that a quarter of Ireland's population migrated out of the country due to the food shortage in Ireland between 1852 and 1856. This case is critical in showing how food shortages and loss of livelihoods can push a society into forced international migration movement.

Oklahoma:

The great drought in the United States, known as the "Dust Bowl" in the 1930s, reveals the consequences of environmental pressure on rural communities that rely on agriculture. While the consequences of drought led some societies to migrate due to the deterioration of land conditions, the situation was embodied in the case of Oklahoma: As a result of the extreme drought in Oklahoma in the 1930s, 300,000 farmers migrated to California in search of better living conditions.

These two historical examples reveal the different dimensions of drought that cause forced migration. While the Irish case shows the devastating scale of international migration due to famine and deprivation; The Oklahoma case is concrete evidence of how extreme drought makes agricultural activities unsustainable, leading to large-scale and massive intra-country (internal) migration movements. Both events confirm that food shortages and land degradation as a result of natural phenomena linked to climate change affect poor and rural communities most profoundly and expose them to forced mobility.

3.5. Social Perception of the Climate Crisis in Turkey and Emerging Terms

The environmental transformations created by the climate crisis have become a concrete reality in social life, rather than a scientific warning or an abstract threat. The increase in the frequency and severity of natural disasters such as regional extreme rainfall, fires and droughts has caused individuals to accept the existence of the climate crisis and reduce their suspicions that it is human-caused. This situation creates social pressure on policymakers in the form of increased expectations for action.

The example of Istanbul, which is one of the studies examining social climate change awareness in Turkey, reveals the level of knowledge and awareness of the citizens regarding this global problem. Considering the fact that a significant portion of the population lives in cities, measuring the awareness level of city dwellers is critical for the success of policies to combat climate change.

Basic Perceptions According to the Findings of the Istanbul Example:

- **General Awareness:** 91% of the **participants from Istanbul who participated** in the study stated that they had heard of the concept of "climate change" before.
- **Cause of the Climate Crisis:** The vast majority of respondents (78.2%) marked factory and industrial wastes as the first cause of climate change. This is followed by human activities (76.9%) and excessive carbon emissions of developed countries (67.3%). These findings show that the social consciousness in Istanbul coincides with the general acceptance in the international literature that the crisis is anthropogenic (human-caused). Only 18.2% of respondents attribute climate change to natural causes.
- **Consequences of the Climate Crisis:** Among the first expressions that come to mind when they hear the concept of climate change, the melting of glaciers (79.4%), drought (68.7%) and extreme temperatures (66.2%) have come to the fore. It is interpreted that these results are related to the main sources of awareness (Internet: 73.8% and Social Media: 67.2%).
- **Sense of Responsibility:** The overwhelming majority of respondents (84.7%) stated that the main responsibility for combating climate change **should belong to states**, followed by individuals with 70%. This shows that social expectation is concentrated on policy makers.
- **Gender Factor:** In the case of Istanbul, there was a statistically significant difference in women's climate change awareness higher than men's.

The increase in this concrete perception and knowledge level has brought along the psychosocial reactions (anxiety, fear) of individuals and society in the face of crisis and has led to the addition of new concepts to the literature. (Ağıralan & Sadioğlu, 2021)

3.5.1. Eco-anxiety

The environmental destruction caused by the climate crisis has caused individuals to have deep concerns about their future prospects. Eco-anxiety (or eco-anxiety, climate anxiety) is defined as an excessive and pervasive fear of the consequences of climate change.

- **Mechanism of Formation: Eco-anxiety has** entered the psychological literature as a future anxiety or disaster expectation that individuals experience as a result **of the helplessness and hopelessness** they feel in the face of ecological destruction.

- **Social Pressure: This** anxious impression in the society creates pressure on the rulers to demand political action within the scope of urgent measures and containment strategies to be implemented for the climate crisis.

- **Academic Value:** Eco-anxiety is important because it has the potential to provide the impulse to make the right decisions and take the necessary steps (reference to Kurth and Pihkala, 2022). In the Turkish literature, it is stated that this concept has not yet been sufficiently studied in the fields of social sciences such as political science, public administration and environmental sciences, but its importance is increasing.

3.5.2. Eco-keder

Eco-grief is another important psychosocial response to the devastating effects of the climate crisis. This concept is characterized as a feeling of grief reminiscent of the loss of a relative.

- **Definition and Scope:** Eco-grief is associated with the helplessness and hopelessness experienced by individuals in the face of ecological destruction.

- **Political Impact:** Emotions such as eco-grief, together with the accepting perception of the climate crisis in the public, are considered as a positive factor in terms of developing solutions and implementing climate policies sustainably.

- **Position in the Literature:** Just like eco-anxiety, eco-grief is a concept that has recently joined the international literature and is increasing in frequency. In the Turkish academic literature, it is stated that there has not yet been sufficient research in the field of social sciences and that this interdisciplinary approach should be developed. A clearer understanding of these psycho-social responses will contribute to making social demands and needs more understandable for policy makers.

3.6. Developed Climate Policies and Response Framework

The global climate crisis needs to be constructed within a framework that integrates social, economic and environmental goals. Because climate change; It is extremely important to develop appropriate strategies and policies as it triggers many social issues such as access to basic social services and needs, from employment to immigration, from poverty to basic social services and needs. In academic sources, basic policy measures regarding the social dimension of climate change; Just Transition Policies are examined within the framework of the Paris Climate Agreement and the Green New Deal.

3.6.1. Just transition policies

Just Transition is a central social policy approach that aims to maximize social benefit through climate actions and policies. This strategy is defined as providing employment opportunities worthy of human dignity, creating them to end poverty and significantly supporting increasing social inclusion.

Just Transition aims to minimize all kinds of obstacles through effective social communication while making the best use of social and economic opportunities. The necessity of this transition is emphasized in order to promote social justice. The International Labour Organization's (ILO) Just Transition Directive includes active labour market programmes, including skills development, that establish a systematic link to social protection. In addition, it is emphasized that social protection strategies should be developed and implemented with the participation of social partners and other interested parties through an inclusive social dialogue.

3.6.2. Paris Climate Agreement

The Paris Climate Agreement is one of the basic agreements that embody the international practices developed within the scope of combating climate change. This agreement, signed by more than 190 countries, aims to bring greenhouse gas emissions to net zero in the second half of this century.

Among the main objectives of the Paris Climate Agreement; robust, sustainable and balanced development, reducing global poverty, creating environmentally friendly jobs by increasing employment opportunities, and providing a safer future for people and the planet.

Climate Justice Mechanism: The agreement aims to financially support countries that are most affected by climate change and do not have the capacity to adapt. For this purpose, it is planned to establish an annual climate finance mechanism (Green Climate Fund) of 100 billion dollars for the post-2020 period. This fund is critical for addressing climate injustice, providing financial support to poor regions, preventing migration, and increasing urban resilience in vulnerable countries.

3.6.3. Green Deal (Green New Deal)

The Green New Deal (or Green New Deal) is the economic resources of the society under the legitimate actor of the state; it's a framework that aims to mobilize around a transformative vision of rapid decarbonization, environmental sustainability, and distributive justice.

Although this consensus may be perceived at first glance as a mere infrastructural or economic framework, it will have a dynamic physical impact on landscapes, cities and societies. Policies such as the European Green Deal are expected to contribute to the formation of new business and employment areas that will enable green development.

3.6.4. Key social dimensions these frameworks focus on

The effectiveness of climate policies depends on the degree to which social dimensions are successfully integrated as well as environmental goals.

Employment:

One of the main goals of policies for the climate crisis is to regulate the labor market in the transition to a new green economy.

- The third main goal of social protection programs is; to improve opportunities by providing better employment, business and livelihoods.
- To compensate for the negative impacts on individuals due to climate change, social security measures should offer unemployment benefits for those who have lost their working hours or jobs as a result of a climate crisis.
- The Paris Climate Agreement aims to create green jobs and increase employability. In addition, attention should be paid to the risks of new growth business areas such as "green energy".
- The implementation of green development policies will contribute to the formation of new business and employment areas.

Poverty:

Since the climate crisis disproportionately affects low-income groups and the poor, it is essential that policy frameworks focus on the fight against poverty.

- The first of the main objectives of social protection is to reduce poverty and inequality.
- Among the goals of the Paris Climate Agreement is to reduce global poverty.
- Just Transition Policies also aim to contribute to the eradication of poverty.
- Migrations as a result of climate-related events either create new poverty or deepen existing poverty; This situation causes the beginning of a cycle of poverty. Strategies should be developed at the microeconomic and macroeconomic level to prevent the poverty of climate refugees. Protecting individuals' right to employment is one of the most effective ways to reduce the risk of poverty for migrants.

Social Justice:

Social justice should be the basic principle in the construction of climate policies. Social justice is the principle that ensures that the cost of climate change is distributed fairly and that the highest level of social benefit is targeted.

- The effects of climate change cause social injustice due to social inequality. For this reason, the fight against the climate crisis needs to produce policies that establish social justice.
- The Green New Deal includes the principle of distributive justice among its main objectives.
- The Just Transition approach is necessary to promote social justice.
- Climate justice is a sensitive issue that needs to be integrated into policy-making and implementation processes. Climate justice; should be built on the basis of human rights, and regulations should be made to compensate for the problems caused by inequalities.
- The rights-based approach requires the inclusion of human rights principles in every step of programs and projects, and aims to support vulnerable groups that are particularly neglected.

3.7. The Effects of the Climate Crisis on Society: Risks, Inequalities and Solution Approaches

3.7.1. Anthropogenic destruction and global threat: Human-induced activities such as fossil fuel consumption, uncontrolled urbanization, and land use have triggered the climate crisis with irreversible effects such as global temperature increase, extreme weather events, and sea level rise. It is clear that this crisis is a political, social, economic and ecological danger and that social unrest and security will increase if it is not intervened.

3.7.2. Climate Injustice and Vulnerability: The deepest dimension of the climate crisis is the disproportionate and unequal distribution of its consequences among layers of society. The peoples of underdeveloped countries, the poor and disadvantaged groups (women, children, the elderly, immigrants), which contribute the least to greenhouse gas emissions, are most affected by this process. The existing vulnerabilities of these groups create a vicious circle of poverty by reducing their exposure to climate hazards and their capacity to cope. For example, people living in high-vulnerability areas are 15 times more likely to die from disasters.

3.7.3. Victimization and Migration: The crisis causes human rights and health grievances as well as economic and social grievances on vulnerable groups. Consequences such as loss of livelihoods, unemployment and food insecurity have the potential to displace millions of people. It has been historically proven that slow-onset disasters such as droughts lead to mass migrations (examples of Ireland, Oklahoma). Most importantly, the lack of a clear equivalent of the concept of "climate refugee" in legal regulations brings with it the problem of loss of rights and international protection status for these displaced groups.

3.7.4. Social Perception and Responsibility: Awareness studies conducted in Turkey show that the public largely accepts the existence of the climate crisis and that it is human-caused. The case of Istanbul revealed that the overwhelming majority of citizens (84.7%) attribute the main responsibility in the struggle to the state. This situation creates an expectation for policymakers to take strong and decisive action; The increase in psychosocial reactions such as eco-anxiety and eco-grief also confirms the increase in the perception of social urgency.

3.7.5. Social Justice-Based Solutions: The study showed that the framework to combat the climate crisis should focus on the integration of social policies, not just technical goals such as greenhouse gas reduction. In this context, Just Transition Policies should aim to minimize the risks of unemployment and inequality created by the decarbonization process through social dialogue and decent work opportunities. Frameworks such as the Paris Climate Agreement and the Green New Deal should include social goals such as poverty reduction and employment growth.

4. Conclusion and Recommendations

This academic paper revealed that the climate crisis**, which has accelerated as a result of human activities (anthropogenic) since the Industrial Revolution**, has turned into the biggest and most urgent social injustice problem of today, rather than just an environmental problem . In the study, using qualitative research approach and descriptive content analysis methods, the climate crisis was examined by focusing on social inequalities, exposures of vulnerable groups and social policy requirements in solution frameworks.

In the light of the findings and discussions, the following policy recommendations are presented in order to manage the social dimension of the climate crisis and eliminate climate injustice:

- Adopting a Rights-Based and Social Justice-Oriented Approach: Climate policies should be built on the basis of human rights principles such as non-discrimination and participation. This approach should include positive discrimination, especially for the most vulnerable groups, and ensure that regulations are made to ensure social justice.

- Strengthening Adaptive Social Protection Systems: The adaptability of social protection systems should be enhanced in order to respond to shocks (unemployment, disease, disasters) related to climate change. In this context, it is critical to implement flexible and fast-scalable measures such as unemployment protection, cash or in-kind benefits for those who have lost their jobs due to the climate catastrophe.

- Legal Solution for Climate Migration: Urgent legal solutions should be implemented at the international level regarding the status problem of people displaced due to climate change (climate refugees) and possible loss of rights should be prevented.

- Ensuring Global Financial Solidarity: Developed countries and international organizations should provide financial and technological support to poor and vulnerable regions

and countries (including regions at risk such as Sub-Saharan Africa, South Asia, and Turkey) that contribute the least to the climate crisis. These funds should be used to increase the urban resilience of fragile countries and reduce migration pressure.

- Increasing Social Awareness: The internet, social media and educational curricula should be used effectively to disseminate accurate information and awareness about climate change. Women's higher levels of awareness should be used as a catalyst for social participation and policy development.

- Although the effects of the climate crisis are not equally severe globally, it is a necessity for the future of social welfare and social peace to resolutely maintain effective, long-term and scientific-based policies with a participatory and transparent management approach for countries with high vulnerability such as Turkey.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics committee permission was not required for the study. All authors contributed equally.

References

Acarbaş, E., Tiryaki, S., & Başıbüyük, H. H. (2025). Disaster gerontology and climate crisis. *Turkish Journal of Healthy Aging Medicine*, 2(3), 1-7. : https://dergipark.org.tr/en/download/article-file/3885389

Ağıralan, E., & Sadioğlu, U. (2021). Climate change awareness and public consciousness: The case of Istanbul. *Anadolu University Journal of Social Sciences*, 21(2), 627-654. : https://dergipark.org.tr/tr/download/article-file/1849471

Coşkun Beyan, A. (2019). There is not enough information on many issues about the effects of global climate change on employee health and safety. *Current Chest Diseases Series*, 7(2), 62-66.:http://ghs.asyod.org/Dosyalar/GHS/2019/2/5feeb548-918b-431c-b042-a2fdeacb9d0f.pdf

Çeçen, B. U., & Güvenç, Ö. G. F. (2022). The effects of climate change and global warming on public health. *SDU Journal of Health Management*, 4(1), 14-25. :https://dergipark.org.tr/tr/download/article-file/2329430

Demircan, M. (2022). The relationship between climate, climate change and water. In A. Bektas (Ed.), Global climate change and its socio-economic impacts (pp. 47-84). TASAV.: https://www.researchgate.net/profile/Mesut-Demircan/publication/365097634_Iklim_Iklim_Degisikligi_ve_Su_Iliskisi/links/656221fe3fa26f66f4281f56/Iklim-Iklim-Degisikligi-ve-Su-Iliskisi.pdf

Memiş, O. B. (2023). Climate change and social justice: A review from the framework of social policy and resilience. *Uşak University Journal of Faculty of Applied Sciences,* 3(2), 20-37.: https://dergipark.org.tr/tr/download/article-file/3629524

Özkaplan Yörüklü, N. (2021). Landscape architecture strategies for climate change and global warming: Climate change policies landscape statement. LANDSCAPE - *Journal of Education, Science, Culture and Art,* 3(1), 43-55.: https://dergipark.org.tr/tr/download/article-file/1757046

Parlak, B., Çetin, M. Ş., & Şenol, S. (2024). Conceptual assessment of the climate crisis and migration. *Kent Academy,* 17(1), 217-230.: https://dergipark.org.tr/en/download/article-file/3372730

Sever, B. C. (2023). An assessment of the possibilities of human mobility and immobility in the context of the climate crisis in Turkey. *International Journal of Human Mobility,* (Special Issue), 34-55.: https://dergipark.org.tr/en/download/article-file/3709941

Sengul, B., & Murat, G. (2024). The social dimension of the global climate crisis and social policy measures. *Süleyman Demirel University Visionary Journal,* 15(41), 342-358. https://dergipark.org.tr/en/download/article-file/3189832

Şıvgın, B., & Afacan, S. (2020). A study on the global and individual fight against the climate crisis: The case of Greta Thunberg. *Journal of Diplomacy and Strategy,* 1(2), 141-158. : https://dergipark.org.tr/en/download/article-file/2885567

Tan Gülcan, D. (2024). The impact of the perception of the climate crisis on climate policies. *International Journal of Economics, Politics, Humanities & Social Sciences,* 7(4), 344-363.: https://dergipark.org.tr/en/download/article-file/4163106

Tugac, C. (2022). The climate change crisis and cities. *Journal of Environment, City and Climate,* 1(1), 38-60. :https://dergipark.org.tr/tr/download/article-file/2369220

Turkish Academy of Sciences. (2020). Report on climate change and public health in Turkey (TÜBA Reports No: 37). Ankara: Turkish Academy of Sciences.: https://www.tuba.gov.tr/files/yayinlar/raporlar/T%C3%9CBA-%C4%B0klim%20De%C4%9Fi%C5%9Fikli%C4%9Fi%20ve%20Halk%20Sa%C4%9Fl%C4%B1%C4%9F%C4%B1%20Raporu.pdf

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Applications of HVAC Condensate Water in Landscaping and Its Water–Energy–Carbon Impact

Buğrahan ÇETİNKAYA [1*]

ORCID 1: 0009-0005-5347-735X
[1] MSc Student, Süleyman Demirel University, Institute of Natural Sciences, Department of Landscape Architecture, Isparta- Türkiye
yl2530126009@ogr.sdu.edu.tr (Responsible Author)

Murat AKTEN [2]

ORCID 2: 0000-0003-4255-926X
[2]Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
muratakten@sdu.edu.tr

Abstract

This study examines the on-site evaluation of HVAC condensate water at the building/campus scale within a water-energy-carbon (WEC) framework. First, on-site water resources (rainwater, gray water, etc.) are briefly outlined; then, condensate water is detailed in terms of its source characteristics, quality profile, and safe use principles. The methodology integrates scope and functional unit definition, system boundaries, monitoring/QA-QC, production estimation, quality assessment, design and operation-maintenance protocols, and economic (LCC/ROI) and environmental (WEC) analysis approaches. The findings show that, thanks to its low mineral content and seasonal timing compatibility, condensate water can significantly reduce the demand for tap water in non-potable uses such as landscape irrigation and cooling tower makeup water; this, in turn, reduces the energy and carbon impacts associated with supply/distribution and wastewater treatment. Hybrid use with rainwater is the primary strategy for increasing supply continuity and savings. The economic assessment reveals that payback can be attractive, particularly in hot-humid climates and commercial buildings with high operating hours; however, implementation success depends on regular risk management (WMP) and clear identification/permit processes.

Keywords: HVAC condensate water, water efficiency, water-energy-carbon nexus, life cycle assessment, biofilm management, iot-based monitoring, green building technologies

1. Introduction

Water is an indispensable natural resource for the continuity of ecosystems, public health, food security, and economic production. Over the past forty years, global freshwater demand has increased by approximately 1% annually; population growth, urbanization, dietary patterns, and climate change have intensified this pressure(UNESCO 2024). Therefore, water is not only a fundamental determinant of environmental stability but also of social and economic stability.

1.1 Global Water Budget and Accessibility

Approximately 96–97% of the Earth's water mass is saltwater found in oceans; freshwater accounts for about 3%. Of the freshwater stock, 68% is found in glaciers and permanent snow cover, and 30% is underground. Surface freshwater (lakes and rivers) directly accessible for human activities constitutes a very small portion of this pool; for example, rivers account for approximately 0.49% of surface freshwater and represent an almost negligible share of total water. This distribution demonstrates that the “usable” water pool is both limited and fragile(USGS).

1.2. Sectoral Water Withdrawals

Globally, the largest share of freshwater withdrawal is for the agricultural sector. According to UNESCO's 2024 World Water Development Report and FAO AQUASTAT data, approximately 69–70% of global withdrawals are for agriculture, 19–20% for industry, and 12% for municipal/domestic use. (UNESCO 2024 and FAO AQUASTAT data). Although these ratios vary at the country level depending on climate and economic structure, they confirm that the primary pressure on water resources stems from agricultural irrigation.

1.3. Access to Safe Water (SDG 6 Context)

Although progress has been made in indicators of **access to safely managed drinking water** over the period 2015–2024, **one in four people in the world** still does not have access to safe drinking water. Current WHO/UNICEF JMP estimates show that global coverage **has risen to** 74%, while **2.1 billion** people lack safe drinking water (WHO/UNICEF JMP). This picture requires a significant acceleration of the pace of coverage growth, especially in low-income countries .

1.4. Water Stress, Time-Space Inequality and Climate Risk

The amount of water is not only scarce, but it is also extremely unevenly distributed in time and space. WRI's Aqueduct indicators show that at least **50% of the world's population lives under** conditions of high water stress **for one month of the year, and** 25 countries, **including a quarter** of the population, experience extremely high **water stress each year** (World Resources Institute, 2023). This highlights the imperative for resilience-focused approaches to water management in the era of climate change, where droughts and flood cycles are exacerbated .

1.5. Water-Energy-Carbon Bond (General Framework)

Water requires energy **in the processes of extraction-treatment-pumping-distribution(UNEP Copenhagen Climate Centre, 2023)**, and the collection and treatment of wastewater is part of this cycle (UNEP Copenhagen Climate Centre, 2023). The energy intensity of the urban water supply is reported in the literature in the range of **approximately 0.3–0.7 kWh/m³**; therefore, the efficient use of water reduces the cubic meter in the meter as well as **the indirect energy demand** and the associated **carbon impact**.

2. On-site Water Sources and HVAC Condensate

2.1. Other On-Site Resources

On-site water resources; rainwater, gray water (sink/shower/laundry), black water (toilet), surface runoff/flood water, and similar flows (Austin Water, 2024). A "fit-for-purpose" approach is adopted for non-drinking use (landscaping, cleaning, cooling tower make-up, etc.) in cities; Each source requires different levels of treatment and monitoring based on its quality/risk profile. Table 1 shows on-site water resources and representative quality ranges.(U.S. Environmental Protection Agency, 2018)

- **Rainwater**: Often defined by low minerality and near-neutral pH; roof and surface contact can affect particulate and microbial load.
- **Greywater**: Higher risk of microbials due to detergent/nutrient loads and organic matter, so risk-based treatment/disinfection and operation protocols are recommended (WHO, 2017).

- **Blackwater and mixed streams**: Subject to advanced treatment and strict hygiene conditions due to its pathogen load; in on-site reuse scenarios, it is often collected separately or diverted to the central system (subject to local regulations). Most municipal guidelines emphasize separate collection lines based on use, backflow prevention, and monitoring mandates.

Table1 – On-site water resources and representative quality ranges

Source	Typical pH	TDS(mg/L)	Feature Highlight	Microbial Risk
Rainwater	5.6–7.0	10–50	Hardness ≈0, no sodium; May be slightly acidic	Roof/surface contact dependent; middle
HVAC Condensate	6.0–7.5	10–300	Low minerality; variable according to installation/device contact	Risk due to biofilm in drain pan/pipes
Grey Water	6.3–8.2	450–1100+	Detergent/nutrient loads; BOD/TSS is high	High; Treatment and disinfection required
Mains Water (Drinking water)	6.5–8.5 (SMCL)	100–500 (SMCL 500)	Purified for human consumption; Salinity varies by region	Miscarriage; Distribution network subject to standards

2.2. Definition, Formation, and Systematics of HVAC Condensate

HVAC condensate is a freshwater flow with atmospheric moisture source, which occurs when the water vapor in the air condenses on the cooling coil in the air conditioning system of a building(U.S. Environmental Protection Agency, 2015). When the indoor air is lowered below the dew point temperature during cooling, moisture that the air can no longer hold adheres to the battery surface in the form of droplets and percolates into the condensate pan; from here, the condensate is removed by a drainage line (CoC). In most buildings, this current is given to the sewer without any economic/functional response; However, in buildings with high water stress and strong irrigation/cooling needs, this flow can be considered as a reusable resource on site.

Logic of formation

The primary task of air conditioning systems is not only to reduce the temperature but also to provide humidity control. Especially in summer, when the fresh air taken from outside and the air drawn from the indoor environment have high relative humidity, the coil surface is kept colder than the ambient air and condensation begins at the point where the air relative humidity reaches 100%. The amount of water that emerges;

- Moisture content of the outdoor air (i.e. climate/humid season),
- How many hours the system works,
- How much air passes through the device (CFM / flow rate),

- It increases or decreases depending on the cleanliness and slope of the cooling coil used. Therefore, it is natural for two buildings of the same capacity to produce different condensation amounts even in the same city. This production is much more evident in humid coastal cities and tourism structures.

Water quality features

Condensate contains low dissolved matter, similar in origin to rainwater; because when it passes from water vapor to liquid, it does not carry any significant salinity except for atmospheric dust and a small amount of minerals dissolved from the surface of the device. However, this does not mean that the water is "drinkable". There are two main reasons:

1. **Drainage path contamination:** Water first comes into contact with metal/plastic surfaces and the condensate pan; poorly maintained pans are conducive to biofilm and microbial growth.

2. **Storage stagnation:** If the collected condensate sits in a dormant tank for a long time, microbial growth can be seen, albeit with low nutrients.

Principles of collection, separation and marking

In current applications, a completely separate condensate line is drawn from the mains so that the HVAC condensate can be reused in the future. This line:

1. It starts from the condensate pan,
2. Prevents odor and airlock with siphon/trap,
3. Goes to a collection point with sufficient inclination,
4. From there, it is taken to the balance/storage tank.

In addition, in order not to create a cross-connection with the drinking water network, an air gap is left indicating that there will be no backflow from the tank or booster line to the network in any way. Many city and campus standards require these pipes to be marked in purple; This way, maintenance personnel on site can recognise at first glance that this line is non-drinking. This trio is the foundation of safe design in HVAC condensing systems.

Areas of use

The following uses are typical scenarios where HVAC condensate can be treated and safety measures for non-potable water requirements. In all cases, local regulations, physical separation with air-gap and purple pipe marking/warning signs are mandatory.

1. Landscaping/green space irrigation

- Why is it appropriate? Condensation increases in summer and humid days; This period coincides with the time when irrigation demand is also high in most campuses ("timing harmony").

- How? It is used effectively in drip / underground drip and pot / terrace applications after pre-filtration + appropriate disinfection. Aerosol-forming methods such as spray/lawn sprinklers require stricter control and marking due to the risk of public contact.

2. Cooling tower make-up water

- Why is it appropriate? The low minerality of condensate can help raise concentration cycles (CoC) in some systems; this has the potential to reduce makeup and blowdown volumes (U.S. Environmental Protection Agency, 2023).
- How? Tower chemistry should be managed with a professional water treatment program; conductivity/chemical balance should be observed. The U.S. Department of Energy (FEMP) guidance notes the decisive role of the CoC in water efficiency and the suitability of alternative sources (e.g., AHU condensate) as make-up water.

3. Toilet/urinal cistern supply (depending on local legislation)

- Why is it appropriate? It can be implemented with a closed use, regular disinfection and subsequent storage control.
- How? On-site reuse programs; It requires clear identification such as purple pipe obligation, valve/equipment labeling and warning signs in toilets. Design-operation permit processes are defined step-by-step in city guides (e.g., SFPUC Onsite Non-Potable Water Program).

4. Hard floor washing / general cleaning

- Why is it appropriate? It is suitable for open/closed hard surface cleaning that does not require drinking water quality.
- How? Simple filtration + disinfection; Anti-backflow warnings at hoses and connection points, air-gap and "Non-potable" warnings at filling stations are essential. Austin and similar municipal directories detail the identification and operation steps for cleaning use.

5. Construction site dust suppression / process non-contact uses (outdoor)

- Why is it appropriate? It provides an alternative to mains water in non-potable and outdoor applications where there is no direct contact with people (e.g. dust suppression).
- How? Spray configurations that minimize aerosol contact are preferred; Warning signs are placed in the access areas in the field. The WateReuse guidelines outline the general requirements for switching from on-site sources to edge uses such as WC/irrigation/tower/dust suppression.

Recommended application-specific treatment and safety

- Filtration: Coarse sieve/bag + fine cartridge or equivalent; additional filtration against clogging for drip irrigation.
- Disinfection: UV or chemical oxidant according to use; Residual monitoring when necessary in distribution lines.
- Separation and marking: Air-gap, purple pipe, valve/equipment labeling, warning signs in access areas. (SFPUC/Austin guides)
- Tower-specific: Water chemistry/conductivity. control, professional program; CoC optimization (FEMP).
- For every use involving aerosols: Risk-oriented monitoring with WMP (Water Management Program) (CDC Toolkit).

What to avoid

- Drinkable uses, shower/bath, avoiding food preparation.
- Aerosol-intensive applications such as fogging, decorative sprinklers, etc. in confined spaces where people are present: Only with advanced treatment + approved WMP + explicit warning/restriction; cautious approach in most municipal programs.

2.3. Hybrid use of HVAC condensate

HVAC condensate can be combined **with** other on-site water sources and indoor non-potable **distribution networks to** increase continuity and **balance demand-supply fluctuations** throughout the year . The following hybrids are common scenarios in practice, compliant with municipal manuals and industry guidelines. Table 2 shows the on-site water resources and representative quality ranges.

A) Condensation + rainwater **(common storage / common treatment)**

When? Rain is high during the rainy season and condensation is high during the hot-humid season; when stored together, they **produce a** more balanced volume throughout the year.

How? The sources are mixed **in a common non-drinking tank**; "fit-for-purpose" treatment (filtration + disinfection) is applied at the outlet. **Physical separation from the grid with** air-gap and **purple pipe** identification are mandatory; in entrance/landscape areas

B) Condensation + green infrastructure **(rain garden/bioretention supplement)**

When? On dry/hot days, rain gardens and biocapture areas experience **a lack of water**; low minerality **condensation** can meet this need for "lifewater".

How? Pre-filtration + subsurface feeding after simple disinfection is preferred (to reduce aerosol contact and algae growth). Green infrastructure practices are included as appropriate edge usage in on-site reuse programs .

C) Condensation + cooling tower management (operational hybrid)

When?Low TDS water **in tower make-up** helps to increase concentration cycles **in some systems,** so make-up/blowdown volumes and chemical consumption can be optimized.

How? Condensate **is used as** make-up water;**The blowdown** is managed separately (mixing is not recommended). Tower chemistry is necessarily monitored by a professional program (corrosion/scale and bio-control); CoC limits **depend on water quality + treatment regime** (DOE FEMP and GSA/NREL guidelines).

D) Condensation + purified grey water **(to balance the flow rate, conditional)**

When? For closed-contact end uses, **such as WC/urinal supply or cleaning**, the flow rate of treated greywater can be balanced by condensation; condensation can **dilute the relatively high** salinity of greywater **and some parameters** .

How? The mixture **is made only in the** common warehouse AFTER treatment;Warning signs are mandatory at **air-gap,** purple pipe and end points. The WateReuse and NYC/SFPUC guidelines detail the weld–tip usage matrix and marking rules(WateReuse, 2023; NYC DOHMH, 2025).

E) Condensation + indoor non-potable network **(toilet cistern, cleaning, dust suppression)**

When?In campus/mixed-use buildings, it is efficient to feed multiple end uses **(WC, cleaning station, dust suppression, landscaping)** from a single non-drinking backbone line.

How? The distribution network is **purple** and labeled "non-potable"; valve/equipment labeling, flow direction arrows, room/access point warnings are mandatory. The CDC's **WMP** approach mandates risk reduction and monitoring for uses involving aerosols (e.g., sprinklers).

Table 2. On-site water resources and representative quality ranges

Source	Typical pH	TDS(mg/L)	Feature Highlight	Microbial Risk
Rainwater	5.6–7.0	10–50	Hardness ≈0, no sodium; May be slightly acidic	Roof/surface contact dependent; middle
HVAC Condensate	6.0–7.5	10–300	Low minerality; variable according to installation/device contact	Risk due to biofilm in drain pan/pipes
Grey Water	6.3–8.2	450–1100+	Detergent/nutrient loads; BOD/TSS is high	High; Treatment and disinfection required
Mains Water (Drinking water)	6.5–8.5 (SMCL)	100–500 (SMCL 500)	Purified for human consumption; Salinity varies by region	Miscarriage; Distribution network subject to standards

2.3. Production dynamics and orders of magnitude

HVAC condensate is formed by condensing moisture from the air in a cooling coil. Production amount; It depends on factors such as cooling load, relative humidity/dew point, amount of fresh air (make-up air) and operating time. The guidance documents emphasize that production increases significantly with long working hours and high fresh air rates, especially during humid and hot periods. Table 3 shows the HVAC condensate production coefficients.

Key determinants:

Climate and seasonality: Production peaks on hot-humid days; this period coincides with the peak of landscape irrigation demand in most cities (timing alignment).

Business profile: Daily working hours, internal heat-humidity loads, and fresh air ratio (e.g., AHU design) increase/decrease production.

Building type: Condensate volume is usually higher in buildings that operate for long periods of time and at high loads, **such as hotels, airports, shopping malls** ; in office buildings, it fluctuates with operating hours.

Maintenance and hygiene: Clean serpentine surfaces and open drainage lines promote both **continuous flow** and **microbial control** ; clogging and stagnation negatively affect both quantity and quality.

Storage and distribution: Proper bulking prevents overflow and unnecessary evaporation losses; physical separation with non-drinking networks **(air-gap, purple pipe)** ensures safety.

Orders of magnitude (expressional): While there were small daily **volumes at the residential scale** , significant daily and significant annual recoveries were reported at the campus scale in large commercial/institutional buildings. These findings are supported by field studies in different climates and types of use.

Planning principle: The "rules of thumb" used in pre-feasibility are instructive, but calibration with local climate data and actual operational measurements is recommended for each project. The municipal handbooks recommend the practice of record keeping/tracking throughout the design and operation (e.g., sample and log record templates) as good practice.

Table 3. HVAC condensate production coefficients

Indicator	Upper-Lower Range	Note
GPH/ton (cooling capacity)	≈0.1–0.3	Climate and internal burdens are effective; SAWS/AWE field data
gpd / ton	≈6–12	Field data is typically reported at 8–10 gpd/ton
gph / 1000 sq ft (gross interior area)	≈0.5–0.6	Literature example in hot-humid climates
Annual production (sample large building)	≈700,000–800,000 gal/year	San Antonio field measurement example

2.4. Areas of Use in Landscaping and Harmonious Timing

Condensate increases in summer/humid days; This period coincides with the peak of landscape irrigation demand. Low-pressure drip and subsoil irrigation, along with small storage + filtration, are the most efficient uses; It is widely applied in pot/terrace/roof gardens, median/grass islands and campus green areas.

2.5. Health-hygiene and System Safety

The low minerality of condensate does not completely prevent the formation of biofilms on the drip and filter surfaces; Legionella risk management (CDC, 2021) and disinfection are essential, especially in applications that can form aerosols, such as cooling tower makeup. The CDC's guidance for building water systems recommends a risk-based management plan and regular testing/monitoring approach(CDC, 2025).

2.6. Regulatory and Policy Trends

San Antonio (SAWS) regulations stipulate that in new commercial buildings, the condensate line must be collected independently and ready for future reuse; In many cities, alternative water usage guidelines (eg. Austin Water) gives step-by-step the requirements for design-build-operation (SAWS, 2022).

3. Water–Energy–Carbon Relationship (WECN)

3.1. Concepts and Interrelationships

Water, energy and carbon affect each other in two directions (Kitessa, et al., 2020); The "water-energy nexus" approach proposes to manage resources together (Table 4).

Table 4 – WECN components and relationships (conceptual)

Component	What it means	Impact on others	Typical indicators
Water	Supply–treatment–distribution–wastewater treatment cycle	Every step consumes energy; energy consumption determines the carbon footprint.	kWh/m³ (water), kWh/m³ (wastewater)
Energy	Electricity/heat that powers the water cycle	Determines the energy portfolio and efficiency emission intensity	kWh/m³, specific pumping (kWh/m·m³)
Carbon	Emissions resulting from energy use	Less energy = less CO_2e; grid emission factor is critical	ΔCO_2e = kWh × EF_grid

3.2. Effects of WECN on Conventional (mains) Water Usage

The extraction, treatment, and pumping of urban water requires energy; the collection and treatment of wastewater is also part of the same cycle. The literature and field guides report energy consumption of ~0.3–0.7 kWh/m³ for urban water supply(Hamawand, I., et al., 2023) and a similar level for wastewater treatment (varying by facility/country and processes). This consumption translates into a carbon impact when multiplied by the local grid's emission factor.

3.3. Effects of HVAC Condensate Water on WECN

HVAC condensate water is a stream originating from atmospheric moisture that is suitable for on-site and non-potable use; its increase, particularly during the humid summer period, coincides with landscape irrigation demand (timing alignment). When used on-site, the energy and carbon impacts associated with supply/distribution energy and wastewater treatment are avoided because no water is drawn from the network; the only additional load on the system is a small amount of electricity consumption for on-site treatment (filtration + disinfection) and pumping (Table 5).

Table 5 – Effects of condensation water on WECN (mechanism-focused):

Stage	Water effect	Energy effect	Carbon footprint	Note
Replacing tap water	Water intake ↓	Supply/distribution kWh ↓	CO_2e ↓ (Dependent on EF_grid)	Local energy density ~0.3–0.7 kWh/m³ can be used as a reference.
Wastewater generation	Wastewater volume ↓	Raw water treatment kWh ↓	CO_2e ↓	Depending on the type of use (irrigation →

				soil instead of canal).
On-site treatment & pump	Water neutral	Small kWh ↑	CO_2e ↑ (the)	UV/oxidant and pump consumption; remains low with good design.
Seasonal compatibility	Supply–demand balance ↑	Storage requirement ↓	Indirect CO_2e ↓	Summer production ↔ irrigation demand.

3.4. Comparative summary

Policy/planning link: The UNESCO/IEA/UNEP WEN framework advocates addressing water efficiency alongside energy and climate goals, integrating on-site resources (e.g., HVAC condensation) with fit-for-purpose treatment and safe separation principles (Water-Energy-Nexus). Table 6 shows a WECN comparison.

Table 6. Tap water vs. HVAC condensate water (WECN comparison):

Step	Tap water (conventional)	HVAC condensate water (on-site)	Net difference (condensation – network)
Procurement/distribution	kWh↑ (pumping/lifting) → CO_2e↑	0 (avoiding)	Energy/CO_2e ↓
Usage (landscaping, cleaning, etc.)	Water consumption 1 m^3	1 cubic meter (on site)	Water consumption ↓ (from the network)
Wastewater	1 cubic meter (sewer/treatment)	Application-dependent (field infiltration, etc.)	Wastewater kWh/CO_2e ↓
On-site treatment/pump	-	Small kWh↑ (UV/oxidizer/pump)	A small counterweight
Seasonality	Limited supply-demand balance	High compatibility (summer season)	Storage/peak loads ↓

4. Implementation Challenges, Constraints, and Economic Analysis

4.1. Initial Setup Cost (CAPEX) and Operating Expenses (OPEX)

The CAPEX cost of the recovery system consists of the storage tank, pipelines, and treatment units. OPEX includes low energy consumption and periodic filter/chemical replacement costs. Compared to gray water systems, the OPEX cost is up to 30% lower due to the cleanliness of the condensate water.

4.2. Storage Management, Health Risks, and Cross-Contamination Hazards

The storage requirement means that water must be used or treated within a maximum of 72 hours. Otherwise, the microbial load increases rapidly. For plumbing safety, ASPE standards require that reclaimed water lines be separated from potable water lines by an air gap and clearly marked with purple piping(SFPUC, 2022).

4.3. Lack of Legislation and Need for Standardized Protocols

In Turkey, there is no specific and binding legislation on the recovery and quality of condensate water, such as regulations on gray water or rainwater. This gap slows down project approval processes and leads to differences in implementation between different local administrations.

4.4. Sensitivity Tests and ROI Optimization in Cost-Benefit Analysis

The financial success of the recycling project depends on LCC-based sensitivity analyses conducted against dynamic variables.

Water Tariff Sensitivity: A 10% increase in local water tariffs should be modeled to reduce the ROI period by up to 15%.Enerji Fiyatı Duyarlılığı:

The energy savings achieved through recycling are a critical financial lever that accelerates ROI by 1-2 years in regions with high electricity rates..

Risk Cost: The extent to which using condensate water in cooling tower operations reduces the risk of scaling and the associated equipment failure costs should be calculated monetarily and included in the analysis.

5. Findings – HVAC Condensate Samples from Around the World

Table 7 shows a comparison of water savings and WEC effects in global examples.

USA – EPA SEDS, Athens/Georgia (tower makeover)



Figure 1. EPA – Athens, Georgia (USA): EPA laboratory complex

What did they do? Condensate water was collected from the rooftop AHUs and fed directly into the cooling tower makeup water.

Results: ~540,000 gallons recovered between May–December 2008 alone; met 16% of the facility's total water usage; $3,500/year savings; $24,500 investment, ~6-year payback. Since the condensate was nearly distilled, there were no quality issues.

Energy/carbon impact: Water not drawn from the grid → avoided embedded energy in supply/distribution and wastewater treatment, and associated CO_2e.

USA – GSA Metcalfe Federal Building, Chicago/Illinois (tower facade)



Figure 2. GSA Metcalfe Federal Building – Chicago (USA)

What did they do? AC condensation was collected and fed into the tower makeup water.

Results: ~150,000 gallons/year water conservation; 15% of the tower's water demand was met by condensate; water going to the sewer was reduced.

Energy/carbon impact: Using low-conductivity condensate instead of potable water simplifies tower water management and reduces grid water-related energy/CO_2e.

USA – UT Austin Belo Center for New Media, Texas (irrigation; rain + condensation hybrid)



Figure 3. UT Austin – Belo/Dealey Center (USA)

What did they do? Roof rainwater and AC condensation were collected together and stored in a tank with a capacity of approximately 30 m³ (≈ 7,180 gallons × 4 tanks) for use in landscape irrigation.

Results: Average ~465,000 gallons/year of potable water savings and ~$2,700/year in cost reductions.

Energy/carbon impact: For every m³ not drawn from the grid, kWh and CO_2e impacts from water supply and wastewater treatment decrease; seasonal matching reduces storage pressure.

Singapore – Marina Bay Sands (landscape; multi-building application)



Figure 4. Marina Bay Sands – Singapore

What did they do? Condensate water is collected from ~3,000 AC units in three hotel towers and used for landscaping; the casino section was added in 2024.

Results: Average daily water savings of ~77,000 liters (≈ 20,000 gal/day).

Energy/carbon impact: Singapore PUB guidelines also recommend AHU condensate for tower makeup; lower conductivity means higher cycle (CoC) and less blowdown potential → reduced total water/chemical and indirect energy/CO_2e loads.

Table 7 - Water gain and WEC effect in global samples

Location & application	Annual water savings (approx.)	Usage	WEC effect (in short)
EPA SEDS, Athens, GA (USA)	~540,000 gallons (in 8 months)	Tower makeup	Water and wastewater treatment kWh/CO_2e avoidance; ~6-year payback period.
GSA Metcalfe, Chicago, IL (USA)	~150,000 gallons/year	Tower makeup	15% makeup without condensation; water/chemical and indirect energy load ↓
UT Austin – Belo Center (USA)	~465,000 gallons/year	Landscape irrigation	Drinkable water withdrawal ↓; seasonal supply-demand balance; indirect kWh/CO_2e ↓.
Marina Bay Sands (Singapore)	~7.7×10^4 L/day	Landscape	Potable/N.E.Water demand ↓; According to PUB guidelines, tower CoC↑ → bluff↓ potential.

6. Examples from Turkey

AND Kozyatağı Office Tower (Istanbul)



Figure 5. AND Kozyatağı Office Tower (Istanbul)

Roof/terrace rainwater + treated gray water from sinks + condensation water generated during building cooling are collected together; it is used for landscape irrigation, eliminating the need for tap water for irrigation. This is a powerful application that effectively reduces outdoor water demand to zero.

Palladium Tower (Ataşehir/Istanbul)



Figure 6. Palladium Tower (Ataşehir, Istanbul)

Condensation water and rainwater are collected together and reused in toilet tanks and landscape irrigation. This results in a significant reduction in total water consumption (LEED CS Gold).

Bursa Gas General Directorate Building (Bursa)



Figure 7. Bursa Gas General Directorate Building (Bursa)

Rainwater and air conditioning condensate are collected and used for landscape irrigation, reservoirs, and urinals (LEED Platinum). The application reduces both tap water consumption and wastewater volume.

Soyak Soho Office (Istanbul)



Figure 8. Soyak Soho (Istanbul)

Building air conditioning condensate water is collected and used in office restrooms; a typical internal usage scenario that reduces the embedded energy/carbon impacts in the water cycle (drinking water production/transportation and wastewater treatment).

Tekfen FNN Sustainability Center (Ceyhan/Adana)



Figure 9. Tekfen FNN Sustainability Center (Ceyhan, Adana)

Rainwater and condensation water systems provide 50% water efficiency; water is used in landscaping and reservoirs (LEED Platinum). Savings on this scale also reduce the indirect energy and carbon associated with water treatment/transportation.

7. Results and Recommendations

This study evaluates HVAC condensate water on-site at the building/campus scale, considering the water-energy-carbon relationship, health and safety, and economic feasibility dimensions. The findings reveal the following main results:

Source characteristics and positioning. Condensate water is a low-mineral-content stream originating from atmospheric moisture; it is not intended for drinking purposes but is technically suitable for non-potable applications such as landscape irrigation, cooling tower

makeup, toilet/urinal feed, and cleaning, provided that appropriate treatment and safe separation principles are followed.

Water-Energy-Carbon (WEC) effect. Each unit of condensate water used on-site reduces the embedded energy and carbon impacts associated with supply/distribution and wastewater treatment, thanks to water not being drawn from the grid; the additional energy load, consisting mainly of filtration–disinfection and pumping, is a relatively small portion. During the summer season, the production–demand timing creates a natural alignment, thereby also reducing storage pressure.

Application practices and hybrid solutions. Hybrid configurations such as rainwater co-storage, operational integration with cooling towers, and multi-point supply feeding through non-potable building infrastructure increase year-round supply continuity and overall savings. Continuous monitoring, recording, and identification (plate/label) discipline is critical in these integrations.

Health and risk management. In applications with aerosol potential, a risk-based water management program (WMP), control points, monitoring frequencies, and corrective actions must be documented. Limiting the stagnation period in storage, drainage/tray hygiene, and regular maintenance directly affect both quality and quantity.

Economy and sensitivity. In the life cycle approach, CAPEX (collection line, treatment modules, storage, automation) and OPEX (energy, chemicals, maintenance) should be evaluated together. The payback period is primarily sensitive to water/wastewater tariffs, energy prices, seasonal production and usage scenarios; financial attractiveness increases particularly in hot-humid climates and commercial buildings with long operating hours. In tower makeup, cycle count (CoC) optimization due to low TDS can result in additional water/chemical savings.

Regulatory and standard requirements. In Turkey, there is a limited binding framework specific to condensate water. In practice, adaptations are made from rainwater/gray water regulations; developing national guidelines/specifications based on the ASHRAE/CDC-based WMP approach will strengthen consistency in project approval and operational processes (CDC, 2024; ASHRAE).

Thanks and Information Notes

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Altensis. (n.d.). FNN Sürdürülebilirlik Merkezi (Ceyhan/Adana): Yağmur + yoğuşma suyu; rezervuar ve sulama uygulamaları. https://www.altensis.com

Altensis. (n.d.). Palladium Tower (Ataşehir/İstanbul): Yoğuşma + yağmur suyu; rezervuar ve peyzajda yeniden kullanım. https://www.altensis.com

Austin Water. (2024). Onsite water reuse program guidebook. City of Austin Water. https://www.austintexas.gov/department/water

Centers for Disease Control and Prevention. (2024). Toolkit: Developing a Legionella water management program (WMP). https://www.cdc.gov/legionella/wmp/toolkit

Centers for Disease Control and Prevention. (2025). Toolkit for controlling Legionella in common sources of exposure (All modules). https://www.cdc.gov/legionella/wmp

EKOYAPI Dergisi. (2015). Soyak Soho: Yoğuşma suyunun ofis WC'lerinde kullanımı. https://www.ekoyapidergisi.org

Hamawand, I., et al. (2023). Energy consumption in water/wastewater treatment and management. *Energies, 16*(x), Article xxxx. https://www.mdpi.com

Kitessa, B. D., et al. (2020). Quantifying water–energy nexus for urban water systems. *AIMS Environmental Science, 7*(x), xxx–xxx. https://www.aimspress.com

Landscape Architecture Foundation. (2015). Belo Center for New Media (UT Austin): Case study brief. https://www.landscapeperformance.org

Lee, M., et al. (2017). Water–energy nexus for urban water systems. UC eScholarship Working Paper. https://escholarship.org

Marina Bay Sands. (2024). Responsible business highlights: Condensate recovery program. https://www.marinabaysands.com

National Blue Ribbon Commission for Onsite Non-potable Water Systems & US Water Alliance. (2023). Guidebook for developing and implementing regulations for onsite non-potable water systems. https://uswateralliance.org

New York City Department of Health and Mental Hygiene. (2025). Nonpotable water systems guidance manual. https://www.nyc.gov/site/doh

Public Utilities Board, Singapore. (2021). Water efficiency in buildings: Case studies. https://www.pub.gov.sg

San Francisco Public Utilities Commission. (2022). Onsite water reuse program guidebook. https://sfpuc.org

Termodinamik. (n.d.). Bursagaz Genel Müdürlük Binası (LEED Platin): Yağmur + klima yoğuşma suları; peyzaj, rezervuar, pisuar. https://www.termodinamik.com.tr

Texas Water Development Board. (2018). Best management practices for commercial and institutional water users. https://www.twdb.texas.gov

U.S. Department of Energy, Federal Energy Management Program. (2010). Case study: Air handler condensate recovery at EPA's Science & Ecosystem Support Division (Athens, GA). https://www.energy.gov/femp

U.S. Department of Energy, Federal Energy Management Program. (2025). Best management practice #10: Cooling tower management. https://www.energy.gov/femp

U.S. Environmental Protection Agency. (2015). Condensate recovery—GSA Metcalfe Federal Building, Chicago (Case study). https://www.epa.gov

U.S. Environmental Protection Agency. (2018). Onsite non-potable water reuse research: Fact sheet. https://www.epa.gov

U.S. Environmental Protection Agency. (2023). WaterSense at work—Section 6.3: Cooling towers. https://www.epa.gov/watersense

U.S. Environmental Protection Agency. (2024). 2024 Onsite water reuse summit: Summary. https://www.epa.gov

U.S. Geological Survey. (2024). Where is Earth's water? https://www.usgs.gov

UNEP Copenhagen Climate Centre. (2023). Water–energy nexus in urban water supply systems (Issue brief). https://unepccc.org

UNESCO World Water Assessment Programme. (2024). The United Nations world water development report 2024: Water for prosperity and peace. UNESCO. https://www.unesco.org/water-wwap

WHO & UNICEF Joint Monitoring Programme. (2025). Progress on household drinking water, sanitation and hygiene 2025. https://washdata.org

World Resources Institute. (2023). Aqueduct 4.0—Country rankings (Dataset). https://www.wri.org/aqueduct

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Contributions of the "Placemaking" Approach to the Urban Environment

Pınar Özge PARLAK [1]*

ORCID 1: 0000 - 0002 - 3905 - 1871
[1] Research Assistant, Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon- Türkiye
yenicirak.ozge@gmail.com (Responsible Author)

Elif BAYRAMOĞLU [2]

ORCID 2: 0000-0002-6757-7766
[2] Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture Trabzon-Türkiye
elifsol_@hotmail.com

Abstract

With the acceleration of urbanization processes, it has become imperative to develop new approaches to address the problems of urban spaces that are becoming increasingly devoid of identity and inadequate in meeting user needsPublic spaces are multifunctional areas where people connect their work, home, shopping, and social relationships in everyday life. The concept of "Placemaking," based on Jane Jacobs and William Whyte's human-centered approach to public spaces in the 1960s, has developed into an internationally recognized approach today, thanks to the contributions of organizations such as the Project for Public Spaces (PPS). The concept of placemaking addresses a participatory process in which public spaces are reshaped not only through physical arrangements but also through social, cultural, and economic dynamics. This concept aims to transform public spaces into living areas where people will choose to work, meet, play, and learn. Within the scope of this study, the placemaking approach will examine four fundamental qualities that determine the quality of public space: accessibility and connections, comfort and image, usage and activities, and sociality. The contributions of the concept to the urban space will be examined under the headings of improving spatial quality and accessibility, strengthening social interaction and community belonging, cultural production and identity building, economic vitality, and sustainability. However, parameters such as gentrification and limited participation levels can weaken the inclusiveness of the approach. Therefore, the concept should be evaluated not only as a design tool but also in terms of the quality and continuity of social participation. Consequently, placemaking, as an inclusive tool that encourages community participation in transforming spaces, offers a comprehensive framework that strengthens the social resilience and sustainability of urban spaces.

Keywords: Public space, placemaking, place quality

1. Introduction

The diversification of cities through economic and social dynamics in order to meet the needs of their growing populations is bringing about transformations in both the physical form and social functions of the urban fabric. Public spaces that influence the relationship between the city and urban society are areas where individuals interact by establishing relationships with their physical environment and other community members and sharing experiences (Uysal Bilge, 2021). The fact that it is effective in creating a collective identity, community consciousness, and sense of security (Hampton et al., 2014; Riberio et al., 2015; Sınmaz, 2015) necessitates that public "space" be evaluated not only as a physical entity but also as a "place" shaped by experience, belonging, and meaning.

The concepts of space and place are concepts that have been addressed in many different disciplines, from phenomenology to geography, philosophy, architecture, urban design, and landscape architecture. First, in 1974, Yi-Fu Tuan drew attention to the transformation of space

into place through memories, emotional ties, and personal experiences, describing space as an area of movement and freedom, and place as an area of security. Then, in 1976, Relph stated that space, an area whose boundaries cannot be clearly defined, becomes a place with a soul, gaining identity and meaning as individuals reflect their own selves, experiences, and routines onto it. Explaining the concept of place through "genius loci," Norberg-Schulz (1980) emphasizes that the essence of a place is determined by the environmental character of the space. Trancik (1991) states that space, when limited by multiple connections and purposes, acquires environmental and cultural meanings and thus constitutes a place. In 1992, Altman and Low, within the context of human-place interaction, examined place through its components of form, function, and meaning, emphasizing that humans are a decisive factor in the formation of place (Yurtseven & Oğuz, 2023). Such intellectual developments and critiques of modernist planning have contributed to the understanding of space not merely as a functional area, but as a place that gains meaning through human experience. Thanks to all these developments, the foundations of the concept of "placemaking" have been laid, which focuses more on social meaning and user experience than physical form, aiming to strengthen the identity and sense of belonging of a place.

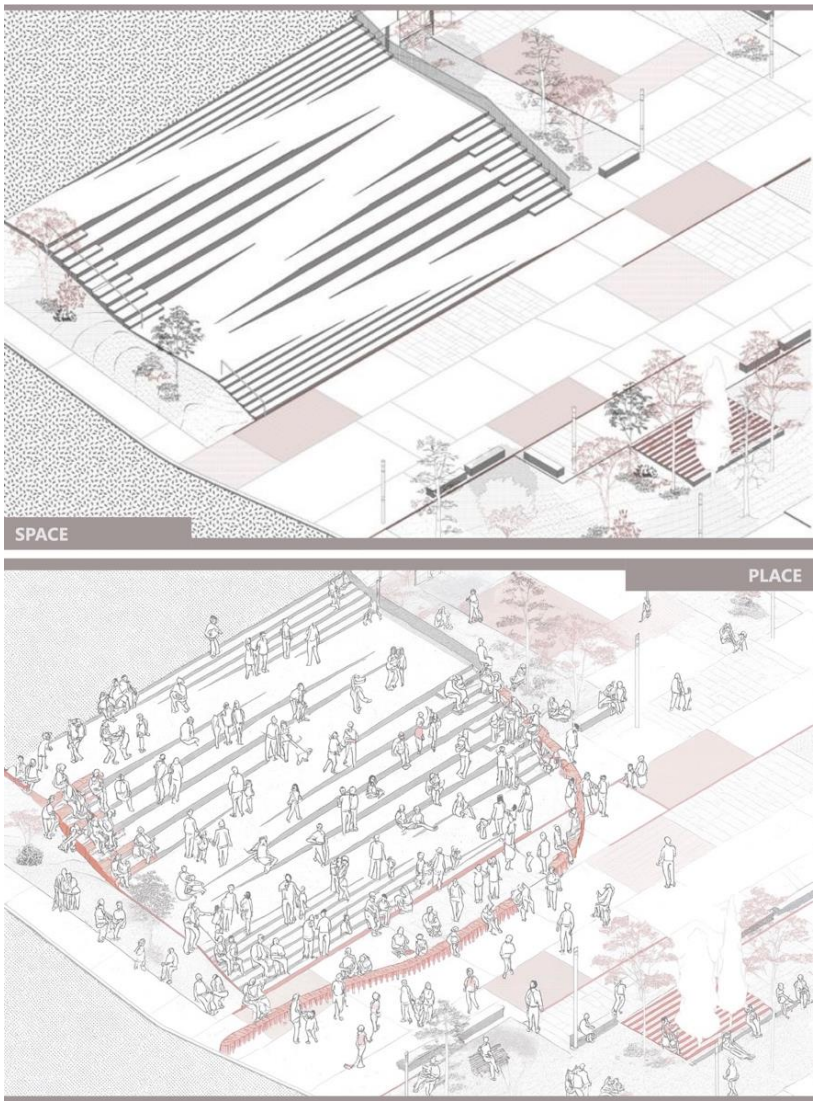


Figure 1. Representation of the space's transformation process URL1, 2025)

2. Theoretical Framework and Contributions to the Urban Environment

Public spaces that focus on the dynamics between community and place function as hubs of social interaction, identity formation, and mutual support (Asadollahi Asl Zarkhah et al., 2025). In The Death and Life of Great American Cities (1961), Jane Jacobs emphasized that public spaces should be shaped by users' everyday practices rather than by planning authorities (White, 2011; Jacobs, 2017). Similarly, in The Social Life of Small Urban Spaces (1980), William Whyte argued that the quality of a public space is determined by the frequency of social interactions and the desire of people to remain there, highlighting design as an instrument that supports such behavior (Whyte, 1980). Jan Gehl later asserted in Cities for People (2010) that cities designed according to the human body and behavioral rhythm can be regarded as successful, and that the vibrancy of public spaces reflects the health of a city (Gehl, 2020; Zapata & Honey-Rosés, 2020). The contribution of such thinkers to the literature, suggesting that public spaces derive meaning from human experience rather than physical form, has laid the theoretical foundation for the concept of placemaking today. Placemaking refers to the process of developing public spaces in a way that takes into account both their physical and social characteristics, aligning them with the values, history, culture, and natural environment of various stakeholder groups (Castell, 2006; Habibah et al., 2013; Furlan et al., 2019; Dash & Thilagam, 2023).

The concept of "Placemaking," based on a human-centered approach to public spaces, has developed into an internationally recognized approach today, thanks to the contributions of organizations such as Project for Public Spaces (PPS). PPS has identified four fundamental characteristics for the successful definition of a public space, regardless of scale, from city squares to neighborhood parks. These are: (1) being accessible and well connected to other important places in the surrounding area, (2) being comfortable and projecting a good image, (3) encouraging participation in activities, and (4) creating a social environment that makes people want to visit again and again.

- ***Access and Linkages:*** The effectiveness of public spaces is associated with their ability to ensure movement and permeability through high accessibility and the strong connections they establish with their surroundings (Gupta et al., 2025). It is easy to reach and navigate a successful public space, and the space is designed so that users can perceive activities both up close and from a distance (Project for Public Spaces. 2018).

- ***Comfort and Image:*** Another feature of a successful public space is that it is comfortable and inviting. Safety, cleanliness, environmental quality, and sensory experiences are associated with comfort, and shade, seating elements, and lighting help increase user satisfaction and encourage use (Project for Public Spaces. 2018; Gupta et al., 2025).

- ***Uses and Activities:*** Place offering a variety of events form the basis of successful public spaces and encourage people to come to the area while supporting social interaction. Active and passive uses at different times of the day attract different age groups and audiences, ensuring the continuity of space usage (Anderson et al., 2017; Project for Public Spaces, 2018).

- ***Sociability:*** The most challenging feature for a space to possess, social interaction, is supported by design solutions that encourage community participation and a sense of belonging (Anderson et al., 2017; Project for Public Spaces, 2018).

These four points defined by Project for Public Space relate to the observable and design-related concrete, spatial, or functional qualities of a space. As shown in Figure 2, the second ring of

the diagram relates to the abstract perceptual and emotional qualities of the space that are difficult to measure based on user experience, such as attractiveness, neighborliness, appeal, and community ties. Third-tier indicators, such as the number of female, child and elderly users, property values and hygiene levels, measure space quality using numerical or observation-based parameters. In short, the fundamental characteristics used to evaluate the quality of a public space represent the main themes that make a place good, the abstract elements represent what that place makes people feel, and the measurable indicators represent the parameters that prove the quality of that place.

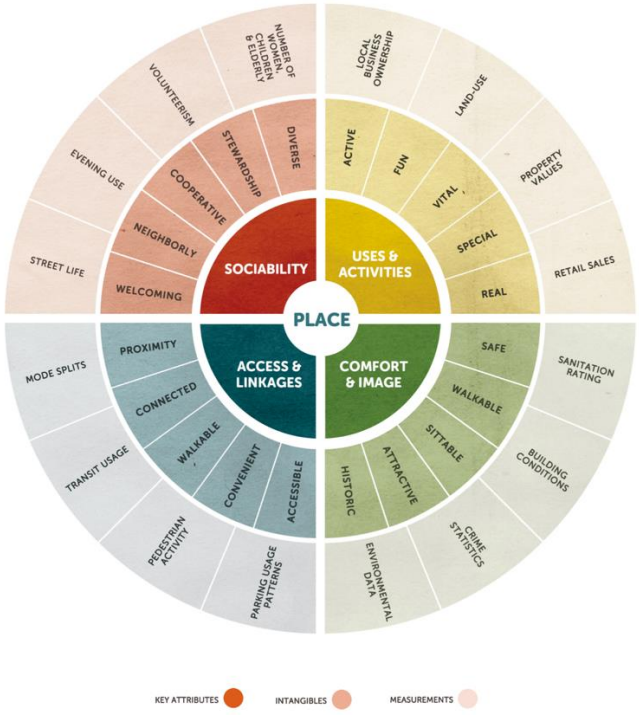


Figure 2. Project for public space place diagram (Project for Public Spaces. 2018)

This participatory approach, which focuses on a collaborative process, empowers urban communities to have a say in shaping their surroundings. By fostering cooperation and trust among diverse community members and disadvantaged groups, it helps strengthen the social fabric and sense of belonging. Activities and shared experiences in public spaces create opportunities to strengthen collective identity and cohesion. The bonds formed between communities foster a sense of ownership, which in the long term contributes to social resilience and societal well-being. Although place-making focuses on social and spatial design, public space design also highlights issues such as ecological sustainability, green infrastructure, biodiversity, and the use of local materials due to sustainability and the value placed on people. By encouraging communities to be environmentally conscious and care for their surroundings, and by raising awareness about the relationship between social well-being and the health of the urban environment, it contributes to urban ecological balance. Inviting and safe public spaces that enhance the appeal of city centers increase customer potential for nearby businesses, while events, markets, and cultural activities held within the area help keep the economy vibrant by creating opportunities for local vendors and entrepreneurs. Community-focused public spaces that create an environment where communities with different cultures and identities can come together and express themselves promote intercultural exchange and innovation, thereby

increasing the city's inclusiveness. Furthermore, this approach supports the transformation of underused or neglected sites into high-quality, functional urban spaces, contributing to the improvement of urban environments (Canadian Urban Institute & Economic Developers Council of Ontario, 2022).

3. Application Examples

As stated in the European Landscape Convention, public spaces, the foundation of identity, are an expression of individual and social well-being, collective life, and the diversity of shared natural and cultural values. Therefore, society discovers itself in public spaces and strives to improve their spatial quality (UN-Habitat, 2015). UN-Habitat (2015) categorizes public spaces into two categories and six classes: physical (streets, public open spaces, public urban facilities) and non-physical (public realm, the city itself, virtual reality). Streets are the most frequently used multi-purpose spaces in daily life, such as avenues, boulevards, sidewalks, and bicycle paths, accessible free of charge at all hours of the day and maintained by the public, where events such as open-air markets, demonstrations, and rallies can take place. Public open spaces refer to free publicly maintained areas such as parks, gardens, playgrounds, public beaches, and riverbanks. Public urban facilities refer to public facilities with high maintenance costs and limited access times, such as public libraries, community centers, municipal markets, and sports facilities. Non-physical public space refers to the institutional space where society delegates power and resources to authorities for the common good. The city, another non-physical public space, emerges as a symbolic space dedicated to, shared by, and entrusted to society. Public space, referred to as virtual reality and considered to pose a risk of diminishing physical social contact, refers to the virtual interaction created by the internet and social networks. Below, selected public spaces, based on the placemaking approach, are evaluated based on criteria such as access and linkages, comfort and image, use and activities, and socialization

- **Bryant Park, New York**

The area now known as Bryant Park was originally constructed in 1842 as a four-acre reservoir and transformed into an urban open space with the addition of Reservoir Park in 1870. This area, which eventually became known as Reservoir Square, was replaced by the New York Public Library in 1911 after the reservoir ceased functioning in 1890. Bryant Park, located behind the building, was named in honor of the poet William Cullen Bryant. Redesigned in 1934 by the New York City Department of Parks, the park was elevated above the surrounding busy streets and conceived as an “urban refuge.”. However, this closed and isolated structure has led to an increase in crime rates over time. In 1981, a report was prepared by William H. Whyte and the Project for Public Spaces, and a new design plan for the park was developed based on this report. Under this plan, narrow entrances have been widened, fences have been removed, cafeterias and event areas have been added, and security and maintenance systems have been strengthened. As a result of this transformation, Bryant Park has become a safe, accessible, active, and social public space; it has increased the value of surrounding real estate by 60%, becoming a focal point that supports the economic and social vitality of the area (PPS, 2002; URL2, 2017).



Figure 3. Bryant Park transformation process (URL2, 2017; URL3, 2025; URL4, 2024)

The renovation project carried out at Bryant Park, which involved removing the fences surrounding the park and opening numerous entrances to adjacent streets, has improved pedestrian flow and enhanced ***access and linkages***. The ability to move over 1,000 chairs within the park when needed, the diversification of landscaping, and the improvement of lighting and enhanced cleaning and maintenance practices have contributed to the park's safe and inviting atmosphere, supporting its ***comfort and image.*** Daily event calendars featuring reading rooms, markets, chess and backgammon tables, concerts, and outdoor movie screenings have been prepared to increase the ***variety of activities*** and keep the park lively at all hours of the day. The various seating arrangements in the park, open-air events, and free activities have encouraged gathering and ***socializing***, supporting the creation of a collective public space. During the restoration process, the library required additional book storage facilities. Landscape architect John M. Carrere proposed placing these storage facilities beneath the park, thereby transforming the park surface into a large-scale green area covering the roof of the underground archive. The library and underground storage areas are connected by a 62-meter tunnel, ventilation shafts are concealed among the plant borders, emergency exits are located beneath commemorative plaques, and stone pavements and iron railings from the 1934 plan were salvaged for reuse and returned to the park. As a result of these measures, Bryant Park has become an example of a green roof that represents both aesthetic and functional sustainability (ASLA, 2010).



Figure 4. Various events at Bryant Park (ASLA, 2010; URL5, URL6, URL7, URL8, 2025)

- **Campus Martius Park, Detroit**

The Campus Martius area, used as a national training ground in the 1800s, was selected as the city's Point of Origin after a fire in 1805 and hosted military ceremonies and the Michigan Soldiers Monument in 1847 (URL13, 2025). In the 1900s, due to increasing vehicle traffic in the city and highway conversions, the park was largely covered with parking lots and asphalt, losing its public function. By the 2000s, the city's population had gradually declined, the city center had been largely abandoned, and nearby stores had closed and been demolished. Vacant lots cause crime rates to rise due to vehicle density, while pedestrian life in the city has gradually declined. In 2001, the goal was to build a new park to revitalize the urban center. To this end, PPS conducted surveys and observations to develop the design concept and determine the design requirements based on the community's needs. Following this process, a design competition was held, and it was decided that Woodward Fountain would be placed in the park as a central and symbolic feature, flexible stage areas would be created to accommodate different events, a café serving visitors would be added, and connections would be established to ensure pedestrian continuity with the surrounding streets. Opened in 2004 and proving highly successful, the park implemented a highly popular urban beach initiative in 2013 to increase the time users spent in the park, social interaction, and the liveliness of the city center, thereby significantly enhancing the appeal and effective use of the public space (PPS, 2008).

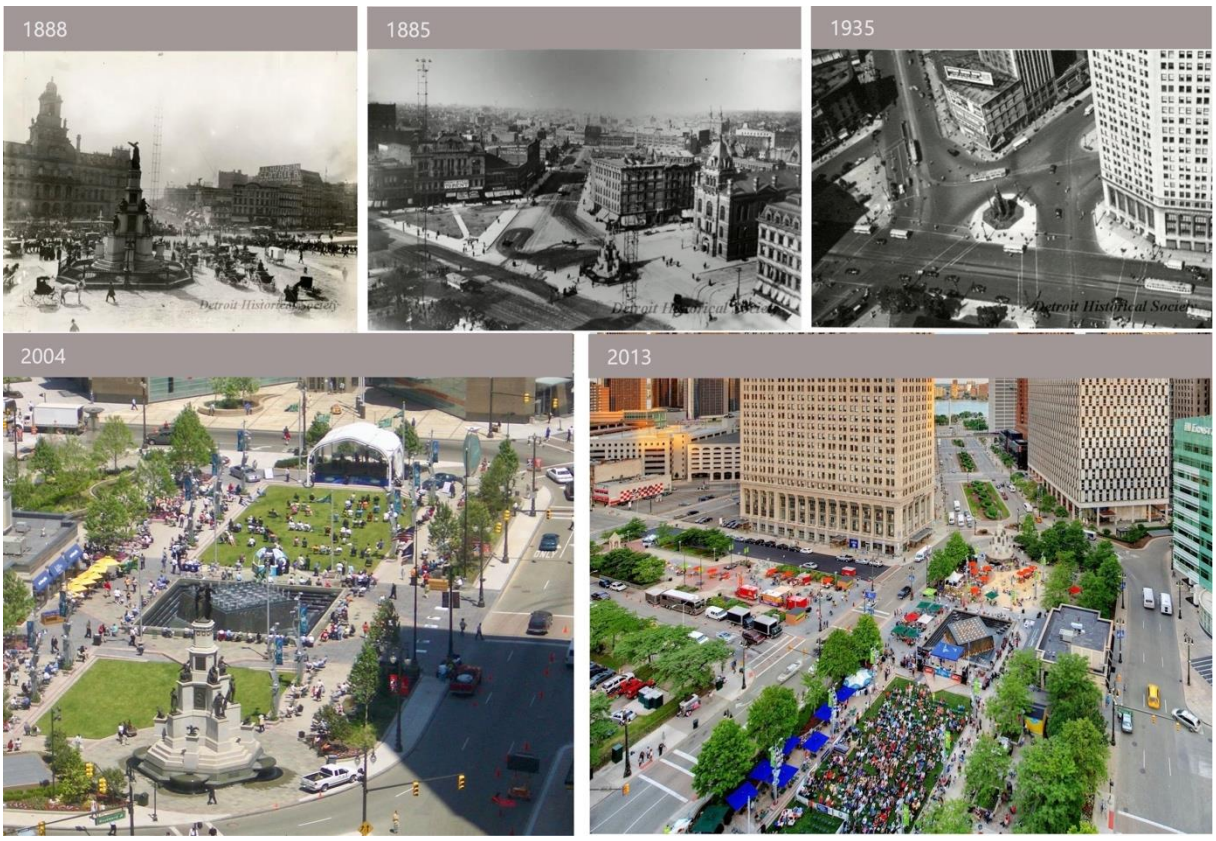


Figure 5. Campus Martius Park transformation process (URL9, URL10, URL11, URL12, 2025)

Campus Martius Park's location at the intersection of six main streets and its transformation into a pedestrian-priority circulation system approach has enabled users to access the area safely and easily. Extending the park's ground texture to the surrounding buildings and sidewalks has

provided visual and physical continuity, strengthening the park's ***accessibility and linkages***. The iconic Woodward Fountain, located in the center of the park, where water interacts with light and music; while creating an ***image*** by enhancing the visual quality of the area with the use of various plants that will provide shade, color, and visual diversity throughout the year, granite seating steps, stone walls, and low-maintenance gravel surfaces; Water walls positioned on the west side of the park to reduce environmental noise have increased user ***comfort*** in the park. The grassy area, stone steps, and hydraulic stage systems arranged at a low elevation next to the Woodward fountain provide flexible use for various activities such as concerts, markets, and shows. With its urban beach application and the conversion of grassy areas into ice rinks during the winter months, the park offers different ***uses and activities*** throughout the year. The relocation of the Michigan Soldiers monument, located in the center of the area, to a different location in the park, along with the addition of new vertical monuments, contributes significantly to the construction of social memory. Thanks to its flexible spatial design and variety of activities, the area encourages ***socialization*** among groups of different ages and cultures, thereby strengthening the city's identity.



Figure 6. Various events at Campus Martius Park (URL14, UR15, 2025)

4. Conclusion

In conclusion, placemaking, as an inclusive tool for transforming spaces by encouraging community participation, offers a comprehensive framework that strengthens the social resilience and sustainability of urban spaces. Therefore, public spaces that are inaccessible or idle/unusable should be considered and evaluated as a potential resource for enhancing urban quality. However, parameters such as gentrification and limited participation levels can weaken

the inclusiveness of the approach. Placemaking should be evaluated not only in terms of spatial design, but also in terms of the interaction, continuity, and decision-making power of the actors involved in the process. The placemaking approach, which redefines urban development as a shared process, contributes to a sustainable urban vision by integrating social, ecological, economic, and spatial quality dimensions, and serves as a strategic tool for contemporary urban transformation policies.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Anderson, J., Ruggeri, K., Steemers, K., & Huppert, F. (2017). Lively social space, well-being activity, and urban design: findings from a low-cost community-led public space intervention. *Environment and Behavior*, *49*(6), 685-716.

Asadollahi Asl Zarkhah, S., Harteveld, M., van Dorst, M., & Adlakha, D. (2025). The socio-spatial roles of public space as an enabler for community resilience. *Urban Design International*, 1-10.

ASLA (2010). https://www.asla.org/2010awards/403.html. Erişim tarihi: 28.10.2025

Canadian Urban Institute, & Economic Developers Council of Ontario. (2022). *My Main Street: Placemaking toolkit.* Federal Economic Development Agency for Southern Ontario. https://mymainstreet.ca/activator-program

Castell, P. (2006). Space for community – the study of resident involvement in neighbourhood space management. *WIT Transactions on Ecology and the Environment*, 93, 703–712.

Dash, S. P., & Thilagam, N. L. (2023). "Creative placemaking": a conceptual model fostering social cohesion in community spaces within residential environments. *Creativity Studies*, *16*(2), 541-564.

Furlan, R., Petruccioli, A., & Jamaleddin, M. (2019). The authenticity of place-making: Space and character of the regenerated historic district in Msheireb, Downtown Doha (State of Qatar). *ArchnetIJAR*, 13(1), 151–168.

Gehl, J. (2020). *İnsan İçin Kentler* (Çev. Erdem Erter). Koç Üniversitesi Yayınları. (Original 2010)

Gupta, A., Yadav, M., & Nayak, B. K. (2025). A Systematic Literature Review on Inclusive Public Open Spaces: Accessibility Standards and Universal Design Principles. *Urban Science*, *9*(6), 181.

Habibah, A., Mushrifah, I., Hamzah, J., Er, A. C., Buang, A., Toriman, M. E., Selvadurai, S., & Zaimah, R. (2013). Place-making of ecotourism in Tasik Chini: From exploratory to the contemporary biosphere reserve. *Asian Social Science*, 9(6), 84–95.

Hampton, K.N., Goulet, L.S. and Albanesius, G. 2014. Change in the Social Life of Urban Public Spaces: The Rise of Mobile Phones and Women, and the Decline of Aloneness Over Thirty Years. *Urban Studies* 52. s.1489-1504.

Jacobs, J. (2017). *Büyük Amerikan Şehirlerinin Ölümü ve Yaşamı* (Çev. Bülent Doğan). Metis Yayınları. (Original 1961)

PPS (2008). https://www.pps.org/article/mcintyrelanov2006. Access date: 28.10.2025

PPS. (2002). https://www.pps.org/places/bryant-park. Access date: 28.10.2025

Project for Public Spaces. (2018). *Placemaking: What if we built our cities around places?* Project for Public Spaces, Inc.

Ribeiro, A.P., Barranha, H. and Pereira, R. 2015. Towards the metaphorical transformation of urban space: Digital Art and the City after Web 2.0. 1st International Symposium Global Cities and Cosmopolitan Dreams. International Network for Alternative Academia. Barcelona, 18-20 May 2015.

Sınmaz, S. (2015). Gelişen iletişim teknolojilerinin kentsel yaşam ve kamusal mekânlar üzerindeki yansımaları. *Tasarım+ Kuram*, *11*(20), 63-75.

Trancik, R. (1991). *Finding lost space: theories of urban design*. John Wiley & Sons.

UN-Habitat. (2015). *Global public space toolkit: From global principles to local policies and practice*. United Nations Human Settlements Programme (UN-Habitat).

URL1 (2025): https://pin.it/1HndpXokN, Access date: 26.10.2025

URL2 (2017): https://bryantpark.org/blog/history. Access date: 28.10.2025

URL3 (2025): https://www.nycgovparks.org/about/history/before-they-were-parks/manhattan. Access date: 28.10.2025

URL4 (2024): https://www.newyorkinfo.nl/en/sights-in-new-york/bryant-park-in-new-york/. Access date: 28.10.2025

URL5 (2025): https://pin.it/5jTvhYj9D. Access date: 28.10.2025

URL6(2025)https://www.google.com/imgres?imgurl=https%3A%2F%2Fassets.isu.pub%2Fdocument-structure%2F240517144304-a10d48cd6168d20fdd45c75ee33724ad%2Fv1%2F171333e91e2a4d83948a74df282dcc8b.jpeg&tbnid=F3uI6cFVvrPhdM&vet=10CAYQxiAoAmoXChMIsJD5gYTJkAMVAAAAAB0AAAAAEAc..i&imgrefurl=https%3A%2F%2Fissuu.com%2Fbryant_park%2Fdocs%2Fmap_guide-2024&docid=tRz5T1msMn8mgM&w=1671&h=1400&q=bryant%20park&ved=0CAYQxiAoAmoXChMIsJD5gYTJkAMVAAAAAB0AAAAAEAc. Access date: 28.10.2025

URL7 (2025): https://www.nyc.gov/assets/lpc/downloads/pdf/presentation-materials/20250617/Bryant-Park.pdf. Access date: 28.10.2025

URL8 (2025): https://pin.it/7gZ75agE9. Access date: 28.10.2025

URL9 (2025): https://www.detroithistorical.org/learn/online-research/collection/photo/print-photographic-5320 Access date: 28.10.2025

URL10 (2025): https://www.detroithistorical.org/learn/online-research/collection/photo/print-photographic-5316 Access date: 28.10.2025

URL11 (2025): https://www.detroithistorical.org/learn/online-research/collection/photo/print-photographic-8274 Access date: 28.10.2025

URL12 (2025): https://www.sociallifeproject.org/the-transformation-of-the-center-of-detroit/ Access date: 28.10.2025

URL13 (2025): https://www.detroithistorical.org/learn/online-research/encyclopedia-of-detroit/campus-martius-park Access date: 28.10.2025

URL14 (2025): https://www.sociallifeproject.org/the-transformation-of-the-center-of-detroit/ Access date: 28.10.2025

URL15 (2025): https://www.reasite.com/projects/campus-martius-park Access date: 28.10.2025

Uysal Bilge, F. (2021). Kamusal alanların evrilmesi. *Mimarlık ve Yaşam*, *6*(1), 141-156.

White, R. (2011). *Jane Jacobs and Toronto, 1968–1978. Journal of Planning History, 10*(1), 53–71. https://doi.org/10.1177/1538513210385787

Whyte, W. H. (1980). *The Social Life of Small Urban Spaces.* Project for Public Spaces.

Yurtseven, B. & Oğuz, D. (2023). Evaluation of the concepts of "space, place and loss of place" through examples. GRID Architecture, *Planning and Design Journal*, 6(2), 805-836.

Zapata, M., & Honey-Rosés, J. (2020). The behavioral response to increased pedestrian and staying activity in public space: A field study of two Canadian Plazas. *Journal of Urban Design, 25*(6), 661–681. https://doi.org/10.1080/13574809.2020.1751349

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Nature-Based and Digital Solutions for Flood- Resilient Urban Systems

Pınar Özge PARLAK [1]*

ORCID 1: 0000-0002-3905-1871
[1]Research Assistant, Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon- Türkiye
yenicirak.ozge@gmail.com (Responsible Author)

Elif BAYRAMOĞLU [2]

ORCID 2: 0000-0002-6757-7766
[2]Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture Trabzon-Türkiye
elifsol_@hotmail.com

Abstract

In the Anthropocene era, where human activities have significantly shaped the planet, climate change has become a global crisis causing rising global temperatures, changes in rainfall patterns, and extreme weather events. Rapid urbanization and changes in land use have led to an increase in built-up areas, disrupting natural hydrological processes in urban areas and making these areas more vulnerable to the effects of climate change. This situation also causes climate change to intensify rainfall patterns, overloading urban drainage systems and increasing the frequency and severity of floods. Current approaches demonstrate that traditional engineering solutions alone are insufficient for managing flood risks, while integrated systems provide longer-term and sustainable solutions. Today, integrating smart city technologies with nature-based solutions is gaining prominence in order to increase the resilience and sustainability of cities; this approach produces innovative solutions by combining real-time data and automation with ecological design. Nature-based solutions seek to manage floodwaters through natural processes by enhancing ecosystem services, while digital technologies aim to increase intervention capacity by predicting flood risks using IoT sensors, satellite-based early warning systems, and data analysis. The integration of digital technologies and nature-based solutions facilitates the effectiveness and traceability of ecological interventions. This study will examine the complementary aspects of nature-based solutions and digital technologies and discuss the opportunities these approaches offer in designing resilient cities.

Keywords: Climate change, flood resilience, nature-based solutions, smart cities

1. Introduction

Cities, which are places of economic development, political change, and the emergence of new values and attitudes, have a significant impact on preparing the ground for social and technological developments (Alkan, 2022). Today, 55% of the world's population lives in urban areas, and this figure is projected to rise to 68% by 2050 (United Nations, 2019). Population concentration in urban areas triggers rapid urbanization processes and significant changes in land use; this situation has negative effects on water quality and hydrological processes (Qin et al., 2013; Mottaghi et al., 2016; Berndtsson et al., 2019). The inadequacy of urban drainage infrastructure systems and the increase in impervious surfaces due to land use changes have made cities more vulnerable to flooding caused by the intensity of rainfall resulting from climate change (Abbasov, 2025). It is accepted that traditional engineering solutions are insufficient in protecting cities against flood risks, and that integrated systems produce more

effective solutions instead. Smart cities utilize digital technologies such as sensors, IoT, and data analytics to optimize urban systems and improve quality of life. Nature-based solutions, on the other hand, seek to address urban challenges such as climate adaptation, air quality, and biodiversity loss by utilizing or mimicking natural processes and ecosystems. In this context, nature-based solutions that aim to manage floodwaters through natural processes using applications such as permeable surfaces, rain gardens, water squares, and ecological corridors, combined with real-time data collection, early warning systems, and IoT sensors, offer an innovative approach to increasing flood risk monitoring and management capacity in urban areas. The integration of smart city technologies with nature-based solutions has led to the emergence of smart nature-based solutions that combine real-time data and automation with ecological design to create resilient and sustainable cities (Kaluarachchi, 2021).

2. Smart Nature-Based Solutions

The increasing frequency and severity of urban flooding caused by climate change has highlighted the need for new approaches that will strengthen cities' capacity to adapt to climatic and hydrological processes. Nature-based solutions, such as green infrastructure, artificial wetlands, and permeable surfaces, reduce urban heat island and flood risks, and improving air quality by mimicking nature's ecological wisdom, contributing to urban sustainability and resilience. Meanwhile, smart systems capable of performing complex tasks such as artificial intelligence, the Internet of Things, and data analytics facilitate the monitoring of environmental factors in urban areas, contributing to the mitigation of urban environmental challenges through early intervention and adaptive management. Smart nature-based solutions are an approach that combines the ecological compatibility and functionality of nature-based solutions with the data-driven and automation capabilities of information systems. Nature-based solutions aim to reduce flood risks and ensure the sustainability of ecosystem services by combining nature's self-regulating mechanisms with information technologies (Li & Nassauer, 2021). Digital tools facilitate public participation and feedback, while data-driven decision-making processes enable participatory urban governance by supporting urban planning and resilience strategies (Kolokotsa et al., 2023; Wellmann et al., 2023). Sensor-supported urban forest management, smart green roof systems, automated wetland control, sensor-based dust suppression areas, IoT-supported rainwater management, and adaptive coastal protection applications with smart nature-based solutions not only mimic natural processes but also optimize them with data, contributing to the more effective, flexible, and scalable management of environmental issues in cities (Bressane et al., 2024).

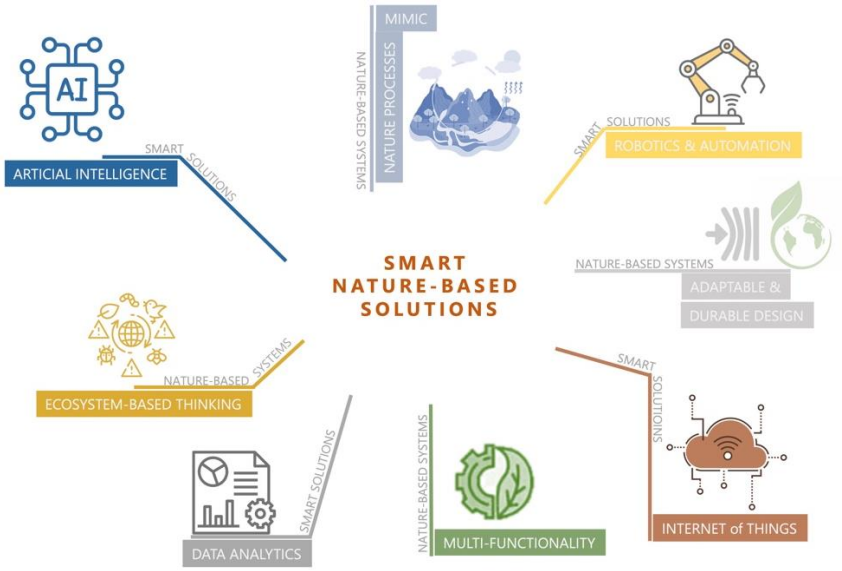


Figure 1. Smart Nature-Based Solution Components (Bressane et al. (2024) was consulted)

Examples of Smart Nature-Based Solutions

a. **Digital Twin:** The digital twin approach is based on creating a virtual copy of a physical process or system and establishing real-time data flow between the physical system and the virtual environment. This approach is also used to monitor and optimize the performance of nature-based solutions. Nature-based solution systems are approached as decision support and performance monitoring tools by creating a dynamic, updatable digital copy using sensors, modeling, and data flow (Brasil et al., 2022). Following a series of devastating floods in Singapore, the city recognized that due to intensive urbanization and land conditions, flood management required not only engineering-based solutions but also data and simulation-focused approaches. It began using digital twin technology as a strategic tool to increase urban resilience against flood risk. The Singapore Land Authority (SLA) has developed a national digital twin covering the entire country called Virtual Singapore by using aircraft and ground vehicles equipped with laser scanners to transfer topographic data, urban land, buildings, infrastructure, and drainage systems to a digital environment with millimeter accuracy. This digital twin contributes to the development of early warning mechanisms against potential floods by providing real-time sensor data. During periods of heavy rainfall, the flow direction of water, accumulation areas, and high-risk zones are identified in advance, enabling data-driven planning of interventions and improvements to the drainage infrastructure. Therefore, Singapore has developed an effective integrated decision support system that combines nature-based and technology-enabled solutions to support flood management, land use optimization, and urban resilience planning under conditions of limited land and dense population (Walker, 2023).



Figure 2. Singapore's digital twin examples (Walker,2023; URL1, 2025)

b. **Smart Rainwater Ponds:** Smart rainwater ponds are an enhanced version of rain gardens or ponds created for rainwater storage, supported by digital sensors, automatic control systems, and prediction models. Sensors that regularly monitor water level, rainfall amount, flow rate, and weather conditions collect data, send it to the monitoring and control platform in real time, and the reservoir outlet structures are managed based on this data and meteorological forecasts. If heavy rainfall is predicted, controlled drainage is implemented to increase storage capacity, and during flooding, water is either retained or released in a controlled manner. This reduces the risk of flooding and improves water quality by facilitating the sedimentation of pollutants. Smart reservoirs, which offer an adaptive and predictive hydrological approach continuously optimized with sensor data and model outputs, reduce hydrological pressures on urban infrastructure while supporting the enhancement of ecosystem services by preserving the nature-based solution principle (Li & Nassauer, 2021).

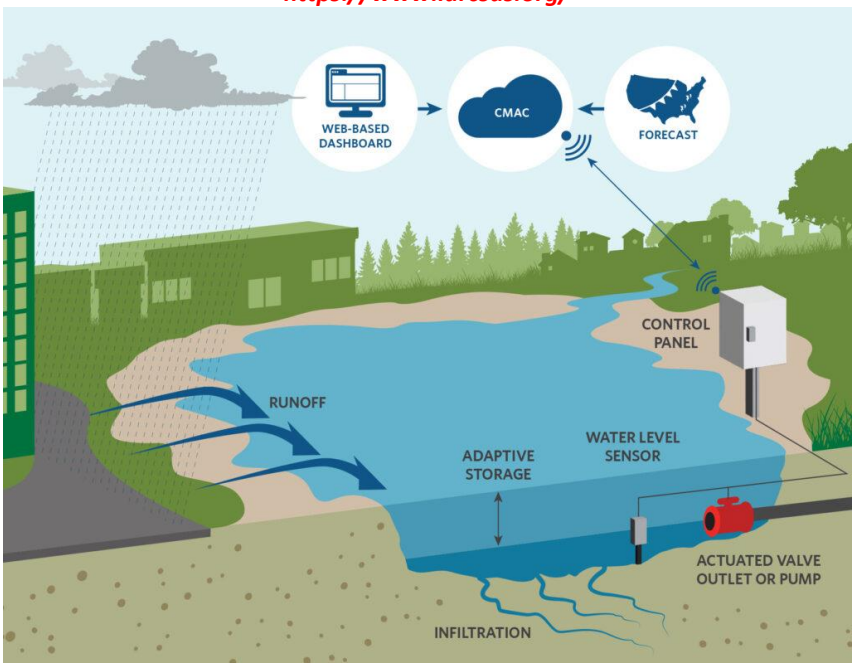


Figure 3. Smart Rainwater Ponds (URL2, 2025)

c. **Smart Mangrove Flood Barriers:** Mangroves, with their natural wave-breaking and sediment-trapping properties, are crucial in preventing sea level rise and erosion. The capacity of natural mangrove ecosystems to reduce wave energy and provide protection, when addressed through an integrated approach supported by Internet of Things-based sensors and early warning systems, reveals a hybrid flood management approach that slows coastal flooding through natural means while preparing communities for early intervention. Simultaneous data from sensors measuring wave motion and rising water levels provide alerts when critical levels are reached, combining the physical defense effect of mangroves with a digital early warning mechanism to support coastal management (Shubnam, 2025).

3. Conclusion

It is crucial to recognize that flood management approaches focused solely on resistance and based only on gray infrastructure are insufficient in the long term, and that nature-based and adaptable systems centered on ecological processes are essential for sustainable urban management and resilience. Smart nature-based solutions that combine engineering, ecology, and technology in flood risk management are highly successful in producing sustainable and flexible solutions to complex problems by increasing cities' resilience to floods. However, challenges such as high investment costs, extensive data management requirements, and lack of corporate coordination limit the widespread adoption of smart nature-based solutions.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Abbasov, R. (2025). The Impact of Climate Change on Urbanization Processes: Comprehensive Analysis. *International Journal of Science and Research Archive*, *14*(3), 10-30574.

Alkan, A. (2022). Kentsel Planalamda Yeni Arayışlar: Ontoloji ve Planlama. Yem Yayın. İstanbul

Berndtsson, R., Becker, P., Persson, A., Aspegren, H., Haghighatafshar, S., Jönsson, K., ... & Tussupova, K. (2019). Drivers of changing urban flood risk: A framework for action. *Journal of environmental management*, *240*, 47-56.

Brasil, J. A. T., de Macedo, M. B., de Oliveira, T. R. P., Ghiglieno, F. G., de Souza, V. C. B., Marinho e Silva, G., ... & Mendiondo, E. M. (2022). Can we scale Digital Twins of Nature-based Solutions for stormwater and transboundary water security projects?. *Journal of hydroinformatics*, *24*(4), 749-764.

Bressane, A., Loureiro, A. I. S., de Castro Medeiros, L. C., Moruzzi, R., Formiga, J. K. S., Negri, R. G., & Saraiva, A. C. V. (2024). Intelligent nature-based solutions in the 1st smart sustainable Brazilian city: Insights and lessons learned. *Nature-Based Solutions*, *6*, 100161.

Ernwein, M., & Palmer, J. (2025). Making the mos (s) t of nature? Cleantech, smart nature-based solutions, and the 'rendering investable'of urban moss. *Environment and Planning E: Nature and Space*, *8*(1), 306-324.

Kaluarachchi, Y. (2021). Potential advantages in combining smart and green infrastructure over silo approaches for future cities. *Frontiers of Engineering Management*, *8*(1), 98-108.

Kolokotsa, D., Lilli, A., Tsekeri, E., Gobakis, K., Katsiokalis, M., Mania, A., ... & Bisello, A. (2023). The intersection of the green and the smart city: a data platform for health and well-being through nature-based solutions. *Smart Cities*, *7*(1), 1-32.

Li, J., & Nassauer, J. I. (2021). Technology in support of nature-based solutions requires understanding everyday experiences. *Ecology and Society*, *26*(4).

Shubham, N., Omkar, S., Nitin, R., Mayur, M., Shraddha, S., & Jayshree, S. (2025). Improvement of Coastal Flood Protection with Mangroves: A Nature-Based Solution Integrating Sensors for Monitoring and Engineering Approaches. *International Journal of Advanced Research in Science, Communication and Technology*. https://doi.org/10.48175/ijarsct-25030.

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision- *Key Facts* (ST/ESA/SER.A/420). New York: United Nations.

URL1 (2025): https://geospatialworld.net/prime/case-study/national-mapping/virtual-singapore-building-a-3d-empowered-smart-nation/. Erişim tarihi: 28.10.2025

URL2 (2025): https://brightstorm.org/impact/smart-stormwater-ponds/ Erişim tarihi: 28.10.2025

Walker, A. (2023). Singapore's digital twin – from science fiction to hi-tech reality. https://infra.global/singapores-digital-twin-from-science-fiction-to-hi-tech-reality/. Erişim tarihi: 28.10.2025

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Study on the Use of Parametric Design Tools in Architectural Education

Berfin YILMAZ [1]*

ORCID 1: 0000-0002-8326-8699
[1] Research Assistant, Istanbul Aydın University, Faculty of Architecture and Design, Department of Architecture, Istanbul-Türkiye
berfinyilmaz@aydin.edu.tr (Responsible Author)

Ümit ARPACIOĞLU [2]

ORCID 2: 0000-0001-8858-7499
[2] Prof. Dr. Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, Istanbul- Türkiye
umit.arpacioglu@msgsu.edu.tr

Abstract

The development of technology has brought about many lifestyle changes, as well as changes and developments in the fields of architecture and design. Digital design tools are one of these developments. The use of various digital tools resulting from technological advancements continues to increase in the architecture and construction sectors. Parametric design and parametric/algorithmic design tools, emerging as current approaches in architecture, reinforce these technologically driven changes in architecture. Adapting to this constantly evolving sector has become a necessity for students of architecture. The extent to which parametric design tools are incorporated into architectural education in Turkey varies, but it is a topic that deserves further investigation. This study aims to examine the proficiency of using current parametric design digital tools in undergraduate architecture education in Turkey and their adaptation to the sector through student experiences. The first section of the study examines parametric design and parametric design tools in architecture. The second section presents data from surveys administered to students as part of the workshop. The third section examines the state of architectural education in Turkey, in light of the topics discussed in the first section, using content analysis using data obtained from surveys conducted with students at various universities. The analysis concludes that the Turkish architectural curriculum needs to embrace parametric design thinking.

Keywords: Parametric design, parametric design tools, architectural education

1. Introduction

The constant change and evolution of the Earth has impacted lifestyles and, consequently, many sectors. Architecture is one of the fields affected by this situation. Today, studies on architectural approaches that incorporate complex geometries are increasingly being conducted. Traditional design tools do not support change and development in architectural designs because they require excessive time and effort for changes in the design process. Modeling non-Euclidean geometries and advancing data exchange and collaboration between disciplines have created the need for faster exploration of design alternatives and better management of the complexity of design problems. Consequently, computers have become an important tool in the design process, transforming the way architects design (Kolarevic, 2003). Recent technologies allow the design process to go far beyond traditional possibilities, encouraging the development and widespread adoption of complex shapes and advanced production techniques. Computers are expanding the potential limitations of human imagination and providing tools for new design approaches, discovery, experimentation, and research. Increased access to computational design tools, coupled with the rapid development of algorithmic and parametric modeling and multidisciplinary design optimization, has enabled design teams to explore a variety of new design approaches. Architecture is now experiencing a proliferation of

approaches and techniques for generating, rationalizing, and optimizing design processes and outcomes. This not only improves the design process but also leads to a shift toward algorithmic-based modeling and simulation programs and nonlinear systems as a way to enhance design approaches through adaptation and emergence, facilitating the production of higher-performance design approaches without reducing geometric complexity. Considering these developments, an increasing number of building designs are characterized by geometrically complex and flexible structural envelopes. Tool-enabled development in architectural design has enabled the introduction of new design approaches such as parametric, adaptive, and biomimetic into the architectural design literature. The aim of this study is to examine the adequacy of teaching and using parametric design digital tools used in undergraduate architecture education in Türkiye and their compatibility with the sector through student experiences. In this context, the answer to the study question was sought through workshops and surveys conducted with the voluntary participation of architecture students.

2. Materials and Methods

A survey method was used in the study. The data used in the study were obtained from surveys administered to volunteer participants before the "Parametric Energy-Efficient Facade Design and Daylight Analysis Workshop," which took place at Mimar Sinan Fine Arts University from December 17-20, 2024. The participants were undergraduate and graduate students of architecture and interior architecture studying in Turkey. The surveys were conducted digitally and covered parametric design and its tools, as well as the use of daylight in architecture and simulation tools. Data within the scope of parametric design were examined in the study. Graphs were created based on the results obtained from the surveys. Conclusions were reached based on the generated graphs. The first part of the study examined parametric design and its tools. The second part presented the data obtained from the surveys administered to volunteer students. The final part interpreted the data, and the current use of parametric design tools in architectural education in Turkey was analyzed.

3. Findings and Discussion

3.1. Change and Development in Architectural Design Tools

Between the late 20th century and the present, noticeable changes have occurred in the context of developments in construction techniques. Until the late 20th century, it can be said that the ability to create any structure, object, or product envisioned in one's mind was not as advanced as it is today. Complex calculations, the increasing number of specialized fields, and designers working across multiple disciplines were insufficient. While architects could clarify their designs in their minds, they had not yet overcome the challenges of the construction phase. At this point, computers and computer technologies have become a solution for architects to realize the designs they envisioned in their minds and through technical drawings.

From the 2000s to the present, software companies have increased their products serving the fields of design and architecture, and architects have become active users of these software and begun to incorporate programming languages into their designs (Silver, 2006). The relatively low cost of computer calculation and trial-and-error compared to real-world methods, coupled with the ability to simulate damage and load-bearing experiments, has made computers a tool used by architects not only in the design process but also in the construction and implementation processes to complete their buildings (Ergün, 2008). Ecological and sustainable architectural approaches have been among the factors that have influenced and changed architectural design

and its tools from the early 21st century to the present day. The goal of sustainable energy technologies can be summarized as preventing the use of depletable fuels, maximizing the efficiency of energy production and use as a temporary measure, developing new resources, saving energy production and fuel selection for the last resort, developing energy-consuming technologies and systems for optimal efficiency, minimizing the environmental impact of energy technologies on the ground, preventing the extraction of more energy from natural resources than the local ecosystem can handle, and designing technologies to ensure that human activities remain below energy limits and do not exceed the planet's capacity (Elliot, 1997). The rise of technological possibilities is crucial for achieving ecological and sustainable designs in a world where resources are dwindling, environmental pollution, and global warming are making living conditions more difficult. Material selection, the appropriate evaluation of material potentials based on their location, the use of developments in construction techniques, and design decisions throughout the design process have gained importance in this regard. While the concepts of ecological sustainability and sustainability have been prevalent in the architectural field since ancient times, they have gained importance today for the evolution of architectural design approaches and their contribution to energy transformation. The constant transformation of the Earth due to climatic, geographical, industrial, and political factors makes it essential that buildings and facades be designed without ignoring the requirements brought about by these changes (Ergün, 2008). Architectural structures, which could previously be designed with a human-enabled design approach, are now being designed with the aid of digital tools. These tools generally emphasize the relationship between the physical environment and the facade, comfort, energy use in architecture, and sustainability. They are designed to maximize the performance of facades and other designs through various simulations. Furthermore, technical software, frequently used in engineering and whose use in architecture has become widespread in recent years, is also being used. These tools/software, used in the 21st century and beyond, demonstrate that architectural building performance is becoming increasingly important, parallel to visuality and aesthetics, and even more so with the increasing prevalence of environmental issues. The use of these tools has led to the implementation of different approaches in architecture, particularly in façade design. Consequently, performance-oriented approaches to architectural façades have gained prominence. The development of digital modeling tools since the late 20th century has inevitably led to the emergence of parametric, adaptive, biomimetic, and other performance- and aesthetic-oriented façade designs, which have gained a significant share in architectural façade literature and practice. The table below lists the features of innovative architectural design tools mentioned in articles published in WoS. These design tools are used in a variety of architectural topics, including algorithmic and parametric modeling, energy and daylight simulations, and life cycle design.

Table 1. Digital design tools (Created by the authors)

Innovative Design Tools	Features
BIM	BIM is a system that stores all the information about a building in a single digital model and coordinates all project phases through this model. This model incorporates not only 3D drawings but also the physical and functional characteristics of the building. The fundamental principle of BIM is to ensure that all stakeholders have access to the same model and work in a consistent and coordinated manner throughout the project. This minimizes errors and delays, and optimizes project costs and timelines.

Rhinoceros	Rhino is a high-precision modeling software for generating complex geometry, surfaces, and curves. It is widely used in industrial design, architecture, jewelry design, automotive design, CAD/CAM, mass production, reverse engineering, and multimedia and graphic design.
Grasshopper	Grasshopper is an algorithm editor integrated with Rhino's 3D modeling tools. It is frequently used to dynamically modify parametric forms via algorithmic inputs. It integrates environmental influences such as sun and wind into the model created in the program, allowing for easy modification of form and size.
LadyBug	Ladybug is a collection of computer applications for simulation. Ladybug Tools works with Rhinoceros and Grasshopper, allowing data transfer between simulation engines, enabling geometry creation, simulation, and visualization within a single interface.
HoneyBee	Honeybee enables detailed daylight simulations and thermodynamic modeling in the advanced design stages by connecting the Grasshopper/Rhinoceros environment to these engines.
EnergyPlus	EnergyPlus is a building energy simulation engine. EnergyPlus applies detailed building physics for air, humidity, and heat transfer, including separate consideration of radiative and convective heat transfer to enable modeling of radiant systems and calculation of thermal comfort metrics; calculates lighting, shading, and visual comfort metrics; and configures HVAC systems.
DesignBuilder	DesignBuilder is a software tool that handles three-dimensional building modeling with energy simulations based on EnergyPlus used for energy, carbon, lighting and comfort measurement and control.
ClimateStudio	ClimateStudio is a Rhinoceros plugin that allows simulations under topics such as illumination, annual glare rates, area analyses.
ESP-r	ESP-r (Environmental Systems Performance - Research) is a modeling tool for building performance simulation. When performing its assessments, the system is equipped to model the flow of heat, air, humidity, light, and electrical power in user-specified spatial and temporal contexts.
OPOSSUM	OPOSSUM is a simulation and optimization tool integrated with Grasshopper. Opossum includes the best-performing model-based RBFOpt and evolutionary CMA-ES optimization algorithms in Grasshopper.
DIVA	It is a daylight and energy simulation tool that works integrated with Rhinoceros.
OpenLCA	OpenLCA is a lifecycle software designed for professional ecological, social, and economic lifecycle assessments. It can be used in architecture and construction, from the construction phase to the demolition phase of a building.

3.2. Parametric Design

The concept of algorithm, which forms the foundation of mathematics and computer science, has over time become a subject of other sciences and disciplines. An algorithm, which can be defined as the set of steps required to solve a problem, and the algorithmic thinking that develops from it, form the basis of parametric design. In its most basic form, a parameter can be explained as a quantity that can be defined and modified for a situation, and a situation that contains one or more of these quantities can be perceived parametrically (Erbaş, 2013). Design is considered the process of posing a problem and generating and exploring options for a solution that meets the problem's requirements. Any measurable factor that defines or defines the boundaries of a system is called a "parameter." While the definition of parametric design may seem straightforward when considered solely in the context of form, its understanding as a design concept is complex. The concept of parametric design refers to the use of parameters

in creating a form and a procedure where variables are used to define a problem. Furthermore, by manipulating these factors, various potential solutions can be generated, and then a final solution can be selected according to certain criteria (Gero, 1990). Jabi (2013) defined parametric design as "a technique based on algorithmic thinking that enables the formulation of parameters and rules that define, codify, and explain the relationship between the design intent and the design response." The most significant advantage of parametric design is its effective use of description to flexibly specify and create geometries and to link selection variables to geometries. Parameters in the parametric model are modified to develop a new solution to the design problem. The model adapts to changes by adapting to new values of parameters or restructuring parameters without deleting or repeating anything (Hernandez, 2006).

Parametric design is not only a design process but also an approach that shapes the forms of architectural structures. Parametric design has transformed the traditional design process into one where changes can be made without rewinding and complex problems can be solved. This has led to forms that appear complex but can be designed systematically through the parametric design process. These forms, especially common in today's architectural facades, may appear complex, but each represents different parameters, and changes are easily implemented. With parametric plugins and software, designers can instantly create large, dynamic forms graphically by entering various values (input) and creating appropriate constraints. Designers can generate complex forms thanks to the ability to detect changes made in real time using these plugins and software. When the parameters of a parametrically designed model are changed, the form is automatically updated (Burry, 1999). With the use of digital design tools and parametric design in architecture, two new approaches that can be examined within the scope of parametric design have emerged: biomimetic and adaptive design. Both approaches have found a place in architecture to provide solutions to the environmental problems facing the Earth, and are being studied alongside concepts such as energy-efficient design, sustainable design, climatic design, and comfort in architecture. Biomimetic design, also referred to as biomimicry or biomimesis in the literature, is an approach that emerges through the transfer of knowledge and methods between technology, biology, and the discipline of architecture (Yılmaz, 2024). Benyus (1998) defined biomimicry as "a new discipline that examines nature's best ideas and imitates its designs and methods to solve human problems." On the other hand, Gruber (2011) stated, "It is the collaborative work of the disciplines of biology and architecture, which has innovative potential for architectural problems." An example of biomimetic design is the New York TWA Terminal, whose design was inspired by the wing structure of birds (Yılmaz, 2024) (Figure 1). Adaptive design was defined by Kolodziej and Rak (2013) as a system that responds to a specific stimulus in a predefined manner, and by Pan and Jeng (2008) as a dynamic structural system that can change shape according to environmental conditions and user needs. Today, the concept of adaptive design is understood as the reversible change or transformation of buildings, building materials, or components to adapt to environmental factors and enhance structural performance (Razaz, 2010; Schmidt and Austin, 2016). An example of adaptive design is the Arab World Institute, designed by Jean Nouvel (Figure 2).



Figure 1. TWA Terminal (Welch, 2019)

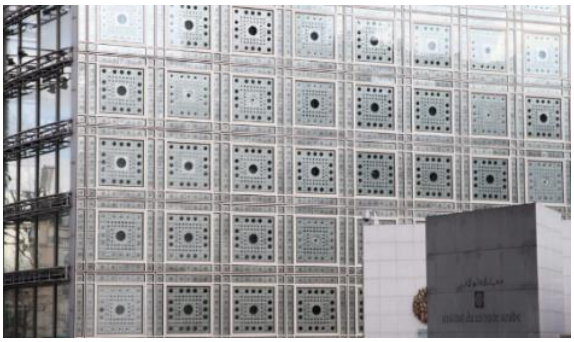


Figure 2. Jean Nouvel's Arab World Institute (Onniboni, 2024)

3.3. Digital Design Tools and Parametric Design in the Architectural Sector

The 1980s and 1990s were a period when neoliberal economic structuring was encouraged worldwide, the free market developed, and information technologies emerged. This led to the integration of information technologies with creative industries in accordance with the economic policies of the time (Mitchell et al., 2003). Software companies and programs, particularly those with a wide range of CIS programs and their popularity in the liberal economy, maintain their presence in the sector and are constantly updating themselves. Annual license and version updates of these programs are seen as a significant opportunity for these companies to maintain their existence (Taşdelen & Gül, 2017). Considering the current "softwarization" era, this sector's connection to all other sectors and its vast sphere of influence are fueling its continual development, leading to its integration with many different sectors. Considering the history of "softwarization," it can be said that software companies and programs have a significant influence in the global economy. Software companies operating in the architectural field are also observed to have an impact on the construction and architecture sectors. Architectural software companies collaborate with architectural design offices with the stated aim of "influencing, changing, and shaping the future of design, etc." In fact, it can be said that all digital design technologies are developed for specific purposes and specific audiences. Therefore, understanding which software is used in the architectural sector for which purposes, which modeling classes it falls into, and its technical specifications will enable integration into the architectural software culture, awareness of software policies, and active use in the design process (Taşdelen & Gül, 2017). BIM (Building Information Modeling), a significant development in the 21st century in architecture and digital design, is used as a design policy in design offices in many countries, including the UK and the US. Renowned architectural design offices worldwide are closely following design software developments and have research and development teams to keep up with developments in this field. Similarly, software companies may use the names of renowned architecture and engineering firms when advertising their products. In other words, there can be a mutual benefit between software companies and architecture firms in the sector.

Parametric design is the most prominent computational design method that challenges traditional design practices. Searches conducted on prominent databases such as Web of Science (WOS), Scopus, and Science Direct have identified parametric design as the most popular term. The increase in studies on parametric design, particularly in the last 20 years, is noteworthy (Caetano et al., 2020). Frequently cited in academic studies, parametric design is also a design approach employed by the industry, particularly by world-renowned architectural offices. One of the most important reasons for this is that parametric design offers diverse solutions by systematically breaking down problems encountered in the design process into smaller components, enhancing the value not only of the final product but also of the process (Özdemir & Yıldırım, 2018). Changes resulting from designers' manipulation of parameters allow designers to explore the structure in depth. Another reason is that parametric forms possess complex aesthetics, require design with digital design tools, and provide energy efficiency for building facades, leading architectural offices to view these designs as advertising tools. Hudson (2010) identified six applications of parametric design in architectural practice: (1) transforming design ideas into parametric models, (2) directing and rationalizing designs into constructible shapes, (3) controlling and organizing architectural forms, (4) generating design variants based on various criteria and expert input, design exploration and optimization, (5) creating construction documents, and (6) gathering design information from different stakeholders. The implementation of the parametric design process in architectural offices and its translation into design form also involves similar stages, although the implementation depends on the organizational structure of the architectural office. Four common strategies for incorporating parametric design strategies into design offices have been observed: consulting groups within the practice, independent consultants, integration with design teams, and an ambiguous position. The size of some practices allows for more than one of these structures to be present. Other practices make no commitment or offer any opinion on the position of the parametric design role, but there is material suggesting a role within the relevant offices. These are identified in a fourth category as an unspecified position (Hudson, 2010).

3.4. The Use of Parametric Design and Digital Design Tools in Architectural Education

This section of the study, based on the idea that the parametric design approach is not only a representation/transmission problem but also a production/design problem, will examine the extent to which the parametric design approach is considered a design problem in the project design process in architectural education, how parametric/algorithmic design tools are integrated into the project process to address these design problems, and whether all of these are conveyed to students. In this context, the "Parametric Energy-Efficient Facade Design and Daylight Analysis Workshop" was held at the Fındıklı Campus of Mimar Sinan Fine Arts University on December 17-20, 2024, led by Prof. Dr. Ümit ARPACIOĞLU (Figure 3). The workshop covers the main topics of parametric design, parametric energy efficient façade design and use of daylight in architecture.



Figure 3. Workshop poster (Created by the authors)

After lectures on the workshop topic were held on the first day, over 150 students from various universities who applied to the workshop were divided into working groups and began their work under the leadership of their group facilitators (Figure 4, figure 5). Six subgroups were identified within the scope of the workshop: "Adaptive Facade Approaches to Achieving Optimum Illuminance Levels in Spaces, Daylight Analysis of Different Materials in Parametric Energy-Efficient Facade Design, Parametric Approaches in Energy-Efficient Facade Design, Biomimetic Approaches in Energy-Efficient Facade Design, Comparison of Glass and Kinetic Facades in the Context of Daylight, and Glare Control in Adaptive Facades" (Figure 6, figure 7).




Figure 4, Figure 5. Workshop seminars (Taken by the authors)




Figure 6, Figure 7. Students' work with group executives (Taken by the authors)

Participating students received education in Rhino-Grasshopper and ClimateStudio, algorithmic design and simulation programs used in the workshop. With the help of their group leaders, the participating students conducted literature research on relevant topics and created parametric, adaptive, and biomimetic façade designs using Rhino and Grasshopper. They then imported their designs into ClimateStudio to generate daylight simulations to measure the

daylight control performance of innovative, energy-efficient façade designs. The resulting data was interpreted, and recommendations were developed. The workshop outputs were exhibited in the Mimar Sinan Hall of the Fındıklı Campus of Mimar Sinan Fine Arts University from January 6–12, 2025 (Figure 8, figure 9).



Figure 8. Preparation process



Figure 9. Exhibition of the workshop

A survey was administered to the students participating in the workshop to assess their knowledge beforehand. Sixty-five students volunteered to participate. The survey assessed the students' departments, grades, and universities of study, as well as their theoretical knowledge of parametric design, adaptive design, and biomimetic design, and their ability to use the digital design tools used in these approaches. This provided information about the role of parametric design and parametric design tools in architectural education.

The first question posed to the students in the survey was their department and grade. Based on the responses given in the first section of the survey by the 65 students who volunteered to participate in the workshop, 90.8%, or 59, were architecture students. The remaining 9.2% were primarily studying in interior architecture and architecture graduate programs. The Interior Architecture Department comprised three students (4.6%), one student from the Restoration, Renovation, and Conservation graduate program (1.5%), one student from the Architecture and Built Environment Renovation graduate program (1.5%), and one student from the History of Architecture graduate program (1.5%) (Figure 10). Furthermore, 53.8% of the participating students were 2nd grade students, 18.5% were 4th grade students, 10.8% were 3rd grade students, 10.8% were graduate thesis students, and the remainder were graduate coursework students (Figure 11).

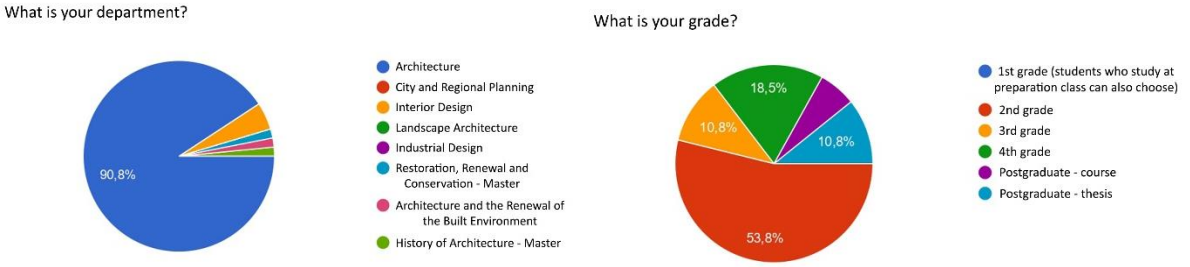


Figure 10, Figure 11. Datas from the first section of the questionnaire

The first section of the survey also included questions regarding whether their program knowledge of parametric modeling was sufficient prior to the workshop. For those who had knowledge of Parametric Energy-Efficient Facade Design and Daylight Analysis before attending the workshop, they also asked where they obtained their information. Accordingly, 87.7% of the students stated that they did not have sufficient knowledge of Parametric Energy-Efficient Facade Design and Daylight Analysis before the workshop, while 12.3% stated that they did (Figure 12). Of the students who did have knowledge, 23.1% obtained their information online, 18.5% from their educational institution, 7.7% from seminars/conferences, 6.2% from printed publications, and 3.1% from various workshops (Figure 13).

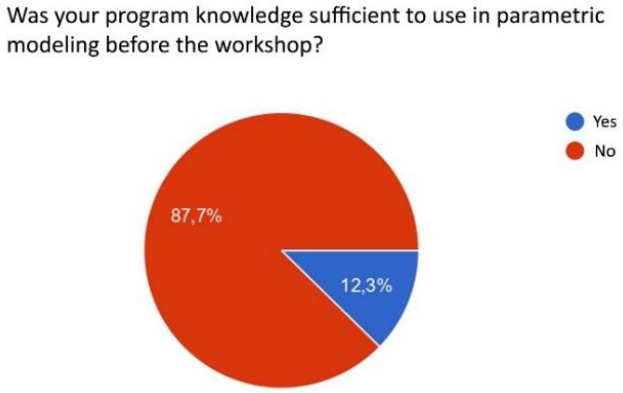


Figure 12. Datas from the first section of the questionnaire

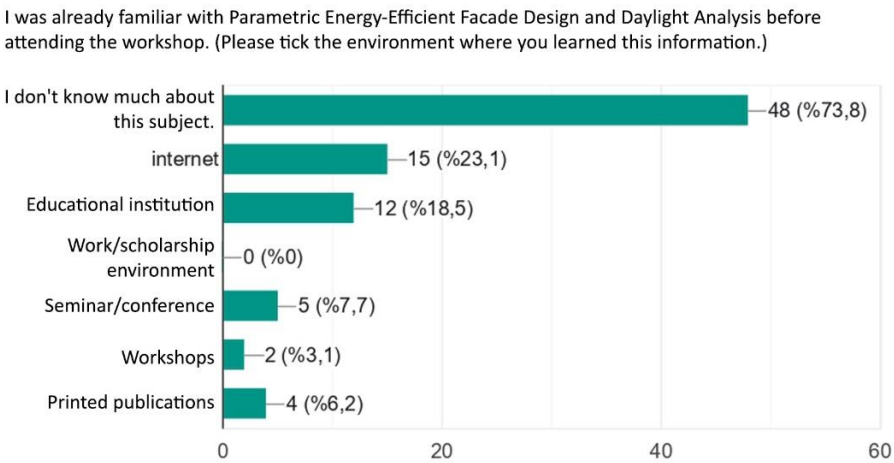


Figure 13. Datas from the first section of the questionnaire

The second section of the survey inquired about the students' prior knowledge of parametric design, adaptive design, and biomimetic design, as well as their theoretical and digital programming knowledge. The first section of the second section addressed questions about parametric design, the second section addressed questions about adaptive design, and the third section addressed questions about biomimetic design. According to the results of the survey on parametric design in the first section of the second section, 27.7% of the participating students had some knowledge, 26.2% had a good knowledge, 10.8% had a very good knowledge, and 12.3% had no knowledge at all (Figure 14).

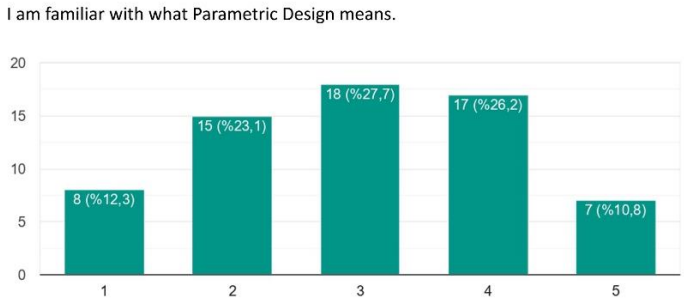


Figure 14. Datas from the second section – "Parametric Design" title of the questionnaire

According to the responses to questions about digital parametric design tools, 55.4% of the participants were unaware of the use of digital design tools in the parametric design process. However, 44.6% were theoretically familiar with Rhinoceros, 41.5% with Grasshopper, 18.5% with Revit, and 15.4% with Dynamo (Figure 15). Regarding the use of digital design programs, 63.1% of the participants had not received education on the use of digital tools in adaptive design, 29.2% had received education but were unable to use them, and 7.7% had received education and were able to use them (Figure 16). Of the students who can use digital parametric design tools, 40% learned the tools from educational institutions, 40% from the internet, 38.5% from online video platforms, 16.9% from online education platforms, 1.5% from elective courses at their university, and 1.5% from face-to-face courses (Figure 17).

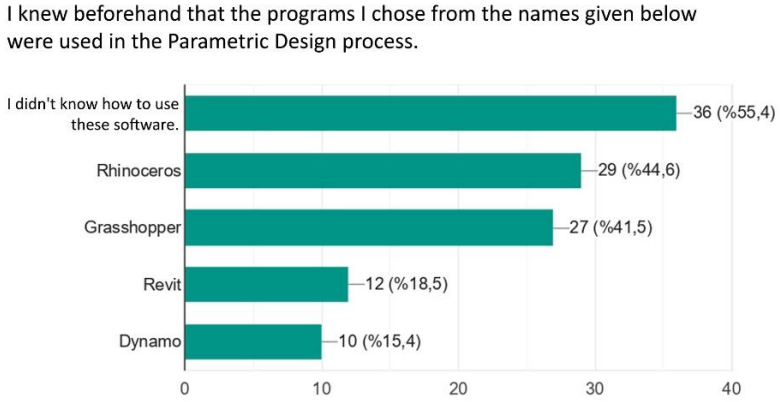


Figure 15. Datas from the second section – "Parametric Design" title of the questionnaire

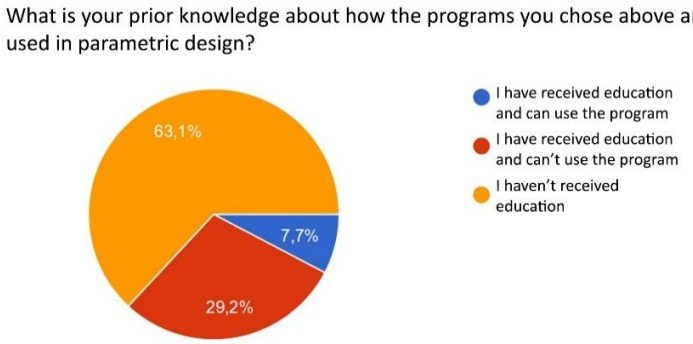


Figure 16. Datas from the second section – "Parametric Design" title of the questionnaire

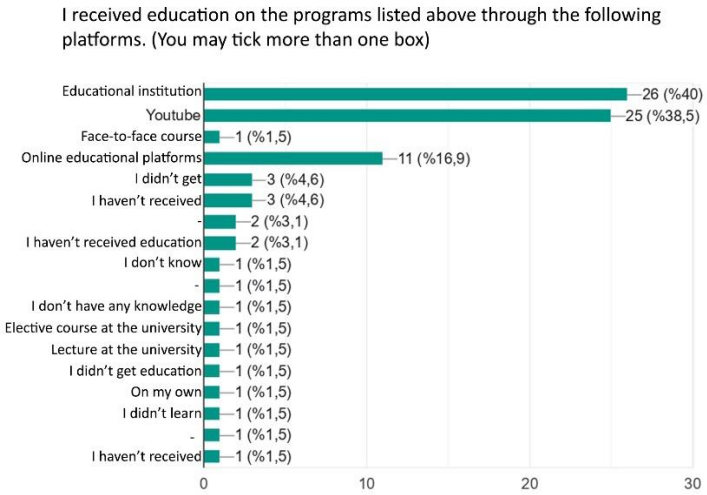


Figure 17. Datas from the second section – "Parametric Design" title of the questionnaire

According to the survey results in the adaptive design subheading of the second section, 33.8% of workshop participants had some knowledge, 13.8% had a good knowledge, and 4.6% had a very good knowledge of adaptive design (Figure 18). 56.9% of participating students were unaware of the digital design tools used in adaptive design. Conversely, 40% of students were aware of Rhinoceros, 30.8% of Grasshopper, 21.5% of Revit, and 9.2% of Dynamo digital design tools used in adaptive design (Figure 19).

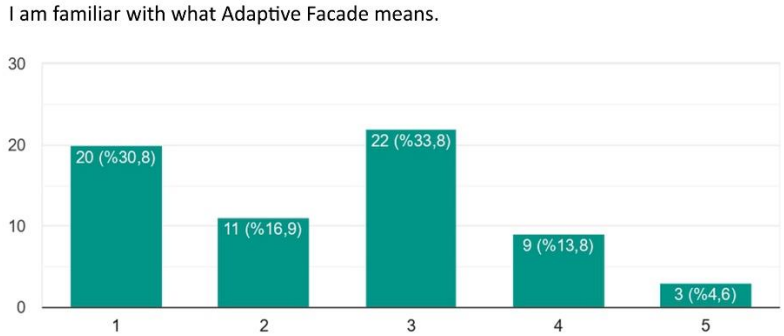


Figure 18. Datas from the second section – "Adaptive Design" title of the questionnaire

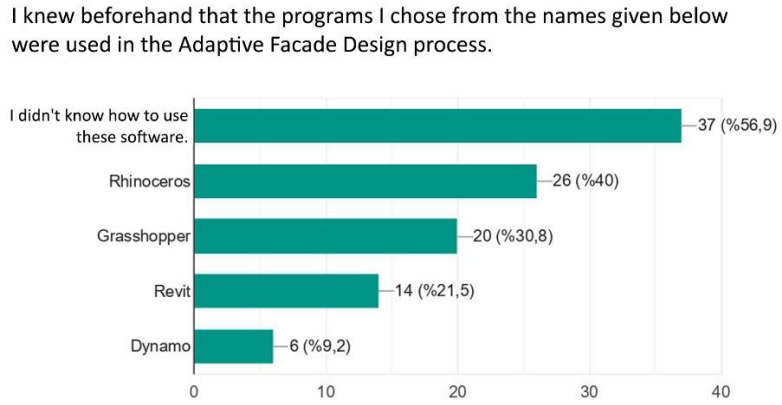


Figure 19. Datas from the second section – "Adaptive Design" title of the questionnaire

Regarding how digital design programs are used, 64.6% of participants have not received education on how to use digital tools in adaptive design, 26.2% have received education but are unable to use them, and 9.2% have received education and are able to use them (Figure 20). Of the students who received education on these programs, 46.2% stated that they learned digital design tools from educational institutions, 40% from the internet, 16.9% from online education platforms, 1.5% through elective courses at their university, and 1.5% by experimenting with the programs on their own (Figure 21).

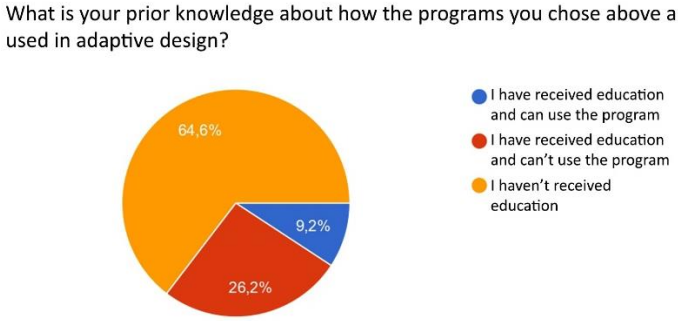


Figure 20. Datas from the second section – "Adaptive Design" title of the questionnaire

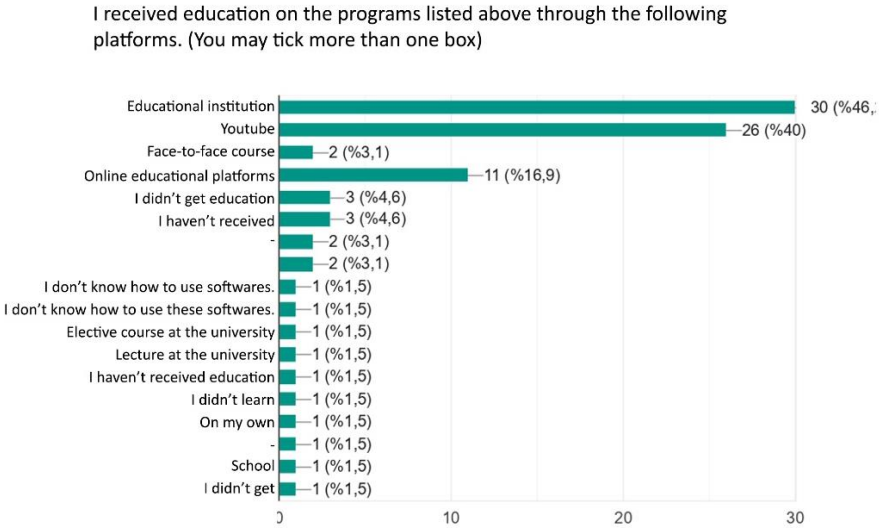


Figure 21. Datas from the second section – "Adaptive Design" title of the questionnaire

According to the survey results under the biomimetic design subheading of the second section, 26.2% of workshop participants had partial knowledge, 13.8% had good knowledge, and 3.1% had very good knowledge of biomimetic design. However, 32.3% stated that they had no knowledge of biomimetic design (Figure 22). According to the answers to questions about digital parametric design tools, 73.8% of participants were unaware of the use of digital design tools in the biomimetic design process. However, 21.5% had knowledge of Rhinoceros, 20% of Grasshopper, 13.8% of Revit, and 6.2% of Dynamo programs (Figure 23).

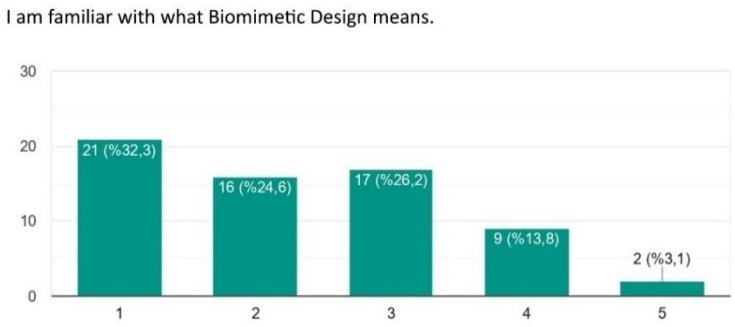


Figure 22. Datas from the second section – "Biomimetic Design" title of the questionnaire

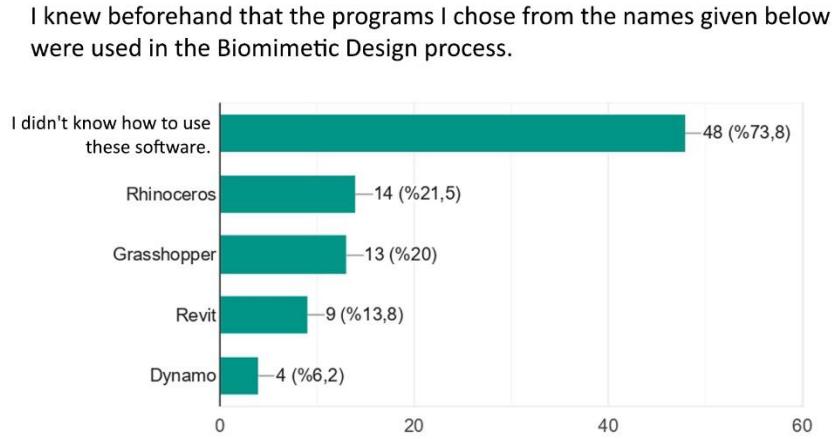


Figure 23. Datas from the second section – "Biomimetic Design" title of the questionnaire

76.9% of participants had not received education on the use of digital tools in biomimetic design, 16.9% had received education but were unable to use them, and 6.2% had received education and were able to use them (Figure 24). 40% of the students who received education on these programs stated that they received education from educational institutions, 32.3% from online video platforms, 13.8% from online education platforms, and 4.6% from face-to-face courses (Figure 25).

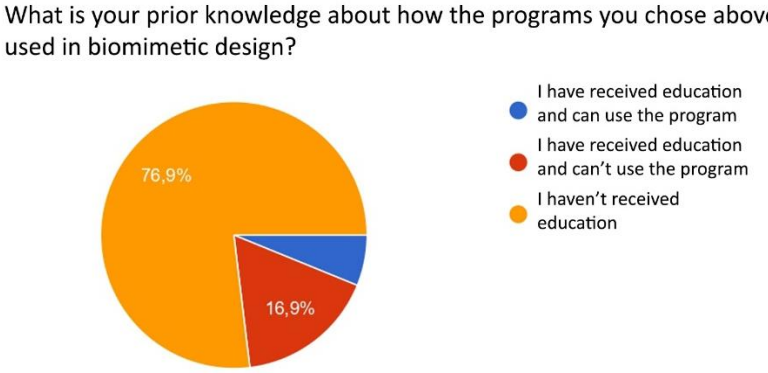


Figure 24. Datas from the second section – "Biomimetic Design" title of the questionnaire

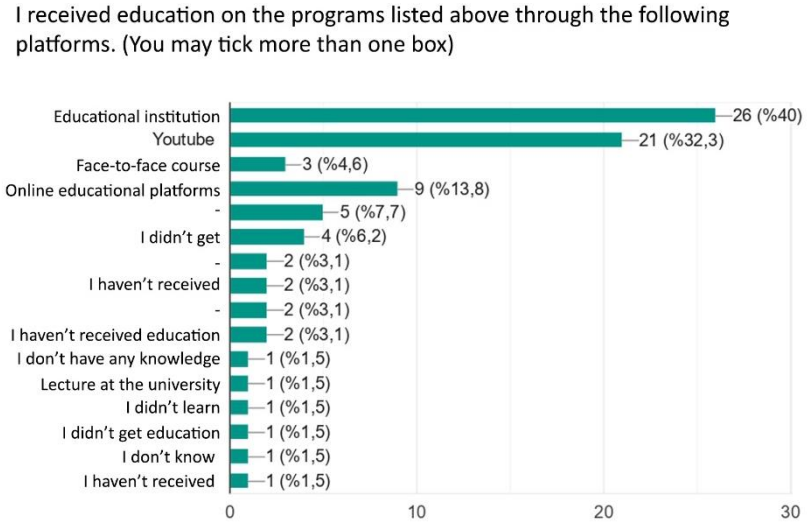


Figure 25. Datas from the second section – "Biomimetic Design" title of the questionnaire

4. Conclusion and Recommendations

From past to present, the world has experienced and continues to experience innovations and developments in many areas, including technology, industry, and economics. The field of architecture, influenced by global changes and social dynamics, has evolved and experienced numerous innovations. The most important of these is "digital design tools," a representation of our increasingly digital age. Furthermore, the simultaneous introduction of sustainable and ecological design concepts into the industry has accelerated the development and integration of digital design tools into architecture, bringing with it new approaches. With digital design tools, a shift away from traditional design processes has begun, and a transition to innovative design processes has begun. The most significant approach facilitating this transition is the parametric design approach. With the proliferation of digital design tools, the parametric design approach has become increasingly prevalent in architectural literature, facilitating designs with complex and non-Euclidean geometries and elevating imagination and abstraction to another dimension. Adaptive and biomimetic designs, considered within this context, have become a sign of the development of nature-based solution mechanisms in architecture. These methods, frequently employed in the industry, should also be addressed in architectural education. However, the current importance given to this issue remains a matter of curiosity.

In this context, data was collected from pre-workshop surveys conducted at the Parametric Energy-Efficient Facade Design and Daylight Analysis workshop held at Mimar Sinan Fine Arts University, with the participation of undergraduate and graduate students in architecture and interior architecture. The survey results indicate that students studying architecture at various universities in Türkiye have limited theoretical knowledge of parametric design, adaptive design, and biomimetic design. Given that universities are the primary institutions where students receive education, it appears that new approaches are not sufficiently included in theoretical and project courses in architectural education in Türkiye. The survey results indicate that the knowledge of students studying parametric design approaches at university is not retained. Accordingly, it has been observed that, primarily from a theoretical perspective, current architectural design approaches are not sufficiently addressed in architectural education in Türkiye, and even if they are, the knowledge is not retained. The possibility that this is due to teaching techniques or insufficient coverage of these topics in course content should be considered. Similarly, students' competence in digital design tools remains limited, and those who receive education in this field at university have not retained their knowledge. The results indicate that a significant number of students who receive education but are unable to use the programs are also at risk. This may be due to student-related factors, a lack of materials and facilities at universities to teach digital design tools, a failure to keep up with current trends, or a failure to incorporate relevant topics into the curriculum.

According to surveys conducted with workshop participants at various universities, it was concluded that architectural education in Türkiye needs to be kept up to date, incorporate current design approaches and tools into the curriculum and course content, provide adequate materials, and be compatible with the sector. According to the results obtained from the study, improvements should be made in the curricula and course contents of the architecture departments of universities to include controls and new design approaches, and students should be provided with parametric thinking skills and adapted to the current situation and the sector, thus preventing them from experiencing difficulties in their professional lives.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

We would like to thank Germany-based Schüco Türkiye, one of the leading companies in the industry that has been developing building facade products for decades, for signing a cooperation protocol with our Parametric Energy-Efficient Facade Design and Daylight Analysis workshop held at Mimar Sinan Fine Arts University, and everyone who contributed to the workshop.

References

Benyus, J.M. (1997). *Biomimicry: Innovation Inspired by Nature*, New York: Morrow.

Burry, M. (1999), Paramorph: Anti-accident methodologies, Hypersurface Architecture II, 69 (141), pp. 78-83.

Caetano, I., Santos, L. & Leitaao, A. (2020). Computational Design in Architecture: Defining Parametric, Generative, and Algorithmic Design. *Frontiers of Architectural Research*, 9, 287- 300.

Erbaş, S.K. (2013). Mimaride Parametrik Tasarım ve Eğitimi, *Journal of Research in Education and Teaching,* 2(4), 119-124.

Gero, J. (1990). Design prototypes: A knowledge representation schema for design. *Ai magazine,* 11(4): p. 26-36.

Hernandez, C. (2006). Thinking parametric design: introducing parametric Gaudi, *Des Stud,* 27:309–24.

Hudson, R. (2010). *Strategies for parametric design in architecture: An application of practice led research. (Ph.D. Dissertation). Bath, UK: University of Bath.*

Jabi, W.E. (2013). *Parametric Design for Architecture.* Laurence King, London.

Kolarevic, B. (2003). Architecture in the Digital Age - Designing and Manufacturing, London, UK.

Kolodziej, P., & Rak, J. (2013). Responsive building envelope as a material system of autonomous agent. Open Systems: Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia, 945-954.

Mitchell, W., Inouye, A., Blumenthal, M. (2003). Beyond Productivity: Information, Technology, Innovation and Creativity, National Research Council.

Onniboni, L. (2024). Institute du Monde Arab in Paris, Jean Nouvel, Access Date: 11.11.2025, https://www.archiobjects.org/institute-du-monde-arab-in-paris-jean-nouvel/

Oxman, R. (2006). Theory and design in the first digital age. Design Studies, 27(3), 229-265.

Özdemir, M., & Yıldırım, M. T. (2018). Productıon of ThreeDimensional Form Alternatives from Iconic Building Plans in Parametric Design Environment. *Gazi University Journal of Science Part B: Art Humanities Design and Planning,* 6 (1), 19-30.

Pan, C.A., & Jeng, T. (2008). Exploring sensing-based kinetic design for responsive architecture. *13th International Conference on Computer-Aided Architectural Design Research,* (s. 285-292). Thailand.

Silver, M. (2006). Programming Cultures, Wiley & Sons, Oxford.

Taşdelen, H.S. & Gül, L.F. (2017). Mimarlıkta Dijital Piyasa: Mimari Tasarım Süreçlerinde Yazılım Teknolojisi Politikaları, MSTAS, Istanbul.

Welch, A. (2019). TWA Flight Center New York, Access Date: 11.11.2025, https://www.e-architect.com/new-york/twa-flight-center-jfk-airport

Woodbury, R. F. (2010). *Elements of parametric design.* London; New York: Routledge.

Yılmaz, B. (2024). *Biyomimetik Cephelerde Gün Işığı Kontrolü, Master's Thesis, Mimar Sinan Fine Arts University Institute of Science and Technology, Istanbul.*

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Ecological Compatibility and Accessible Design in Archaeological Sites

Bilgenur AK [1*]

ORCID 1: 0000-0002-3060-4361
[1] Dr., Kırıkkale University, Faculty of Fine Art, Department of Landscape Architecture, Kırıkkale-Türkiye
bilgenurak@kku.edu.tr (Responsible Author)

Öner DEMİREL[2]

ORCID 2: 0000-0002-8102-5589
[2] Prof. Dr., Kırıkkale University, Faculty of Fine Art, Department of Landscape Architecture, Kırıkkale-Türkiye
demirel@kku.edu.tr

M. Bihter BİNGÜL BULUT[3]

ORCID 3: 0000-0003-4496-8198
[3] Assoc. Prof., Kırıkkale University, Faculty of Fine Art, Department of Landscape Architecture, Kırıkkale-Türkiye
mbbingul@kku.edu.tr

Tuba Gizem AYDOĞAN[4]

ORCID 4: 0000-0003-0717-4751
[4] Research Assistant, Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale-Türkiye
taydogan@kku.edu.tr

Abstract

Archaeological sites are places that carry the fragile traces of past civilisations, situated at the intersection of the natural environment, the cultural landscape, and collective memory. This sensitivity necessitates not only the protection of archaeological sites but also careful attention to site planning and design. As emphasised in UNESCO's World Heritage Convention (1972), cultural heritage is not merely a remnant of the past but also a component of humanity's shared identity and a body of values that must be transmitted to future generations. Therefore, the conservation of archaeological sites should not be limited to the preservation of physical remains; it should also encompass the ecological integrity of these areas and consider them as inclusive spaces that accommodate all segments of society. In these areas, accessibility is as important as conservation. The concept of universal design provides an essential framework for enhancing inclusivity in archaeological sites by addressing the needs of diverse user groups. These environments must be accessible to everyone—from older adults to children, from individuals with special needs to users with varying abilities—and flexible design solutions should be developed to accommodate this diversity. Within the scope of this study, ecological and universal design principles were evaluated for archaeological sites, and structural and vegetative landscape design recommendations were developed accordingly. In doing so, the study aims to ensure the transmission of heritage to future generations while enabling these environments to be experienced more holistically by all users and supporting ecological sustainability.

Keywords: Archaeological sites, universal design, accessibility, landscape design, cultural heritage

1. Introduction

Archaeological sites are sensitive areas that have survived from the past to the present and represent the shared heritage of humankind. These areas should not be evaluated solely on the basis of the remains they contain; rather, they must be considered together with the landscape, ecosystem, and the social and cultural values in which they are embedded. According to the ICOMOS Charter for the Protection and Management of the Archaeological Heritage (ICOMOS 1990) archaeological heritage "is that part of the material heritage in respect of

which archaeological methods provide primary information. It comprises all vestiges of human existence and consists of places relating to all manifestations of human activity, abandoned structures, and remains of all kinds (including subterranean and underwater sites), together with all the portable cultural material associated with them.". This approach supports the necessity of preserving and managing archaeological heritage without detaching it from its context. Therefore, these areas are not merely spaces where historical remains are stored, but spatial manifestations of collective memory intertwined with the natural environment. Consequently, the conservation and management of archaeological heritage should incorporate dimensions such as environmental sustainability, landscape integrity, cultural values, and the participation of local communities (Ahunbay 2010).

Furthermore, the idea that this heritage should be accessible to everyone should be understood not only as a matter of physical access but also as a cultural and social right. The World Heritage Convention (UNESCO 1972) defines the protection, presentation, and transmission of heritage to future generations as the responsibility of the States Parties and emphasises that such heritage possesses outstanding universal value. The perception of heritage as the common property of humankind is also consistent with international frameworks affirming the right of all individuals to access and benefit from cultural heritage. For example, the Council of Europe's Faro Convention (2005) states that "everyone, alone or collectively, has the right to benefit from the cultural heritage and to contribute towards its enrichment". In this context, arranging archaeological sites to serve all segments of society is of great importance for achieving social inclusivity and ensuring equal access (Council of Europe 2005).

The implementation of universal design principles in archaeological contexts must be evaluated in conjunction with conservation requirements, ecological sensitivity, and the biotic and abiotic characteristics of archaeological sites. While universal design is directly related to accessibility, it represents a broader concept: designing with all individuals in society in mind. In this respect, ensuring that people of all ages and abilities can reach and experience archaeological sites is a right supported by international conventions. The literature also contains numerous studies on how archaeological sites can be made accessible (Biocca 2025; Cantarellas 2023; Dascălu et al. 2024; Lauria 2017; Lucchi 2023; Naniopoulos and Tsalis 2015; Plemić 2022). For instance, the Heritage Site Accessibility Tool (HSAT) provides systematic indicators for evaluating accessibility in open-air archaeological environments (Cantarellas 2023). However, while these studies focus on accessibility, there are also many studies addressing the ecological design of archaeological sites. Both universality and ecological sustainability are essential for these sensitive areas that constitute the shared heritage of humanity. In the literature, these two critical components have been examined separately rather than in an integrated manner. Yet ecological sustainability and universal design are inseparable elements.

Within this framework, the present study is positioned at the intersection of heritage conservation, landscape design, ecological integration, and inclusive accessibility. Guided by universal design principles and ecological sensitivity, it addresses spatial components such as pedestrian routes, ramps, surface materials, wayfinding systems, seating and resting areas, viewing platforms, visitor centres, and safety elements. Ultimately, the study proposes a holistic planning framework that supports both conservation and accessibility simultaneously, offering richer and more equitable heritage experiences for all visitors.

2. Materials and Methods

This study adopts a qualitative research approach aimed at integrating ecological design and universal design principles within archaeological site contexts. The main objective of the study is to evaluate how universal design principles can be considered together with ecological design principles in archaeological sites, and to identify the types of interventions that may be implemented within this framework.

2.1. Research Approach

Methodologically, the study is based on a comprehensive literature review and analysis. Within this scope, key international conventions and charters such as the World Heritage Convention **(UNESCO 1972)**, the ICOMOS Charter for the Protection and Management of the Archaeological Heritage **(ICOMOS 1990)**, and the Council of Europe Faro Convention **(2005)** were examined.

Additionally, recent academic sources focusing on ecological design, socio-ecological systems, universal design, and accessibility were reviewed (Crumley, 2021; Knitter et al., 2021; Steinfeld & Maisel, 2012; Lucchi et al., 2023; Biocca et al., 2025).

Drawing from these references, a conceptual framework was developed that integrates conservation, ecological, and accessibility dimensions, and translates them into key planning and design principles applicable to archaeological areas.

2.2. Development of Indicators

Based on this theoretical foundation, two main categories of conceptual principles were synthesised:

- *Ecological Design Principles* – including ecosystem integrity, sustainability (materials, water, and energy), economy of design and processes, participatory design, resource protection, fulfilment and adaptability of user needs (Ak 2024; McLennan 2004; Rottle and Yocom 2010).
- *Universal Design Principles*– equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and appropriate size and space for approach and use.

2.3. Analytical Method

No field measurements were conducted within the scope of this study. Instead, a thematic comparative analysis was employed to identify recurring concepts, design principles, and relationships between ecological and accessibility dimensions. The literature-based comparative analysis was used to explore how ecological integrity and accessibility intersect in archaeological contexts.

The study evaluated how both structural (e.g., walkways, ramps, terraces, urban furniture) and vegetative (e.g., trees, shrubs, groundcovers) components of landscape design in archaeological areas can serve both ecological conservation and inclusive usability.

The analysis focused on identifying planning and design strategies that simultaneously ensure ecological resilience and social inclusivity.

The findings were synthesised under three interconnected themes: ecological integrity and sustainability, inclusive usability, and ethical conservation responsibility. This synthesis enabled the development of a holistic planning approach capable of sustaining both natural systems and inclusive visitor access within archaeological landscapes.

3. Findings

3.1. Ecological Compatibility in Archaeological Sites

The ecological and cultural compatibility of archaeological sites is grounded in understanding these areas as dynamic socio-ecological systems shaped by continuous interactions between people and their environments (Butzer 1975). The socio-ecological model proposed by Knitter et al. (2021) conceptualises archaeological heritage as the product of long-term feedback loops among cultural practices, land use, and ecosystem processes. This model emphasises that heritage conservation should not detach artefacts from their environmental context; rather, they should be interpreted as living components within evolving ecological networks. Through such an approach, ecosystem continuity within heritage areas is maintained while enabling the ongoing use of the site and the continuation of cultural practices.

Building on this foundation, the ecosystem services (ES) framework provides a powerful perspective through which the ecological and cultural dimensions of archaeological landscapes can be mutually reinforced. Katz (2022) demonstrates that archaeological sites provide both regulating and cultural ecosystem services—such as microclimate regulation, biodiversity refugia, and aesthetic value—which support both human well-being and ecological integrity. When accessibility and infrastructure design incorporate permeable surfaces, minimal grading, and the preservation of native vegetation, these ecological functions are respected and enhanced, increasing not only the environmental resilience of the site but also the quality of the visitor experience (Crabtree, Dunne, and Wood 2021; Malavasi et al. 2023).

In archaeological areas, recognising socio-ecological thresholds helps guide contemporary restoration and tourism management toward adaptive and low-impact solutions, preventing the exceedance of environmental carrying capacities. Ecological design and participatory governance can contribute to establishing a balance between conservation obligations and landscape functionality, enabling archaeological sites to function as long-term, protected systems of human–nature coexistence (Knitter et al. 2021; Malavasi et al. 2023).

In conclusion, the ecological compatibility model offers an integrated framework in which biodiversity protection, environmental sustainability, cultural identity, and accessibility converge. Crabtree et al. (2021) argue that heritage should be managed not as isolated monuments but as components of multifunctional landscapes. Aligning conservation with ecological processes transforms archaeological landscapes into resilient, adaptive, and inclusive systems, where the protection of fragile ecosystems becomes inseparable from the experience of heritage itself.

3.1.1. Applying ecological design criteria to archaeological sites

Ecological design in archaeological landscapes is essential for sustaining the healthy interaction between ecosystems and people. Today, due to factors such as unconscious human use of natural resources, ecosystem degradation, and climate change, ecosystems are increasingly damaged, and this directly affects the sustainability of archaeological sites (Council of Europe, 2024; Crumley, 2021). Therefore, ecological integration is not merely about protecting the past but ensuring the co-sustainability of ecosystems and cultural systems within a shared landscape framework. Archaeological sites are integral components of the habitats in which they are situated; damage to either one directly impacts the sustainability of the other. Therefore, ecological design in archaeological areas not only ensures the protection of the ecosystem but

also supports the co-sustainability of ecological and cultural systems within a shared landscape framework.

Within this context, ecological design criteria found in the literature were evaluated, followed by an assessment of how they can be applied in archaeological areas. The principles developed by Ak (2024), drawing on the ecological design concepts of McLennan (2004); Shu-Yang, Freedman & Cote (2004); and Rottle & Yocom (2010), were used. These include:

The following five core principles summarise the ecological integration approach proposed for archaeological contexts: Economy of design and processes, sustainable designs, participatory design, protection of resources, fulfilment of user needs, ecosystem as a whole, habitat restoration and promotion of biodiversity, and protection of landscape patterns.

The following five core principles summarise the proposed ecological design approach for archaeological contexts:

- **Ecosystem Integrity and Habitat Continuity Principle**

Archaeological sites are functioning ecosystems composed of biotic and abiotic components. Maintaining ecological processes such as soil formation, vegetation renewal, pollination, and carbon cycling is fundamental (Crumley 2021). At the same time, ensuring habitat continuity through the preservation of native vegetation, wildlife corridors, and microhabitats strengthens both ecological and cultural resilience (Knitter et al. 2021). In this respect, flora and fauna within archaeological areas must be protected, exotic species should not be introduced, and habitat integrity should be maintained during landscape design interventions (Knitter et al. 2021).

- **Sustainability Principle (Materials, Water, and Energy)**

In archaeological sites, the use of local, natural, and sustainable materials for both pathways and urban furniture is crucial for the sustainability of both the ecosystem and the site. Sustainable material use and reversible interventions are key to balancing conservation with ecological integrity. Employing locally sourced, low-impact, and recyclable materials in construction, restoration, and visitor infrastructure enhances harmony with the natural and archaeological context (Lucchi 2023). Water is both an ecological and cultural component of archaeological landscapes. Hydrological management practices—such as surface drainage control, rainwater harvesting, and permeable surface design—prevent erosion and help preserve structural stability (Crumley 2021). Viewing water as both a resource and a heritage element encourages the design of sustainable systems that support ecological cycles while respecting archaeological integrity. Energy use within archaeological areas should also be environmentally friendly and sustainable. Photovoltaic lighting systems may be used in ways that do not harm the structural or aesthetic qualities of archaeological heritage. Shaded structures may also be incorporated, particularly in visitor centres and entrances. This principle links environmental responsibility with the ethics of long-term heritage stewardship.

- **Climate Adaptation and Knowledge-Based Innovation Principle**

Archaeological sites are increasingly exposed to climate-related stressors such as rising temperatures, extreme rainfall, and sea-level changes. Adaptive management approaches grounded in climate scenario analysis, monitoring, and flexible planning ensure long-term resilience (DeSilvey et al. 2021). Integrating innovative tools such as remote sensing, LiDAR,

and AI-based monitoring supports evidence-based, data-driven decisions that enhance both ecological and cultural sustainability.

- **Participation, Ethics, Governance, and Awareness Principle**

The success of ecological integration depends on participatory and ethically grounded stewardship. The Council of Europe (2024) defines heritage preservation as both a democratic right and a shared responsibility. Collaborative decision-making among local communities, researchers, and institutions strengthens inclusivity and enhances the social legitimacy of conservation. Educational programs, interpretive trails, and communication initiatives can raise public awareness of the interdependence between nature and culture, transforming archaeological sites into living spaces of ecological ethics and learning.

Integrating these principles—ecosystem integrity, material sustainability, hydrological balance, climate adaptation, and participatory governance—demonstrates that nature, culture, and people function within a single continuous system. Incorporating these principles into heritage management contributes to the development of resilient archaeological landscapes that remain ecologically sustainable, culturally meaningful, and socially inclusive.

3.2. Accessibility Indicators and Universal Design in Archaeological Sites

Universal design refers to the creation of environments that can be accessed, understood, and used to the greatest extent possible by all individuals, regardless of age, ability, or limitations. The concept, developed by the Center for Universal Design at North Carolina State University in 1997, has since become a foundational framework across many fields of application, planning, and design (Centre for Excellence in Universal Design 2025). As archaeological sites constitute a shared heritage of all humankind, ensuring that they are accessible to everyone is an essential requirement.

In this context, the seven principles of universal design were examined, and each principle was analysed in detail regarding its potential application within the landscape design of archaeological sites.

1. ***Equitable Use:*** The design should be useful and accessible to individuals with diverse abilities.

- Ramps should be designed not as alternatives to stairs but as integral parts of the same visitor route.
- Information panels should offer multisensory access, including printed text, Braille, and QR-based audio descriptions.
- Routes must also accommodate visitors with strollers or physical disabilities, providing ramps or lifts where needed.
- Audio descriptions or audio guides may be incorporated for children as well.

2. *Flexibility in Use:* The design should accommodate a wide range of preferences and abilities.

- Resting bays and seating areas can be placed along pathways to account for different walking speeds and endurance levels.

- Given that archaeological sites are predominantly open spaces, climate-responsive elements such as shelters and shading structures (to protect from sun and rain) should be incorporated. These structures should be temporary and portable.

- Modular ramps or movable wooden platforms can be adjusted according to terrain and seasonal conditions without disturbing the archaeological substrate.

3. *Simple and Intuitive Use:* The design should be easy to understand regardless of the user's experience, knowledge, or cognitive ability.

- Wayfinding should rely on simple, internationally recognised symbols.

- Natural reference points—such as distinctive trees, rock formations, or ancient walls—may support intuitive navigation without creating visual clutter. Pathways should be designed in accordance with these reference cues.

- Low boundary elements along walking routes can help guide visitors.

4. *Perceptible Information:* The design should communicate necessary information effectively, regardless of sensory abilities.

- Signage should feature high contrast, large fonts, and tactile or Braille inscriptions.

- Audio guidance systems or smartphone-based navigation may enhance interpretive accessibility for visually impaired visitors, and such applications may also offer age-appropriate explanations for children.

5. *Tolerance for Error:* The design should minimise hazards and reduce the consequences of accidental or unintended actions.

- Low physical barriers such as vegetative buffers can protect fragile archaeological remains while guiding visitor movement.

- Anti-slip surfaces and tactile warning strips can help prevent falls, particularly near elevation changes.

- Railings and boundary markers reduce risks such as falling or becoming disoriented on-site.

6. *Low Physical Effort:* The design should allow efficient and comfortable use with minimal physical effort.

- Ramp slopes should ideally range between 5–8%, with resting platforms at regular intervals.

- Shaded resting areas and benches improve thermal comfort and reduce physical strain at outdoor archaeological sites.

7. *Size and Space for Approach and Use:* Adequate space should be provided for approach, reach, manipulation, and use regardless of the user's body size, posture, or mobility.

- Paths should be at least 100–120 cm wide, with a minimum turning radius of 150 cm for wheelchairs (ADA 2010) .

- Entrances, viewing platforms, and resting areas should be designed to accommodate both individual visitors and groups.
- Waste bins should also be placed in accessible areas.
- Vehicular access should be possible up to visitor reception centres, and these centres must include universally accessible facilities (e.g., accessible toilets).

Accessibility assessment was based on landscape-design components such as route continuity, slope, ramp width, surface texture, frequency of resting points, and visibility of signage.

In archaeological contexts, these criteria must be adapted to the fragility of the site. For example, lightweight modular ramps with adjustable slopes can be installed over uneven terrain without impacting underlying strata. Similarly, tactile paths constructed with natural stone textures can guide visually impaired visitors while remaining compatible with the archaeological material palette. Directional and interpretive signage designed in contrasting tones and placed at accessible heights ensures perceptual inclusivity without visually dominating the landscape (Fielden, 2003).

Balancing conservation and accessibility in archaeological sites require sensitivity to both authenticity and flexibility. Each archaeological site demands context-specific design solutions. While conservation ethics prioritise the preservation of original materials and minimal intervention, accessibility interventions often require physical adaptations. The principle of reversibility—ensuring that any added structure, ramp, or surface can be removed without leaving permanent impact—acts as a mediator between these objectives. Accordingly, accessibility solutions must always be temporary, lightweight, and context-sensitive, enabling inclusive visitor experience while respecting the authenticity of the site.

3.3. Integration of Ecological and Accessibility Dimensions

The integration of ecological and accessibility dimensions allows for a holistic understanding of how natural processes and human experiences intersect within archaeological landscapes. In this framework, both ecological design and universal design indicators serve as essential components for creating environmentally resilient–responsive and socially inclusive spaces. The relationship between ecological and accessibility dimensions is summarised below (Table 1).

Table 3. Integrated ecological compatibility and universal design indicators for archaeological sites

Ecological Design Principle	Universal Design Principle	Integrated Design Implications
Ecosystem Integrity and Habitat Continuity	Flexibility in Use; Low Physical Effort; Simple and Intuitive Use	Routes should follow natural topography, using permeable surfaces. Accessibility should be ensured through steps, bridges, or lifts without fragmenting habitats. Boundary elements along paths should be used for intuitive wayfinding.
Sustainability (materials, water, and energy)	Low Physical Effort	Locally sourced, non-slip, and reversible materials reduce environmental impact and increase safety. Tactile stone surfaces along paths should be used. Rain gardens and water-harvesting systems should be added, particularly near visitor centres. Permeable surfaces should be applied along walkways. Solar-powered lighting should be prioritised. Urban furnishings must use natural, local, non-waste-

Ecological Design Principle	Universal Design Principle	Integrated Design Implications
		generating, and recyclable materials. Waste management should be implemented. Ramps should be placed according to topography, and permeable or elevated structures should support natural drainage.
Climate Adaptation and Knowledge-Based Innovation	Size and Space for Approach and Use; Flexibility in Use	Vegetation and existing tree canopies provide natural shading and thermal comfort. Shade structures should be added near resting areas. Modular ramps and flexible routes allow adaptation to climatic variations without permanent alteration.
Participation, Ethics, Governance, and Awareness	Perceptible Information; Simple and Intuitive Use	Wayfinding and interpretive systems must be inclusive. Signage should incorporate Braille or audio guidance. A participatory approach should be adopted in site management. Visitor management should use remote sensing and AI-based monitoring. Training and awareness activities should be carried out to enhance public understanding.

Ensuring the sustainability of archaeological sites requires a holistic approach that encompasses not only the conservation of cultural remains but also the continuity of natural systems, environmental balance, and social inclusivity. Cultural heritage sites function as living ecosystems that reflect the long-term relationship between humans and nature (Gillings, Hacıgüzeller, and Lock 2020).

In this context, the universal design principles (Hamraie 2017; Mace 1998) offer a fundamental approach to ensuring that archaeological landscapes can be used by individuals of different ages, abilities, and physical capacities. Because archaeological sites are fragile environments, they must be ecologically protected while remaining accessible to all. Accordingly, both structural and vegetative landscape design components in archaeological sites have been evaluated.

Urban Furnishings

Benches: Seating units should be designed with both armrest and armless options at different heights to accommodate users with disabilities. Local, natural, or recycled composite materials may be preferred to reduce environmental impact (Yang et al. 2023).

Waste bins and recycling infrastructure: Waste bins manufactured from recyclable or natural materials should be provided in adequate numbers and designed to harmonise with the site's character. Integrating waste bins into shaded resting areas enhances user comfort while reducing environmental impact. The presence of recycling facilities within archaeological sites supports sustainable waste management.

Lighting: Although nighttime use is limited, lighting may be required for safety. Lighting systems should use low colour temperature and directional fixtures to reduce light pollution. In line with the *Design for Ecosystems* approach, illumination levels should not disrupt biodiversity (AIA 2024). olar-powered lighting systems should be prioritised as sustainable, clean energy solutions.

Boundary elements: While borders are important for safety and orientation, archaeological areas require a minimal-intervention approach. Wooden or rope railings, gabion walls, or natural stone borders provide safety and can also function as microhabitats. Boundary elements additionally provide intuitive guidance for users.

- **Pathways, Ramps, Stairs, and Viewing Terraces**

Surface materials: Walkways should be accessible to wheelchair and stroller users and constructed from non-slip, permeable, local materials. Compacted gravel elevated permeable decks (such as wooden decking), natural stone, or permeable concrete blocks may be used. These materials allow water infiltration to support natural hydrological cycles while ensuring user comfort.

Slope and gradient: Ramp slopes should ideally be between 5–8%, and an alternative route (a ramp or lift) must always accompany stairways (Aile, Çalışma ve Sosyal Hizmetler Bakanlığı 2020). For child safety, stairways should include high contrast and handrails. Steps must be constructed from anti-slip materials.

Viewing terraces and rest points: Viewing platforms should be located at natural vantage points and constructed with durable, non-slip surfaces. Rest areas should be positioned on levelled or ramp-connected zones to ensure full accessibility.

Wayfinding and information: Along pathways, wayfinding signs and information panels should be placed at heights suitable for wheelchair users and include Braille surfaces, high-contrast fonts, tactile maps, and QR codes for audio guidance. Signage should be planned to avoid damaging vegetation or archaeological layers.

Planting Design and Material

Planting elements: Native and drought-tolerant species should be selected; low-allergen and non-invasive plants create safe environments for children and older adults. Vegetation provides natural shading and regulates the microclimate. However, due to the cultural and historical sensitivity of archaeological sites, plant interventions should be minimal within core areas, with planting concentrated in buffer zones and visitor centre surroundings.

Green infrastructure: Rain gardens and bioswales along walkways and ramps help manage surface runoff while protecting natural systems. These should be adapted to the site's environmental characteristics. Such green infrastructure applications should be located away from archaeological remains, mainly in buffer areas and near visitor centres.

Materials: Local stone, recycled composite wood, and natural untreated timber are recommended as low-impact, ecologically compatible materials aligned with universal design principles.

The application of universal design in archaeological landscapes must align with ecological principles such as minimal intervention, reversibility, and respect for natural processes. Each intervention must harmonise with natural systems and respect cultural authenticity.

Through this holistic approach, accessibility becomes a form of ecological stewardship—creating spaces where ecosystem continuity, cultural heritage conservation, and inclusive participation meet in balance.

In summary, ecological and inclusive design in archaeological landscapes represents an integrated approach that combines the principles of conservation, accessibility, and sustainability. Every design element—from benches to ramps, from planting to lighting—must function as part of a living system that protects both heritage and nature. When ecological materials, permeable surfaces, native plants, and low-impact structures are combined with universal design principles, accessibility becomes not merely a technical adaptation but an

ecological responsibility. Such an integrated approach transforms archaeological landscapes into environments where ecosystem continuity, cultural memory, and inclusive participation harmoniously converge.

4. Discussion

The synthesis of findings derived from ecological compatibility and universal design principles demonstrates that inclusive design in archaeological landscapes cannot be considered separately from ecological stewardship. The protection of archaeological heritage requires not only the preservation of artefacts but also the continuity of the ecological systems that sustain them. As recent studies emphasise, heritage management is shifting from a monument-centred approach toward an ecosystem-centred approach in which ecological processes, cultural meanings, and human accessibility are addressed as interconnected systems (Crumley 2021; Knitter et al. 2021; Lucchi 2023).

In heritage planning, ecological stewardship highlights the ethical responsibility to safeguard both the natural and cultural components of archaeological landscapes. Unlike traditional conservation practices, this stewardship encompasses participatory, universal, and ecologically responsive design processes. This approach introduces a new paradigm—grounded in environmental ethics and social justice—that strengthens the notion of "heritage for all" (Council of Europe 2024; Hamraie 2017; Silliman 2020).

Ecological processes such as soil permeability, hydrological balance, vegetation continuity, and microclimatic regulation can coexist with accessibility requirements when planning adheres to principles of minimal intervention, reversibility, and context-sensitive design. For instance, permeable pathways, modular ramps, native vegetation buffers, and solar-powered lighting systems illustrate how inclusive design can contribute to ecological stability (Malavasi et al. 2023). In this sense, accessibility becomes a form of ecological stewardship that harmonises human use with the functioning of natural systems.

From an ethical perspective, inclusive ecological design establishes a balance between the right to access cultural heritage and the obligation to protect fragile ecosystems. This involves both environmental ethics and social ethics. In archaeological sites located within sensitive environments, landscape design must be managed in a way that preserves both site integrity and visitor experience. Adaptive management, supported by ecological monitoring and participatory governance offers a dynamic method for maintaining this balance (Crabtree et al. 2021; DeSilvey et al. 2021).

Every structural and vegetative design element becomes, in essence, an ecological act. Integrating universal design principles with ecological frameworks transforms design into an ethical practice situated between users, heritage, and ecosystems. The use of locally sourced, low-impact materials, the preservation of native vegetation, and the routing of pathways based on topography are examples of this eco-inclusive approach.

In this way, inclusive design enhances environmental resilience while simultaneously supporting cultural continuity and social sustainability (Lucchi 2023). In this context, ecological stewardship and inclusive design emerge as two complementary strategies that evolve together to advance sustainable heritage management.

5. Conclusion

Ecological and inclusive design in archaeological landscapes represents a synthesis of conservation, accessibility, and sustainability principles. Through this approach, it is acknowledged that the long-term resilience of heritage can be achieved not solely through protection but through the integrated consideration of ecological continuity, cultural identity, and universal usability. Therefore, ensuring ecological harmony in archaeological contexts requires a framework that brings together environmental sustainability and universal accessibility.

In conclusion, the ecological compatibility assessment demonstrates that ecological design and accessibility are not competing but complementary strategies. When visitor circulation, material choices, and design elements are aligned with natural systems, archaeological sites can remain both environmentally resilient and socially inclusive. Through this integrated approach, cultural heritage can be transmitted to future generations in a responsible and equitable manner.

The primary limitation of this study lies in the fact that the proposed dual-indicator framework has not yet been empirically validated through site-based data. Future research should test this model in real archaeological settings to evaluate both its ecological and social performance, quantitatively assess the effectiveness of the proposed indicators, and refine its applicability across diverse cultural and environmental contexts.

Acknowledgements and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

ADA. 2010. *2010 ADA Standards for Accessible Design*. Department of Justice.

Ahunbay, Zeynep. 2010. 'Arkeolojik Alanlarda Koruma Sorunlari Kuramsal Ve Yasal Açilardan Değerlendirme'. *Türkiye Bilimler Akademisi Kültür Envanteri Dergisi* (8):103–18. doi:10.22520/tubaked.2010.0007.

AIA. 2024. 'Design for Ecosystems—Framework for Design Excellence'. https://www.aia.org/design-excellence/aia-framework-design-excellence.

Aile, Çalışma ve Sosyal Hizmetler Bakanlığı. 2020. *Erişilebilirlik Kılavuzu*. Engelli ve YaşlI Hizmetleri Genel Müdürlüğü. Uzman MatbaacılıK.

Ak, Bilgenur. 2024. 'Principles and Applications of Ecological Landscape Design'. *Türkiye Peyzaj Araştırmaları Dergisi* 7(2):2013–2229. doi:10.51552/peyad.1566037.

Biocca, Luigi. 2025. 'A Potential Toolbox for Improving the Accessibility Process in Historic Villages'. *Built Heritage* 9(1):43. doi:10.1186/s43238-025-00213-z.

Butzer, Karl W. 1975. 'The Ecological Approach to Archaeology: Are We Really Trying?' *American Antiquity* 40(1):106–11. doi:10.2307/279276.

Cantarellas, Miquel. 2023. 'Archaeological Heritage for All: A Heritage Site Accessibility Tool (HSAT) for Open-Air Archaeological Sites'. *Archaeologies* 19. doi:10.1007/s11759-023-09487-0.

Centre for Excellence in Universal Design. 2025. 'The 7 Principles'. https://universaldesign.ie/about-universal-design/the-7-principles.

Council of Europe. 2005. 'Council of Europe Framework Convention on the Value of Cultural Heritage for Society'.

Council of Europe. 2024. 'L.I.N.K.E.D – Guiding Principles for an Integrated Approach to Culture, Nature and Landscape Management'.

Crabtree, Stefani, Jennifer Dunne, and Spencer Wood. 2021. 'Ecological Networks and Archaeology'. *Antiquity* 95:1–14. doi:10.15184/aqy.2021.38.

Crumley, Carole L. 2021. 'Historical Ecology: A Robust Bridge between Archaeology and Ecology'. *Sustainability* 13(15). doi:10.3390/su13158210.

Dascălu, Vasile-Gabriel, Alexandra Grecu, Andreea Karina Gruia, Viorel Mihăilă, Cristian Constantin Drăghici, Vasile-Gabriel Dascălu, Alexandra Grecu, Andreea Karina Gruia, Viorel Mihăilă, and Cristian Constantin Drăghici. 2024. 'The Role of Road Accessibility for Tourists in the Valorization of Archaeological Resources in the Dobrogea Region, Romania'. *Sustainability* 16(23). doi:10.3390/su162310576.

DeSilvey, Caitlin, Harald Fredheim, Hannah Fluck, Rosemary Hails, Rodney Harrison, Ingrid Samuel, and Amber Blundell. 2021. 'When Loss Is More: From Managed Decline to Adaptive Release'. *The Historic Environment: Policy & Practice* 12(3–4):418–33. doi:10.1080/17567505.2021.1957263.

Gillings, Mark, Piraye Hacıgüzeller, and Gary Lock. 2020. *Archaeological Spatial Analysis: A Methodological Guide*. London & New York: Routledge.

Hamraie, Aimi. 2017. *Building Access: Universal Design and the Politics of Disability*. University of Minnesota Press.

ICOMOS. 1990. 'Charter for the Protection and Management of the Archaeological Heritage'.

Katz, Ofir. 2022. 'The Ecosystem Services Framework in Archaeology (and Vice Versa)'. *People and Nature* 4(6):1450–60. doi:10.1002/pan3.10395.

Knitter, Daniel, Reinhard Bernbeck, Wolfram Schier, and Brigitta Schütt. 2021. 'The Applicability of a Socio-Ecological Model to Landscape Archaeological Research'. Pp. 205–16 in.

Lauria, Antonio. 2017. *Accessibility to Archaeological Sites. From the Accessibility Dimensions to an Access Strategy*.

Lucchi, Elena. 2023. 'Regenerative Design of Archaeological Sites: A Pedagogical Approach to Boost Environmental Sustainability and Social Engagement'. *Sustainability* 15(4):3783. doi:10.3390/su15043783.

Mace, R. L. 1998. 'Universal Design in Housing'. *Assistive Technology: The Official Journal of RESNA* 10(1):21–28. doi:10.1080/10400435.1998.10131957.

Malavasi, Marco, Manuele Bazzichetto, Stefania Bagella, Vojtěch Barták, Anna Depalmas, Antonello Gregorini, Marta Gaia Sperandii, Alicia T. R. Acosta, and Simonetta Bagella. 2023. 'Ecology Meets Archaeology: Past, Present and Future Vegetation-Derived

Ecosystems Services from the Nuragic Sardinia (1700–580 BCE)'. *People and Nature* 5(3):938–49. doi:10.1002/pan3.10461.

McLennan, Jason F. 2004. *The Philosophy of Sustainable Design: The Future of Architecture*. Ecotone Publishing.

Naniopoulos, Aristotelis, and Panagiotis Tsalis. 2015. 'A Methodology for Facing the Accessibility of Monuments Developed and Realised in Thessaloniki, Greece'. *Journal of Tourism Futures* 1(3):240–53. doi:10.1108/JTF-03-2015-0007.

Plemić, Bojana. 2022. 'Accessibility for Everyone and Archaeological Heritage'. *Integration of Archaeological Heritage Interpretation into Practice: Concepts and Case Studies*. doi:10.18485/ARHE_IAHIP.2022.CH9.

Rottle, Nancy, and Ken Yocom. 2010. *Basics Landscape Architecture 02: Ecological Design*.

Shu-Yang, Fan, Bill Freedman, and Raymond Cote. 2004. 'Principles and Practice of Ecological Design'. *Environmental Reviews* 12(2):97–112. doi:10.1139/a04-005.

Silliman, Stephen W. 2020. *Engaging Archaeology: 25 Case Studies in Research Practice*. New Jersey: Cambridge University Press.

Steinfeld, Edward, and Jordana Maisel. 2012. *Universal Design: Creating Inclusive Environments*. Wiley.

UNESCO. 1972. 'Convention Concerning the Protection of the World Cultural and Natural Heritage'.

Yang, Yan, Xuelian Kang, Yafeng Yang, Haoran Ye, Jinxuan Jiang, Guiyang Zheng, Kexin Wei, Shengbo Ge, Su Shiung Lam, Hui Ouyang, Xiangmeng Chen, and Wanxi Peng. 2023. 'Research Progress in Green Preparation of Advanced Wood-Based Composites'. *Advanced Composites and Hybrid Materials* 6(6):202. doi:10.1007/s42114-023-00770-w.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Rainwater Design and Management in Housing Estate Gardens

Melisa EKEN[1]

ORCID 1: 0009-0004-5034-0406
[1] Melisa Eken, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
l2412903812@sdu.ogr.edu.tr **(**Responsible Author)

Irem KAYA [2*]

ORCID 2: 0009-0005-5920-706X
[2] Irem Kaya, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
l2412903063@sdu.edu.tr

Ece YILDIZ [3]

ORCID 1: 0009-0008-0336-1924
[3] Ece Yildiz, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
l2412903810@sdu.ogr.edu.tr

Hatice ADA[4]

ORCID 1: 0009-0008-4638-2338
[4] Hatice Ada, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
l2412903010@sdu.ogr.edu.tr

Abstract

The Turkish population is projected to be 95% urbanized by 2050. Considering the impacts of urbanization—namely, impervious surfaces, fossil fuel use, deforestation, and ecosystem degradation—these factors inevitably pose a major threat to water resources and the hydrologic cycle. Consequently, rainwater utilization and management have become critical due to global climate change. Given that conventional urban infrastructure networks often lead to water loss and flooding, "rainwater management" has gained prominence. This includes the application of Rain Gardens as a "nature-based solution" (NbS) aimed at preserving hydrological functions, infiltrating runoff into groundwater, and favoring ecological solutions for rainwater harvesting. This approach is accepted as a solution to address climate change-related drought, changes in precipitation regimes, and subsequent water scarcity experienced in Turkish cities. Currently, two main techniques are employed in residential and mass housing gardens for water retention and reuse: rooftop harvesting and surface runoff management. This study reviews and evaluates the necessary techniques and management requirements for designing sustainable rainwater systems in mass housing, within the context of existing literature and current legal regulations.

Keywords: Mass Housing Gardens, Rainwater, Climate Change, Water Management, Landscape Design, Rain Gardens, Nature-Based Solutions (NbS).

1. Introduction

1.1. Urbanization Pressure and Threats to the Hydrologic Cycle

The rapid urbanization in Türkiye, with an estimated 95% of the population living in cities by 2050 (Abstract), highlights the extreme environmental pressure on urban areas. The resulting proliferation of impervious surfaces and ecosystem degradation fundamentally disrupt the natural hydrologic cycle. Impervious surfaces prevent rainwater infiltration, halting groundwater recharge and significantly increasing surface runoff.

This situation, combined with global climate change, subjects cities to a dual threat:Drought and Water Scarcity: Changes in precipitation regimes and amounts lead to a decrease in available water resources.

Urban Flooding: During intense rainfall events, inadequate conventional urban infrastructure fails to cope with rapid surface runoff, causing floods.

1.2. The Rise of Nature-Based Solutions

The crisis necessitates the adoption of Sustainable Urban Drainage Systems (SUDS), or Nature-Based Solutions, which treat rainwater as a resource, aiming to restore natural hydrological processes (Fletcher et al., 2014). This approach is crucial for Rainwater Harvesting (YSH). Within mass housing, two main techniques are essential: 1) Rooftop Harvesting (storage-focused) and 2) Surface Runoff Management, exemplified by Rain Gardens (infiltration and management-focused).

1.3. Aim and Scope of the Study

The primary aim of this study is to examine the necessary design and management strategies for sustainable rainwater systems in mass housing gardens, reviewing both structural (rooftop) and peyzaj-based (Rain Gardens) solutions. The focus is on integrating these two approaches within the framework of Turkish legal regulations to propose a holistic and sustainable strategy.

2. Findings and Discussion

2.1. Hydrologic Cycle Degradation and SKYSY/NbS

The SKYSY/NbS philosophy counters the negative impacts of impervious surfaces by emphasizing Source Control—managing water where it falls—and facilitating natural processes like infiltration and retention (Fletcher et al., 2014).

2.2.1. Rain Gardens: Mechanism, Design, and Functions

Rain Gardens are the most effective NbS solution for managing surface runoff in mass housing landscapes (Gümüş & Atik, 2018; Zhou & Huang, 2016).

Mechanism: They are shallow depressions with permeable soil and vegetation designed to slow, filter, and gradually infiltrate runoff, thereby enhancing groundwater recharge and purifying the water (Woods, 2010).

Peyzaj Integration: They serve as both a technical infrastructure element and an aesthetic feature, supporting local biodiversity.

2.3. Analysis of Rainwater Harvesting Techniques in Mass Housing

Sustainable management requires combining structural and landscape-based approaches based on the source of the runoff.

2.3.1. Rooftop harvesting technique (storage and utilization focused)

This technique collects water from roofs for reuse, providing significant potable water savings for non-potable uses like toilet flushing (Ghisi & Ferreira, 2007).

Legal Compliance (Turkey): The mandate to install these systems in structures on parcels over 2,000\,\text{m}^2 makes this a mandatory structural solution (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022).

Design: Requires precise storage volume calculation (Demir, 2015) and use of First Flush devices to ensure adequate water quality.

2.3.2. Surface runoff management technique (infiltration and management focused)

This technique manages runoff from paved surfaces and surrounding gardens.

Objective: To achieve taşkın risk mitigation and groundwater recharge using tools like Rain Gardens, Pervious Pavements, and Infiltration Trenches (UNEP, 2017).

2.3.3. Discussion: the necessity of a hybrid approach

Successful design demands a hybrid and integrated approach. Relying solely on the structural rooftop system is insufficient for flood control and environmental restoration. The two techniques complement each other:

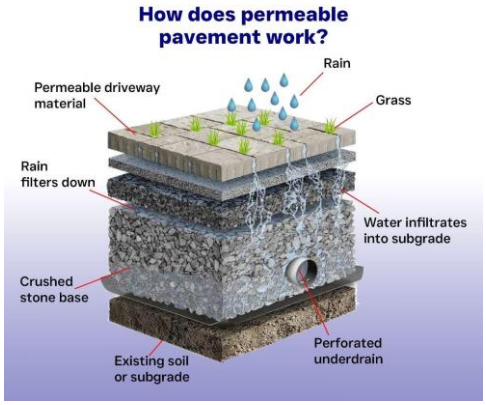


Figure 1. Cross-section of a permeable pavement showing layers and water infiltration (Author unknown, n.d.).

2.4. Review of Regulations and Implementation Challenges

Current Turkish regulations primarily focus on the structural requirements of the rooftop collection system (Demir, 2015). Application Challenges include a lack of integrated design between architectural and landscape disciplines, high initial investment costs (Dündar & Koçer, 2021), and the need for standardized maintenance protocols to ensure longevity.

3. Conclusion and Recommendations

3.1. Conclusion

This study demonstrates that sustainable rainwater management in mass housing areas is no longer an optional environmental practice but a structural necessity shaped by the combined pressures of rapid urbanization and climate change. The significant increase in impervious surfaces, coupled with altered precipitation regimes, disrupts the natural hydrological cycle, leading to reduced groundwater recharge, increased peak runoff, heightened urban flood risk, and growing water scarcity. These conditions highlight the inadequacy of traditional grey infrastructure, which is designed for rapid drainage rather than hydrologic restoration.

The analysis indicates that rooftop rainwater harvesting systems, although essential for potable water savings and legally mandated in Türkiye for parcels over 2,000 m², address only one dimension of the problem. While such systems contribute meaningfully to water conservation

goals, they remain insufficient for controlling surface runoff, mitigating urban floods, or enhancing ecological performance in densely built environments.

Nature-Based Solutions (NbS), particularly rain gardens, infiltration trenches, and permeable pavements, provide the necessary ecological complement to structural approaches by supporting natural processes such as filtration, evapotranspiration, and groundwater recharge. These systems transform landscapes into functional green infrastructure capable of reducing runoff volumes, improving water quality, and restoring urban ecosystem resilience.

A hybrid approach that integrates rooftop rainwater harvesting with NbS-based surface management techniques emerges as the most effective strategy. This integrated system achieves multiple hydrological and environmental goals simultaneously: (1) reduces potable water demand, (2) mitigates flood risk, (3) improves microclimatic conditions, (4) enriches biodiversity, and (5) enhances the overall ecological performance of mass housing environments. Of equal importance, this approach aligns with international sustainability goals and supports Türkiye's transition toward climate-adaptive urban development.

However, the study also identifies major implementation challenges. The current regulatory framework focuses predominantly on structural systems and lacks operational guidelines for NbS. Additionally, barriers such as high initial investment costs, insufficient interdisciplinary collaboration, and the lack of standardized maintenance protocols hinder effective deployment. Without addressing these challenges, the long-term success and functionality of sustainable rainwater systems remain uncertain.

In conclusion, this study argues that restoring the hydrologic balance in mass housing landscapes requires shifting from fragmented, single-focus interventions to integrated systems-thinking. Strengthening the regulatory framework, investing in technical capacity-building, and promoting interdisciplinary design practices will be crucial to achieving resilient, water-sensitive urban environments.

3.2. Recommendations

Recommendations for Designers and Engineers

Integrating Landscape and Infrastructure from the Earliest Design Stages

Hydrologic performance must be positioned as a central design criterion rather than an afterthought. Architectural, civil engineering, and landscape architecture teams should collaboratively model runoff behavior, infiltration capacity, and storage volumes during the conceptual phase of mass housing projects.Adopting Performance-Based Design Standards

Designers should move beyond prescriptive design and instead adopt performance thresholds—such as runoff reduction targets, infiltration rates, or water quality improvement metrics—to guide decision-making. This approach ensures that both rooftop and landscape systems function synergistically.

Enhancing Rain Garden Functionality Through Ecological Design

Soil mixtures must be engineered for rapid infiltration yet high pollutant retention, while plant palettes should prioritize deep-rooted native species that enhance evapotranspiration and provide ecosystem services. Careful spatial distribution of rain gardens can improve both aesthetic quality and hydrologic efficiency.

Maximizing System Interconnectivity

Instead of viewing rooftop harvesting and rain gardens as separate components, designers should create integrated water loops where cistern overflow is directed to rain gardens, thereby preventing system overloading and enhancing infiltration.

Planning for Long-Term Maintenance

Sustainable performance depends on consistent maintenance. Designers should provide detailed maintenance manuals addressing sediment removal, plant health monitoring, seasonal inspections, and soil permeability testing.

Recommendations for Policy Makers and Local Authorities

Expanding Legal Requirements to Include Surface Runoff Management

Current regulations mandate rooftop harvesting but remain silent on NbS. New urban development regulations should require the implementation of at least one infiltration-based NbS system for mass housing parcels above defined size thresholds.

Establishing National Technical Standards for NbS Clear standards for soil composition, plant selection, hydrologic sizing, infiltration rates, and monitoring procedures are essential. Standardization will reduce performance variability and increase public trust in NbS solutions.

Developing Incentive-Based Policy Mechanisms

Economic incentives—such as tax reductions, accelerated permitting, or density bonuses—should be given to mass housing projects that exceed minimum requirements by installing hybrid systems. Such incentives can reduce financial barriers and encourage widespread adoption.

Implementing Capacity-Building and Certification Programs

Local governments should offer training programs and certification for designers, contractors, and maintenance teams specializing in NbS. This will improve implementation quality and ensure systems operate effectively over the long term.

Monitoring, Evaluation, and Public Reporting

Municipalities should conduct periodic evaluations of installed rainwater systems, measuring runoff reduction, water savings, and ecological benefits. Transparent reporting will support data-driven planning and enhance community engagement.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Demir, E. (2015). Bina Ölçeğinde Yağmur Suyu Hasadı Uygulamaları ve Tasarım Kriterleri. *Mühendislik Bilimleri ve Tasarım Dergisi,* 3(3), 305-314.

Dündar, M. S., & Koçer, K. (2021). Toplu Konut Projelerinde Yağmur Suyu Hasadı Sistemlerinin Ekonomik Fizibilitesi ve Geri Ödeme Süreleri. *Journal of Construction Engineering and Management,* 28(2), 112-125.

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., DeBusk, K., ... & Wadzuk, B. (2014). SUDS, LID, WSUD and Green Infrastructure: A Comparative Review. *Journal of Sustainable Water in the Built Environment,* 1(3), 017-024.

Ghisi, E., & Ferreira, F. L. (2007). Potential for potable water savings by using rainwater in the residential sector of Brazil. *Building and Environment,* 42(6), 2530-2537.

Gümüş, V., & Atik, M. (2018). Kentsel Yeşil Altyapı Bileşeni Olarak Yağmur Bahçeleri ve Uygulama İlkeleri. *Selçuk Üniversitesi Ziraat Fakültesi Dergisi,* 32(1), 18-30.

Özdemir, A., & Akın, O. (2022). Sürdürülebilir Yapılarda Yağmur Suyu Geri Kazanım Sistemlerinin Uygulama Örnekleri (Türkiye Örnekleri). *Mimarlık ve Tasarım Dergisi,* 6(3), 481-496.

T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı. (2022). Planlı Alanlar İmar Yönetmeliğinde Değişiklik Yapılmasına Dair Yönetmelik. (Regulations Amending the Regulation on Planned Areas Zoning).

United Nations Environment Programme (UNEP). (2017). Rainwater Harvesting: A Lifeline for Human Well-Being. UNEP Technical Report.

Woods, S. (2010). Water Harvesting: Practical and Ecological Design for Landscape and Architecture. Chelsea Green Publishing.

Yıldız, D., & Yüksel, H. (2016). Rainwater harvesting: a new approach for sustainable water management in urban areas. *Desalination and Water Treatment,* 57(1), 221-230.

Zhou, Q., & Huang, Y. (2016). Nature-Based Solutions for Urban Rainwater Management and Landscape Design: A Literature Review. *Ecological Engineering,* 95, 290-302.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Expert Opinions and Evaluation within the Scope of Urban Forest Management

Öner DEMİREL 1*

ORCID 1: 0000-0002-8102-5589
[1] Prof. Dr., Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale-Türkiye
odofe01@gmail.com (Responsible Author)

Bilgenur AK [2]

ORCID 2: 0000-0002-3060-4361
[2]Assist. Prof. Dr., Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale-Türkiye
bilgenurak@kku.edu.tr

Meryem Bihter BİNGÜL BULUT [3]

ORCID 3: 0000-0003-4496-8198
[3] Assoc. Prof. Dr., Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale-Türkiye
mbbingul@kku.edu.tr

Abstract

In today's cities and settlements, urban forests, which are gaining importance on ecological, social, cultural, and economic scales, face many problems regarding their conceptual approaches, planning/design, site selection, establishment, and management/operation. In this context, it is of great importance to introduce scientifically based approaches so that urban forests can provide sustainable and multi-functional services and contributions in line with their objectives. In recent years, within the framework of the international forestry process that our country has undertaken through international conventions and is actively participating in aiming for "Sustainable Forest Management" intense efforts are being made to balance and enhance the ecological, economic, and social functions of forests. In our country, the design criteria and design framework for the arrangement of the 142 urban forests declared so far have not been developed, and different definitions and approaches are being applied for each region and site. There is a need for methodological approaches to be put forward on the basis of planning approaches that must be addressed with a holistic perspective, as well as for tools that will serve as guidelines and provide guidance for studies. In this scientific study on the urban forest management plan, social research techniques were employed to obtain expert opinions and suggestions with the aim of achieving a holistic and participatory solution. Based on the collected views and recommendations, alternative proposals for the planning and design framework of the area have been presented.

Keywords: Kırıkkale Urban Forest, urban, forest, expert, survey

1. Introduction

In today's cities and settlements, urban forests, which are gaining importance on ecological, social, cultural, and economic scales, face many problems regarding their conceptual approaches, planning/design, site selection, establishment, and management/operation. (Konijnendijk & Randrup, 2004).

In this context, it is of great importance to introduce scientifically based approaches so that urban forests can provide sustainable and multi-functional services and contributions in line with their objectives. In recent years, within the framework of the international forestry process that our country has undertaken through international conventions and is actively participating in aiming for "Sustainable Forest Management" intense efforts are being made to balance and enhance the ecological, economic, and social functions of forests.

In our country, the design criteria and design framework for the arrangement of the 142 urban forests declared so far have not been developed, and different definitions and approaches are being applied for each region and site. There is a need for methodological approaches to be put forward on the basis of planning approaches that must be addressed with a holistic perspective, as well as for tools that will serve as guidelines and provide guidance for studies.

In this scientific study on the urban forest management plan, social research techniques were employed to obtain expert opinions and suggestions with the aim of achieving a holistic and participatory solution. Based on the collected views and recommendations, alternative proposals for the planning and design framework of the area have been presented.

1.1. A Model Proposal for Site Selection of Urban Forests in Turkey: The Case of Kırıkkale Urban Forest

The ability of urban forests to fulfill their expected social and environmental functions,

- depends on being under suitable natural and ecological conditions,
- the utilization being carried out in accordance with the principles of sustainable management,
- and is possible through maintaining them under a natural status in legal and administrative terms (Örücü, 2014).

Based on this holistic approach, it becomes necessary to adopt a conservation-oriented design and planning approach for urban forests, which, due to the functions they provide for all living beings, serve as areas of attraction and, as a natural consequence, are subject to diverse and intensive uses that lead to degradation (Grey & Deneke, 1992).

Studies concerning the Urban Forest and its surroundings represent "*A Sustainable, Ecologically and Hydrologically Based Holistic Blue-Green Infrastructure Model*", which emphasizes the protection of the natural water cycle and integrates contemporary urban green network planning with stormwater management systems. This approach is grounded in rainwater management, river restoration, water quality improvement, acoustic comfort, and the design of recreational spaces.

1.2. Urban Forestry

Afforestation activities conducted within and around cities are often carried out arbıtrarıly by different institutions or individuals, without considering their future role and contributions. In this context, to ensure that such activities are purposeful and sustainable, conscious planning and management at the urban scale must be implemented. Therefore, the selection of the most suitable site for an urban forest is the first step that must be taken for its rational planning and management. For urban forest site selection, it is of great importance to investigate the suitability and feasibility of the areas in terms of balancing or strengthening the recreational, ecological, and urban structure functions.

1.3. The Development Process of Urban Forestry

With the official designation of urban forests in Turkey, a new phase has begun. Urban forests, b.oth **those established through reforestation efforts** and **those integrated with existing forest resources** within and around cities, aim to enhance **urban quality of life** as part of the urban green network through their aesthetic, psychological, and ecological functions (Demirel and Kelkit, 2003; Miller, 1997).

Today, **urban forest planning** is based on the principle of establishing urban groves and green belts around cities where natural and cultural vegetation is absent or insufficient, while also rehabilitating existing plant cover **to balance the integration between urban and rural areas.** All these efforts represent a dynamic and evolving process that goes beyond traditional boundaries of urban forestry, aiming for a more holistic approach to the urban green network.

1.4. Rationale of the Study

Within the scope of this study, the Kırıkkale Urban Forest is evaluated in terms of its recreational and ecological suitability, as well as its compatibility with the city's physical structure in determining its potential as an urban forest. To achieve this,

a) identification of candidate areas,
b) evaluation of suitability, and
c) assessment of feasibility constitute the three stages of the "*Urban Forest Site Selection Model*" applied in this study (Gezer & Gül, 2009).

In addition, after obtaining these criteria, *A Survey Study* involving local residents, visitors, experts and administrators is conducted as a second phase of the research to reveal the recreational and touristic aspects of the area.

This paper presents the views of experts including those from academia, public institutions, and private initiatives on the possibilities of multidimensional evaluation of the area on legal and administrative grounds within the framework of the urban forest site selection model.

2. Materials

2.1. Kırıkkale Urban Forest (*National Forest, Forest Park, 100th Year Park*)

The Kırıkkale Urban Forest (100th Year Forest), located within the boundaries of Kırık Village in the Central District of Kırıkkale Province, was established in December 2006 on a 40-hectare area designated as State Forest (Figure 1). In 2010, according to an agreement made between the Ankara Forest Management Directorate and the Kırıkkale Municipality, the Urban Forest was leased for 49 years to the Department of Parks and Gardens of Kırıkkale Municipality.

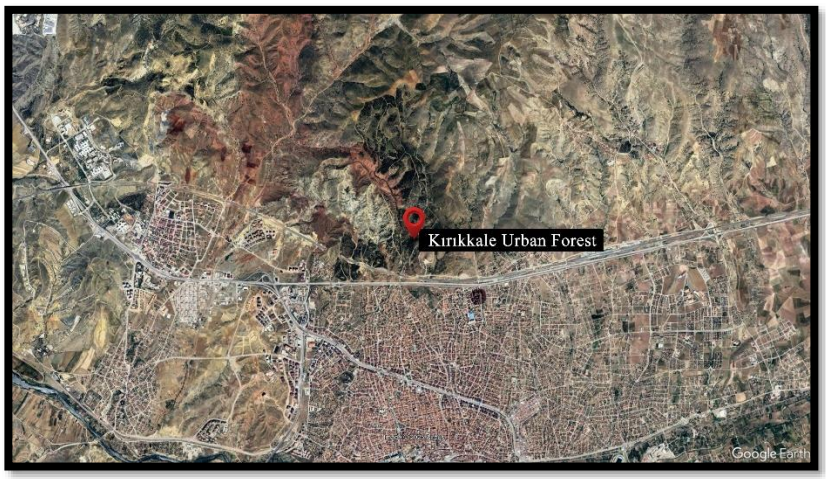


Figure 1. Location of Kırıkkale Urban Forest (Google Earth, 2025)

Since 2006, various structural and landscape development activities have been carried out in the area, including the construction of one building, one pool, three cabins, two restrooms, walking and jogging tracks, picnic tables, a basketball court, and a parking area. Although several structural and environmental arrangements have been implemented, the area is currently closed to public access (Kırıkkale Forest Management Directorate, 2010).

2.3. Evaluation of Expert Opinions and Perspectives

Within and around urban ecosystems, *Urban Forests* are unique green areas of natural or semi-natural character that both sustain and manage biodiversity in peri-urban and urban environments. They enhance nature's ability to provide ecosystem goods and services such as clean air and water, while also establishing vital connections between high-quality natural, semi-natural, and urban areas.

Experts, in line with the characteristics mentioned above, state that, as a result of their ecological, social, and economic evaluations of urban forests, these areas are very important living islands and exceptional ecosystems that, within the urban ecosystem, perform ecological and engineering functions such as climate regulation, creating evaporation surfaces, reducing terrestrial radiation, improving air and water quality, reducing the heat island effect, serving as potential areas for smart agricultural practices, acting as ecological corridors, reducing flood/overflow risks, providing habitats for wildlife, forming windbreaks, and masking noise. In addition to these ecological and engineering functions, they also contribute to the economic vitality of the city through their recreational and touristic aspects.

In this survey study, which consists predominantly of academics, the faculty members and staff from the Department of Landscape Architecture are represented in greater numbers for the sake of representativeness.

Their evaluations are presented in the following statements (Demirel et all., 2025);

- It is stated that urban forests should be protected under the legal status of Protection Forests (42.4%) and Protected Natural Areas (23.5%), and it is emphasized that they should cover a large area within the city (100 hectares or more).
- It is stated that urban forests should be protected under the Provincial Special Administration Law, the National Parks Law, and the Forest Law in legal and administrative terms. The experts also particularly emphasize the importance of their location within or around the city, or at a distance that maintains a meaningful connection with the urban area.
- In the evaluation regarding which institution should manage and operate urban forests, it was stated that the Regional Directorate of Forestry should take the first priority, followed by the Provincial Directorate of Environment and Urbanization in the second, and Local Governments/Municipalities in the third place.
- ***As the primary functional purpose of urban forests***, it has been expressed that they should, first and foremost, serve as recreational and vital spaces that contribute to the physical and mental well-being of urban residents; secondly, play a role in improving the urban climate; and thirdly, function as multifunctional zones within the city as part of the urban green space network.
- ***In the inquiries regarding activities that can be carried out in urban forests,*** it was primarily indicated that nature walks and outdoor sports are the most preferred activities. It was

also stated that wildlife and birdwatching are frequently chosen purposes of use. Furthermore, urban forests were described as very special areas where various events, organizations, and rotational activities can be organized.

- ***It has been stated that urban forests are areas that can be transformed into important functional zones of the city through projects and organizations encouraging public participation at different levels.*** In the conservation and maintenance activities carried out in urban forests, community involvement in voluntary events, promotional and nature education activities, as well as fundraising and donations for the urban forest budget, and guiding or field interpretation programs will ensure that people act together and become part of these efforts. Through such collective engagement, these areas will be further developed, preserved, and passed on to future generations.

3. Expert Recommendations

- These areas are also important reserve zones in terms of ***Green And Blue Infrastructure Strategies,*** functioning as biological habitats and playing a key role in Green Belt initiatives, Green Corridors (greenways and ecological corridors), and Nature-Based Solutions such as naturalized streams and drainage channels.
- They emerge as places that meet the psychological and physical needs of society under evolving and transforming living conditions.
- The existence of urban forests should be legally mandated for every city, and particularly in metropolitan municipalities, the number of urban forests should be increased.
- Urban forests are one of the important urban systems that ensure the organic connection between the city and nature. Laws and regulations specific to urban forests, aimed at protecting and enhancing urban ecology, should be enacted and implemented within an integrated framework together with all other legislations that affect the city.
- In particular, supporting urban biodiversity, preserving local biodiversity, and ensuring connectivity among urban green spaces are of great importance. At the same time, urban forests should function as buffer zones that help maintain the health and continuity of different ecosystems in terms of ecosystem service provision.
- Urban forests should be managed in a way that supports landscape continuity, wildlife, and biodiversity, while ensuring an organic integrity between the city and nature.
- In addition to their positive impact on the natural water cycle of the city, urban forests have significant hydrological effects on spatial water management within urban watersheds. This characteristic should not be overlooked.

4. Results

4.1. Evaluation of Expert Opinions and Perspectives

Forest areas located around cities should be developed, protected, and sustainably utilized, while encouraging their use by urban residents for activities such as walking, sports, cycling, and nature observation. Activities that may harm nature, such as picnicking, should either be eliminated or strictly controlled.

The planning, management, and operation of all forest recreation areas and urban forests should be clearly defined and distinguished by law, and both their resources and administration should

be consolidated under a single unit. A multidisciplinary team within this unit comprising forest engineers, landscape architects, urban and regional planners, and biologist should conduct a comprehensive inventory study and develop strategic plans for both existing forest resources and potential areas, including aspects of forest resource planning and functional planning of forest resources.

Urban forests should be established for appropriate and purpose-driven use and transforming existing areas into urban forests should not be the preferred approach.

• In the conditions of Central Anatolia, in addition to creating new forest areas, protecting existing forests and transferring them to future generations is quite challenging due to climatic factors. Therefore, in afforestation efforts within this region, perspectives and concepts beyond the notion of urban forests should be developed, placing greater emphasis on soil and water conservation and the ecological functions of forests. In this regard, rather than using a uniform definition of urban forest areas across the country, it is recommended to adopt designations that emphasize the character of nature reserves.

• Urban forests should be planned, designed, maintained, and managed properly by expert teams. Relevant legislation should be developed, and specific units for urban forests should be established within the responsible institutions. Legal regulations and organizational models abroad should be examined and used as references in shaping these frameworks.

• Instead of declaring existing forested areas as urban forests, new urban forests should be established through reforestation efforts.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Demirel, Ö., & Kelkit, A**.** (2003). *Ormanların sosyal ve çevresel fonksiyonları ile insan kullanımından kaynaklanan sorunları: Belçika'daki rekreatif ve turistik ormanlar (Chevetogne ve Soignes Ormanı örneği) üzerinde yapılan uygulama çalışması*. March 19–20, II. Ulusal Ormancılık Kongresi: Türkiye Ormanlarının Yönetimi ve Katılımı, Ankara.

Gezer, A., & Gül, A. (2009). *Kent ormancılığı (kavramsal, teknik ve kültürel yaklaşımlar)* (Yayın No. 86). Süleyman Demirel Üniversitesi Orman Fakültesi, SDÜ Basımevi, Isparta.

Google Earth. (2025). *Kırıkkale, Kırıkkale Forest satellite image* [Satellite image]. Google. https://earth.google.com/ (Accessed: 25 November 2025).

Grey, G. W., & Deneke, F. J. (1992). *Urban forestry*. Wiley, New York.

Kırıkkale Orman İşletme Müdürlüğü. (2010). *Kırıkkale (Kırıkköyü) Kent Ormanı bilgi cetveli*. Kırıkkale.

Demirel, Ö., Gül, A., Örücü, Ö. K., Bingül Bulut, M. B., Özçalık, M., Ateş, V., Yılmaz, A., & Aydoğan, T. G. (2022). *Ülkemizde kent ormanları yer seçim modeli oluşturulmasına yönelik bir model denemesi: Kırıkkale Kent Ormanı (100. Yıl Ormanı) örneği* (Proje No.

2022/037; Bütçe: 49.999,99 TL). Kırıkkale Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi. (Kabul tarihi: 30.03.2022; Tamamlanma tarihi: Haziran 2025).

Konijnendijk, C. C., & Randrup, T. B. (2004). Urban forestry. In J. Burley, J. Evans, & J. A. Younquist (Eds.), *Encyclopedia of forest sciences* (pp. 471–478). Elsevier, London.

Miller, R. W. (1997). *Urban forestry: Planning and managing urban green spaces* (2nd ed.). Prentice Hall, New Jersey.

Örücü, Ö. K. (2014). *Kent ormanı yönetim planı: Isparta örneği.* Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Orman Mühendisliği Anabilim Dalı, Doktora Tezi, 274 s.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Reducing the Urban Heat Island Effect with Water Surfaces: The Case of Hazar Lake

Yaşar MENTEŞ [1*]

ORCID 1: 0000-0001-8505-470X
[1]Dr., Ministry of Agriculture and Forestry, Directorate of Provincial Agriculture and Forestry, Elazığ-Türkiye
yasarment@hotmail.com (Responsible Author)

Sevgi YILMAZ [2]

ORCID 2: 0000-0001-7668-5788
[2]Prof. Dr., Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, Erzurum- Türkiye
sevgiy@atauni.edu.tr

Abstract

Urban Heat Islands (UHI), characterized by higher temperatures in urban areas than in rural areas, are observed in various regions around the world. Studies on UHI mitigation have focused on the thermal effects of vegetation. Research on the potential of water surfaces to mitigate UHI is scarce. Open water surfaces are an important landscape element whose UHI mitigation effects have been overlooked. This study investigated the cooling effect of water surfaces on the UHI. Hazar Lake, located southeast of Elazığ, was selected for this purpose. Thermal band analysis was conducted to reveal the lake's cooling effect. For this purpose, the Land Surface Temperature (LST) values for the rural and urban areas of Sivrice District, the central district of Elazığ Province, and the surface areas of Hazar Lake were compared during the summer months. Among the four study areas, the lowest average LST value was found in the Caspian Lake surface area. During the summer months, the Hazar Lake surface area LST value was 17.4°C lower than that in the central district, 15.0°C lower than that in the Sivrice district, and 13.6°C lower than that in the Sivrice district urban area. Strategic location and design of water resources in urban areas can optimize the cooling effect.

Keywords: Urban head island, land surface temperature, remote sensing, water surfaces

1. Introduction

Urban populations have increased significantly due to factors such as technological advances, modernization, comfortable life expectancy, improved health services and concentration of economic opportunities in urban areas (Cuce et al., 2025). Rapid urbanization and diversification in economic activities are reducing the quality of the urban environment globally (Debnath et al., 2025). Human activities directly impact global warming and climate change. Urban areas with impermeable surfaces experience significantly higher temperatures on hot summer days than rural areas (Mathew et al., 2025). This phenomenon, referred to as UHI in the literature, is a condition in which urban areas are characterized by higher temperatures compared to suburban and rural areas (An et al., 2025). The UHI effect can be observed in different parts of the world.

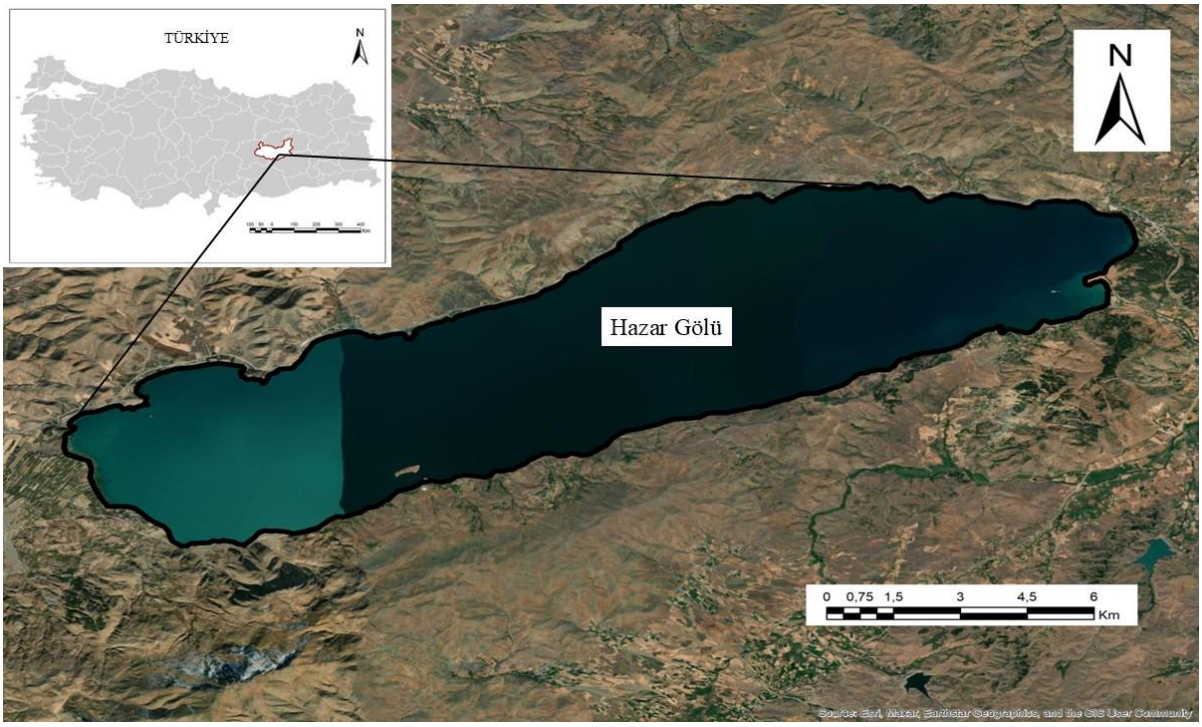
Significant research has been conducted in recent years to reduce the impact of UHI and improve environmental factors (Syafii et al., 2016; Battista et al., 2020; Yilmaz et al., 2025). However, research to date has mainly focused on the urban heat island and the thermal impact of vegetation (Yang et al., 2020). Less research has been conducted on the potential of water surfaces to mitigate UHI (Khan et al., 2019; Wu et al., 2019). Like vegetation use, the climatic effects of water also help reduce UHI. Water bodies play a significant role in reducing UHI. Water surfaces are an important landscape element whose UHI mitigation effects are often overlooked (Wu et al., 2019; Menteş et al., 2025).

This study investigated the cooling effect of water surfaces on the UHI. Hazar Lake, located southeast of Elazığ, was selected for this purpose. Thermal band analysis was performed to reveal the cooling effect of the lake.

2. Material ve Method

2.1. Material

Hazar Lake, located southeast of Elazığ city, covers an area of approximately 81 km^2 (Ünlü et al., 2008). The location map of the study area is shown in Figure 1.



Şekil 1. Çalışma alanı konum haritası

2.2. Method

Remote sensing techniques are widely used to monitor the UHI effect. Thermal band analyses were conducted to reveal the cooling effect of water surfaces. Analyses were performed using ArcGIS 10.7.01 software. Landsat 9 satellite images downloaded from the USGS website (https://earthexplorer.usgs.gov/) were used for thermal band analyses. Because the highest temperature (°C) between 1939 and 2024 was observed in July (MGM, 2025), satellite images for July were downloaded in Elazığ province. The data from the satellite images used in the study are shown in Table 1.

Table 1. Landsat Satellite Images Used in the Research

Satellite Image	Image Date	Path/Row	Bulutluluk Oranı (%)	Harita Projeksiyonu	UTM Zone	Datum
Landsat 9	06.07.2025	173/33	7.96	UTM	37	WGS84

The process steps for thermal band analysis are shown in Figure 2.

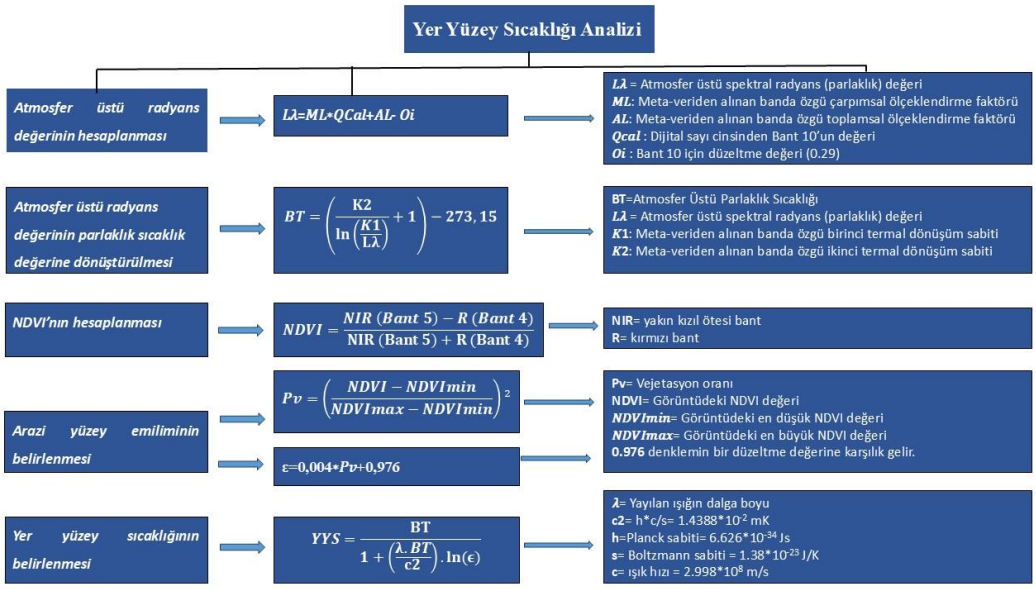


Figure 2. Land surface temperature analysis process steps

3. Findings and Discussion

The central district of Elazığ Province is located northwest of Hazar Lake. Sivrice District is located southwest of Hazar Lake. The urban area of Sivrice District is located southwest of Hazar Lake. Lake Hazar borders these three study areas. The LST maps of the study areas are shown in Figure 3 and Table 2.

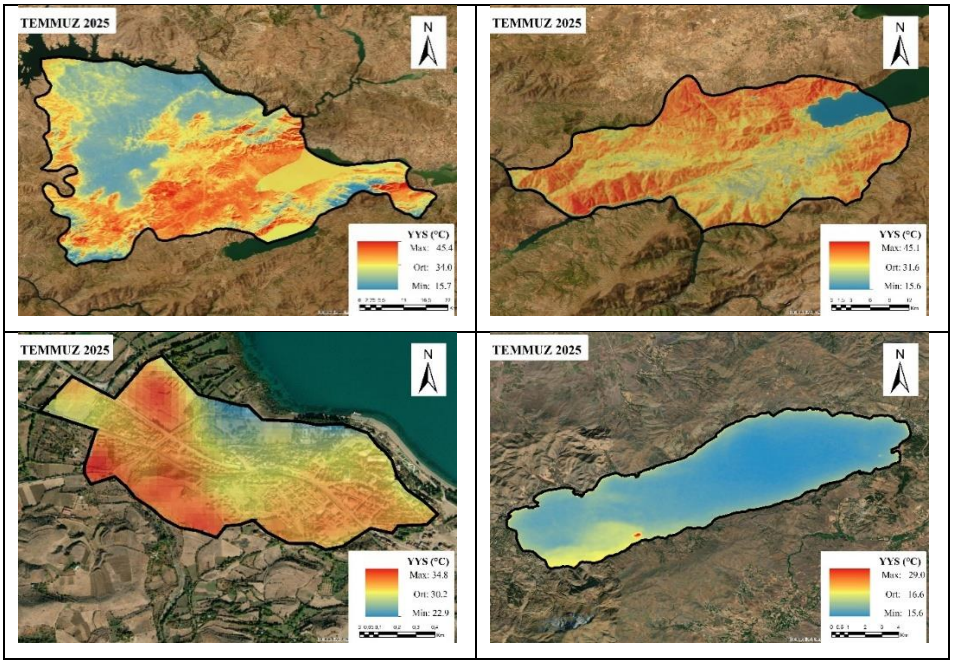


Figure 3. Seasonal LST values of the study areas (Top left: Central District of Elazığ Province, top right: rural area of Sivrice District, bottom left: urban area of Sivrice District, bottom right: surface area of Hazar Lake)

Table 2. Seasonal LST Values of the Study Areas

LST (°C)	Elazığ Central District			Sivrice Rural Area			Sivrice Urban Area			Hazar Lake		
	Min	Ort	Max	Min	Ort	Max	Min	Ort	Max	Min	Ort	Max
July 2025	15.7	34.0	45.4	15.6	31.6	45.1	22.9	30.2	34.8	15.6	16.6	29.0

Among these four areas, the lowest average LST value was found in the surface area of Hazar Lake. The highest LST value was found in the central district of Elazığ Province. The Hazar Lake surface area LST value was 17.4 °C lower than the central district area, 15.0 °C lower than the Sivrice district, and 13.6 °C lower than the urban area of Sivrice district.

In general, urban areas are characterized by higher temperatures than rural areas (Bottyan *et al.* 2005; Mehta 2025). However, when looking at the LST temperature values, it is seen that the urban area of Sivrice district is lower than the temperature value of the rural area. The urban area of Sivrice district is 1.4°C lower than the rural area of Sivrice district. Because the urban area is closer to Hazar Lake, it has a lower LST value than the Sivrice area. This is a clear indication of the cooling effect of water.

4. Conclusion and Recommendations

This study investigated the cooling effect of water masses on the UHI. Hazar Lake, located southeast of Elazığ city, was selected for this purpose. Among the four study areas, the lowest average LST value was found in the surface area of Hazar Lake. The highest average LST value for these months was found in the central district of Elazığ Province. During the summer season, the LST value for the surface area of Hazar Lake was 17.4 °C lower than that of the central district, 15.0 °C lower than that of Sivrice, and 13.6 °C lower than that of the urban area of Sivrice. Because the urban area of Sivrice is closer to Hazar Lake, it has a lower LST value than that of the rural area of Sivrice. This is a clear indication of the cooling effect of water. Reducing the UHI effect is crucial for combating climate change. Surface water bodies can offer a sustainable way to mitigate rising temperatures in regions experiencing rapid urbanization.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

An, Z., Ming, Y., Liu, Y., & Zhang, G. (2025). Investigating 2D/3D factors influencing surface urban heat islands in mountainous cities using explainable machine learning. *Urban Climate*, *59*, 102325. https://doi.org/10.1016/j.uclim.2025.102325

Battista, G., Evangelisti, L., Guattari, C., De Lieto Vollaro, E., De Lieto Vollaro, R., & Asdrubali, F. (2020). Urban heat island mitigation strategies: Experimental and numerical analysis of a university campus in Rome (Italy). *Sustainability*, *12*(19), 7971. https://doi.org/10.3390/su12197971

Bottyán, Z., Kircsi, A., Szegedi, S., & Unger, J. (2005). The relationship between built-up areas and the spatial development of the mean maximum urban heat island in Debrecen,

Hungary. *International journal of climatology*, *25*(3), 405-418. https://doi.org/10.1002/joc.1138

Cuce, P. M., Cuce, E., & Santamouris, M. (2025). Towards Sustainable and Climate-Resilient Cities: Mitigating Urban Heat Islands Through Green Infrastructure. *Sustainability*, *17*(3), 1303. https://doi.org/10.3390/su17031303

Debnath, M., Poddar, I., Saha, A., Islam, N., & Roy, R. (2025). Analysis of land surface temperature and its correlation with urban, water, vegetation, and surface indices in the Siliguri Urban Agglomeration area of the Himalayan foothill region. *Geomatics, Natural Hazards and Risk*, *16*(1), 2470393. https://doi.org/10.1080/19475705.2025.2470393

Khan, Shahid, Chung, Kim, & Ali. (2019). Influence of Surface Water Bodies on the Land Surface Temperature of Bangladesh. *Sustainability,* 11(23), *6754.*

Mathew, A., Aljohani, T. H., Shekar, P. R., Arunab, K. S., Sharma, A. K., Ahmed, M. F. M., ... & Abdo, H. G. (2025). Spatiotemporal dynamics of urban heat island effect and air pollution in Bengaluru and Hyderabad: implications for sustainable urban development. *Discover Sustainability*, *6*(1), 134. https://doi.org/10.1007/s43621-025-00860-3

Mehta, M. (2025). A review of urban heat island mapping approaches with a special emphasis on the Indian region. *Environmental Monitoring and Assessment*, *197*(4), 1-20. https://doi.org/10.1007/s10661-025-13810-3

Menteş, Y., Yilmaz, S. (2025). Effect of Water Surfaces on Urban Heat Island: A Case Study in the City of Elazığ, Türkiye. In: Alberti, F., *et al.* Urban and Transit Planning (Vol 1): Strategies, Innovations and Climate Management . UPADSD 2023. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-031-76096-9_4

MGM. 2025. Meteoroloji Genel Müdürlüğü. https://www.mgm.gov.tr/

Syafii, N. I., Ichinose, M., Wong, N. H., Kumakura, E., Jusuf, S. K., & Chigusa, K. (2016). Experimental Study on the Influence of Urban Water Body on Thermal Environment at Outdoor Scale Model. *Procedia Engineering,* 169, 191–198.

USGS, 2025. https://earthexplorer.usgs.gov/ (02.08.2025).

Ünlü, A., Çoban, F., & Tunç, M. S. (2008). Hazar Gölü Su Kalitesinin Fiziksel ve İnorganik kimyasal Parametreler Açısından İncelenmesi. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, *23*(1).

Wu, C., Li, J., Wang, C., Song, C., Chen, Y., Finka, M., & La Rosa, D. (2019). Understanding the relationship between urban blue infrastructure and land surface temperature. *Science of the Total Environment*, *694*, 133742. https://doi.org/10.1016/j.scitotenv.2019.133742

Yang, L., Liu, X., & Qian, F. (2020). Research on water thermal effect on surrounding environment in summer. *Energy and buildings*, *207*, 109613. https://doi.org/10.1016/j.enbuild.2019.109613

Yilmaz, S., Menteş, Y., & Jamei, E. (2025). Investigating the Effect of Blue–Green Infrastructure on Thermal Condition—Case Study: Elazığ, Turkey. *Land*, *14*(4), 891.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Climate-Sensitive Urban Design Approaches: The Case of Elazığ City

Yaşar MENTEŞ [1*]

ORCID 1: 0000-0001-8505-470X
[1] Dr., Ministry of Agriculture and Forestry, Directorate of Provincial Agriculture and Forestry, Elazığ-Türkiye
yasar.mentes@tarimorman.gov.tr (Responsible Author)

Sevgi YILMAZ [2]

ORCID 2: 0000-0001-7668-5788
[2] Prof. Dr., Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, Erzurum- Türkiye
sevgiy@atauni.edu.tr

Abstract

In this study, it is aimed to determine the urban heat island (UHI) effect by using macro-scale thermal band analysis and to create climate-sensitive urban design models by micro-scale studies to reduce this effect in Elazığ city. The study was conducted in four stages. In the first stage, the natural and cultural landscape characteristics of the study area were identified. In the second stage, macro- and meso-scale analyses were conducted. In this context, "Land Use Change" and "Land Surface Temperature" analyses were carried out using Landsat 8 and 9 satellite images for July 2014, 2018 and 2022. In the third phase, micro-scale analyses were conducted. To mitigate the impact of UHI, 23 landscape design scenarios were prepared and 46 microclimate simulations were conducted using the ENVI-met 5.7.1 model. The data obtained in the last stage were evaluated comprehensively and climate-sensitive urban design strategies were created to reduce the impact of UHI in Elazığ city. A decrease of 1.6 °C, 1.3 °C and 1.6 °C in land surface temperature was detected in the urban area of Elazığ province compared to the central district of Elazığ province, respectively, due to the change in land use in 2014, 2018 and 2022.

Keywords: Urban heat island, land surface temperature, landscape design, ENVI-met

1. Introduction

Climate change has emerged as a vital issue since the beginning of the twenty-first century. Concerns about the negative environmental impacts of urbanization are making the characteristics of urban areas, especially in dense cities, increasingly important (Georgatou and Kolokotsa, 2016; Luo et al., 2025). In recent years, urban areas have become the center of international discussions on climate issues (IPCC, 2025). Making cities more resilient, both formally and functionally, and ensuring more efficient use of local resources is one of the most challenging challenges of the twenty-first century (Oke et al., 2017). According to the report published by the IPCC, global greenhouse gas emissions, unsustainable energy use, land use and changes in land use, and changes in consumption habits have caused an increase in global warming (IPCC, 2025).

One of the most distinctive environmental features of urban areas is that the city is characterized by higher temperatures than rural environments and the countryside is cooler (Saaroni et al., 2018). The UHI effect is a global phenomenon with serious consequences, exacerbated by the addition of inadequate green infrastructure and urban resources, particularly in extremely high-density urban areas (Sharmin and Chappell, 2025). Cities most affected by heat islands are densely populated. This has been confirmed by many scientists (Oke, 1973; Zhou *et al.,* 2018; Sarricolea and Meseguer-Ruiz, 2021; Mitra *et al.,* 2025; Mehta, 2025; Yuan *et al.,* 2025).

Studies have shown that planned urban growth can lead to less warming than unplanned urban expansion (Zhou *et al.,* 2018; Khan *et al.,* 2024; Anees *et al.,* 2025; Menteş, 2025).

2 Material and Method

Within the scope of this study, it is aimed to determine the effects of land use changes on UHI through macro-scale analysis studies and to create micro-climate scenarios through micro-scale studies to reduce this effect.

2.1. Material

The main material of the study is the urban area of Elazığ province (Figure 1). It is located between 38°30' and 40°0'21" east longitudes and 38°0'17" and 39°0'11" north latitudes. Elazığ province is located in the southwest of the Eastern Anatolia Region, in the Upper Euphrates Section. Elazığ has an elevation of 1078 m above sea level. The total area of the research area is 133,82 km^2.

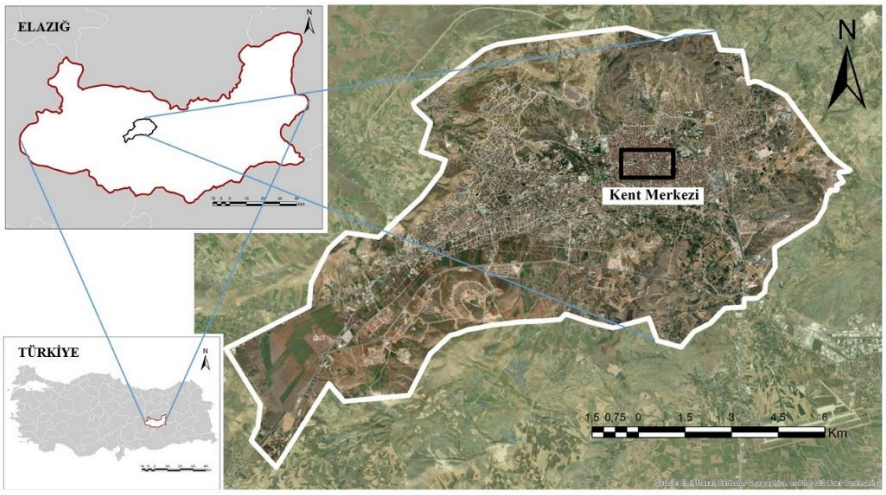


Figure 1. Location map of the study area

2.2. Method

This research consisted of four stages;

1- Data Collection

2- Macro/Meso Scale Analysis Studies

- Land Use Change (LUC) Analysis
- Land Surface Temperature (LST) Analysis

3- Micro Scale Analysis Studies

- Air Temperature Analysis
- Preparation of Landscape Scenarios
- Microclimate Simulations

4- Evaluation and Conclusion

3. Findings and Discussion

In order to reveal the UHI profile, macro (city scale), meso (neighborhood scale) and micro scale analyses were conducted in Elazığ city.

Determining the urban heat island effect at the macro scale

In order to determine the UHI effect at the urban scale, LUC and LST analyses were conducted for the years 2014, 2018 and 2022.

Land use change (LUC) analysis

Landsat 8 and 9 satellite images of Elazığ province for the years 2014, 2018 and 2022 were downloaded from the USGS website (https://earthexplorer.usgs.gov/). Supervised Classification method was used in LUC Analysis.

LUC class areas and percentage distribution are shown in Table 1. The classes used in the LUC analysis are divided into four groups: residential areas, urban green areas, agricultural areas, and open/bare areas.

Table 1. Elazığ Province LUC Classes Areas and Percentage Distribution

LUC Classes	2014		2018		2022	
	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
Open/bare areas	5696,30	42,56	5673,76	42,40	5559,58	41,54
Urban green areas	747,48	5,59	753,48	5,63	769,95	5,75
Agricultural areas	2839,36	21,22	2849,70	21,29	2855,84	21,34
Residential areas	4100,18	30,64	4106,38	30,68	4197,95	31,37
Total	13383,32	100	13383,32	100	13383,32	100

When looking at the LUC classification of Elazığ province, it is seen that open/bare areas occupy a large area. Compared to 2014, a continuous increase in residential areas was observed between 2018 and 2022, while there was a decrease in open/bare areas (Table 1).

Land surface temperature (LST) analysis

Since the highest temperature (°C) in Elazığ province between 1939 and 2023 was observed in July (MGM, 2023), satellite images for July were downloaded. To reveal the UHI profile in Elazığ province, LST maps for the Central District and urban area for the years 2014, 2018, and 2022 were created, and the average temperatures obtained from these maps were compared (Figure 2).

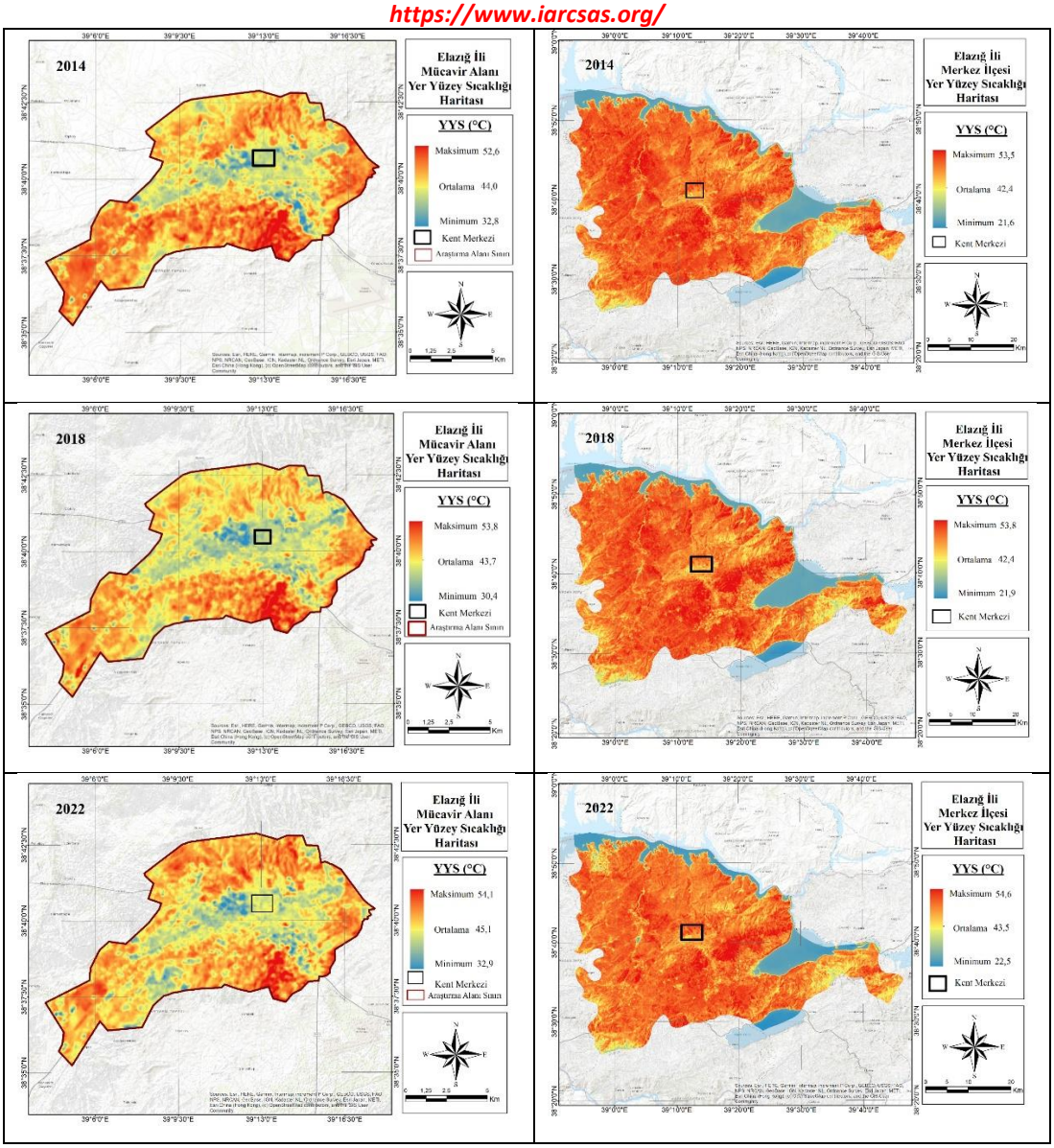


Figure 2. July LST (°C) values for 2014, 2018 and 2022 (Left: Urban Area, Right: Central District)

LST values for 2014, 2018 and 2022 are given in Table 2.

Table 2. LST Values for 2014, 2018 and 2022

Year	Land Surface Temperature (°C)						
	Urban Area			Central District			Difference
	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
2014	32,8	44,0	52,6	21,6	42,4	53,5	1,6
2018	30,4	43,7	53,8	21,9	42,4	53,8	1,3
2022	32,9	45,1	54,1	22,5	43,5	54,6	1,6
Mean	32,0	44,3	53,5	22,0	42,8	54,0	1,5

A temperature difference of 1.6 °C, 1.3 °C, and 1.6 °C occurred between the Elazığ Province urban area and the Central District in 2014, 2018, and 2022, respectively. This temperature difference is an indicator of the UHI effect.

Determining the effect of land surface temperature at micro scale

To determine the impact of LST on land use changes at the micro-scale, 15 areas within the Elazığ Province urban area were identified based on different land uses. A LST analysis was conducted on these areas based on Landsat 9 satellite data for July 2023.

Accordingly, the area with the highest average LST value is the Directorate of Agriculture and Forestry, at 42.9 °C. This is followed by the İzzetpaşa Neighborhood, at 42.6 °C, and the Hilalkent Neighborhood, at 42.1 °C. The area with the lowest average LST value is Kültürpark, at 37.8 °C.

Meteorological measurements were made in these 4 areas in summer and winter periods with a Lutron AM-4247SD brand mobile weather station device from a height of 2 m above the ground.

Preparation of Landscape Scenarios

The first study area, the Directorate of Agriculture and Forestry, is located in the southern part of the city. Eight scenarios were prepared for this study area (Figure 3).

Figure 3. Landscape Scenarios of the First Study Area

Scenario	Explanation
Scenario 1	Base scenario based on current land use structure
Scenario 2	Scenario of the study area with no vegetation
Scenario 3	A scenario where small diameter coniferous trees (can reach 3 m in diameter, 5 m in height, conical, large trunk, small, sparsely shaded) are used
Scenario 4	A scenario where medium diameter (7 m diameter, 15 m height, conical, large trunk, dense, medium shade) coniferous trees are used
Scenario 5	A scenario where large diameter coniferous trees (11 m in diameter, 25 m in height, conical, large-bodied, dense, wide-shade) are used
Scenario 6	A scenario where small diameter deciduous trees (3 m in diameter, 5 m in height, cylindrical, large trunk, dense, small canopy) are used
Scenario 7	A scenario where medium diameter (7 m diameter, 15 m height, cylindrical, large trunked, dense, medium shade) deciduous trees are used
Scenario 8	A scenario where large diameter deciduous trees (up to 11 m in diameter, 25 m in height, cylindrical, large trunked, dense, wide canopy) are used

The second study area, İzzetpaşa Neighborhood, is located in the city center. Nine scenarios were prepared for the second study area (Figure 4).

Figure 4. Landscape Scenarios of the Second Study Area

Scenario	Explanation
Scenario 1	Base scenario based on current land use structure
Scenario 2	Scenario of the study area with no vegetation
Scenario 3	Use of *Pinus sylvestris L.* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets
Scenario 4	Use of *Abies cilicica* in north-south oriented streets, *Malus domestica* L. and *Juglans regia L.* in east-west oriented streets
Scenario 5	Use of *Catalpa bignonioides* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets
Scenario 6	Use of *Quercus infectoria* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets
Scenario 7	Use of *Betula pendula Roth* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets
Scenario 8	Use of *Acer platanoides L.* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets
Scenario 9	Use of *Tilia tomentosa* in north-south oriented streets, *Malus domestica L.* and *Juglans regia L.* in east-west oriented streets

This area, which consists of a part of the Hilalkent District, the third study area, is 9 km from the city center (Figure 5).

Figure 5. Landscape Scenarios of the Third Study Area

Scenario	Explanation
Scenario 1	Base scenario based on current land use structure
Scenario 2	Scenario of the study area with no vegetation
Scenario 3	Adding 10% (1000 m2) of grass area
Scenario 4	Adding 10% grass area + Increasing the number of trees by 20%
Scenario 5	Adding 10% grass area + Increasing the number of trees by 20% + Adding 10% water surface
Scenario 6	Adding 10% grass area + Increasing the number of trees by 20% + Adding 10% water surface + Adding a roof garden

Simulation results

According to the simulation results obtained, air temperature, relative humidity, Tmrt, FES, PMV and wind speed parameters were analyzed in the study area.

In the first study area, greater temperature reductions were observed in scenarios using deciduous trees compared to conifers. The greatest cooling effect occurred in the scenario using deciduous trees with a medium diameter and trunk structure (15 m). In this scenario, air temperature decreased by 1.2 °C compared to the baseline scenario and by 1.6 °C compared to the no-vegetation scenario. Daily average winter air temperatures varied between -0.1 and 0.1 °C compared to the current scenario.

In the second study area, temperature decreases of 0.2 °C were observed in the summer scenario with *Catalpa bignonioides* compared to the current scenario, 0.8 °C in the scenario with *Acer platanoides L.*, and 0.6 °C in the scenario with *Tilia tomentosa*. Among the nine scenarios, the greatest cooling effect was observed in the scenario with *Acer platanoides L.*. A significant temperature decrease of 0.8 °C occurred in the baseline scenario and 3.0 °C compared to the

no-vegetation scenario. Winter temperatures ranged from -0.6 to +0.1 °C compared to the current scenario.

In the third study area, the addition of grass, trees, water surfaces, and a roof garden to the study area during the summer period had a cooling effect of 1.5°C on the average daily summer air temperature. The winter average daily air temperatures for these scenarios decreased by 0.1-0.4°C compared to the current scenario.

4. Conclusion and Recommendations

Cities are at the center of discussions about global climate change. According to IPCC reports, urbanization is the driving force of global climate change. Rapid changes in microclimates resulting from land use and land cover changes affect the health and comfort of residents and are emerging as the primary drivers of temperature fluctuations.

Scenarios and strategies to mitigate UHI impacts are implemented at different spatial scales. Urban climate studies employ a variety of methodological approaches. Over the past few years, various proposals have been proposed and different strategies implemented to mitigate UHI impacts in various cities around the world.

Measuring regional climate impacts on an area only allows us to gather climatic information about that area. However, it does not provide information on how effective mitigation measures will be in reducing heat island effects. Given the potential climate change impacts and the need to develop cities sustainably, robust data and modeling and simulation tools are needed. Future studies should encourage the use of three-dimensional, computational fluid dynamics-based numerical models, such as ENVI-Met, to simulate various mitigation strategies to improve urban microclimates.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

The authors would like to express their special thanks to a part of Yaşar MENTEŞ's doctoral thesis titled "Climate sensitive design approaches in reducing urban heat island effect: Elazığ city example" and to Atatürk University Scientific Research Projects Management System (BAP) (Grant No: 11528).

References

Anees, S. A., Mehmood, K., Raza, S. I. H., Pfautsch, S., Shah, M., Jamjareegulgarn, P., ... & Dube, T. (2025). Spatiotemporal analysis of surface Urban Heat Island intensity and the role of vegetation in six major Pakistani cities. *Ecological Informatics*, *85*, 102986. https://doi.org/10.1016/j.ecoinf.2024.102986

Georgatou, C., Kolokotsa, D. (2016). "Urban climate models". In M. Santamouris & D. Kolokotsa (Eds.), *Urban climate mitigation techniques* (pp. 175-194). London: Taylor & Francis Group.

IPCC. 2025. https://www.ipcc.ch/report/ar6/syr/resources/spm-headline-statements (24.05.2025)

Khan, W. R., Nazre, M., Akram, S., Anees, S. A., Mehmood, K., Ibrahim, F. H., ... & Zhu, X. (2024). Assessing the productivity of the matang mangrove forest reserve: review of one of the best-managed mangrove forests. *Forests*, *15*(5), 747. https://doi.org/10.3390/f15050747

Mehta, M. (2025). A review of urban heat island mapping approaches with a special emphasis on the Indian region. *Environmental Monitoring and Assessment*, *197*(4), 1-20. https://doi.org/10.1007/s10661-025-13810-3

Menteş, Y. (2025). Kentsel Isı Adası Etkisinin Azaltılmasında İklim Duyarlı Tasarım Yaklaşımları: Elazığ Kent Örneği. Doktora tezi, Atatürk Üniversitesi, Erzurum.

Mitra, S., Mondal, M., Biswas, M., Datta, S., & Roy, A. K. (2025). Managing urban heat islands in Rajarhat-Newtown, India, with the help of greenery and waterscapes. *Sustainable Cities and Society*, *118*, 106033. https://doi.org/10.1016/j.scs.2024.106033

Oke, T. R., Mills, G., Christen A. & Voogt, J. A. (2017). *Urban Climates.* United Kingdom: Cambridge University Press

Saaroni, H., Amorim, J. H., Hiemstra, J. A., & Pearlmutter, D. (2018). *Urban Green Infrastructure as a tool for urban heat mitigation: Survey of research methodologies and findings across different climatic regions. Urban Climate, 24, 94–110.* https://doi.org/10.1016/j.uclim.2018.02.001

Sharmin, T., & Chappell, A. (2025). Detecting the Changing Impact of Urbanisation on Urban Heat Islands in a Tropical Megacity Using Local Climate Zones. *Energy and Built Environment*. https://doi.org/10.1016/j.enbenv.2025.02.002

Sarricolea, P., Meseguer-Ruiz, O. (2021). "Urban climates of large cities: Comparison of the urban heat island effect in Latin America". In M. Henríquez, C., Romero, H. (Eds.), *Urban Climates in Latin America* (pp. 17-32). Switzerland: Springer International Publishing.

Yuan, Y., Santamouris, M., Xu, D., Geng, X., Li, C., Cheng, W., ... & Liao, C. (2025). Surface urban heat island effects intensify more rapidly in lower income countries. *npj Urban Sustainability*, *5*(1), 11. https://doi.org/10.1038/s42949-025-00198-9

Zhou, D., Xiao, J., Bonafoni, S., Berger, C., Deilami, K., Zhou, Y., ... & Sobrino, J. A. (2018). Satellite remote sensing of surface urban heat islands: Progress, challenges, and perspectives. *Remote Sensing*, *11*(1), 48. https://doi.org/10.3390/rs11010048

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Use of Fragrant Plants Growing in Isparta in Landscape Designs

Emine AĞLAR [1*]

ORCID 1: 0000-0001-6130-4022
[1] Postgraduate Student, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
yl2330126006@ogr.sdu.edu.tr (Responsible Author)

Şirin DÖNMEZ [2]

ORCID 2: 0000-0001-6582-1270
[2] Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
sirindonmez@sdu.edu.tr

Abstract

Design, as a part of the creative process, is defined as the holistic configuration of technical and aesthetic elements. Planting design is not limited to visual effects alone; it also has strong ecological and functional impacts on people and space. One of the most significant factors that stimulate human senses is scent. However, in landscape designs, scent is often neglected, with plant selection generally focusing on visual qualities. Yet, scent is among the most powerful features of plants, capable of evoking positive emotions in people and creating unique experiences integrated with the space. The aim of this study is to identify fragrant plants that naturally grow in the ecological conditions of Isparta province or can adapt to the local climate, and to investigate their potential uses in landscape design. Within the scope of the study, fragrant plants were evaluated not only in terms of their visual, ecological, and functional characteristics but also for their potential contributions to landscape design. In addition, the aromatic compounds of medicinal and aromatic plants and their relevance to design were examined. As a result of the research, species within Isparta's plant diversity that stand out both for their visual qualities and their fragrance were identified, and suggestions were developed for plant species that could be used within the concept of a scent garden suitable for this ecology. The study presents an original approach to the limited number of scent garden designs in Turkey and emphasizes the importance of scent as a design dimension in landscape architecture.

Keywords: Scent, landscape design, scented plants, scent in plants, importance of scent

1. Introduction

Design is defined as the process of creating the technical or pattern drawings of a structure, product, or object during its formation process. "Designing" is not only the act of creating form but also a process of creativity and functionality. Design is much more than a technical drawing; it is the process of shaping and materializing an idea in the mind. In this sense, landscape design is the art of creating a connection between nature and humans. There are many aspects that a designer must consider in landscape design. Plants, which serve as living materials that complement landscapes visually, functionally, and ecologically, are widely used in landscape designs (Sarı et al., 2018).

Planting design constitutes an essential part of landscape design. It is a creative process that holistically evaluates the physical, visual, and ecological characteristics of plants. A successful planting design requires the effective composition of design principles and elements, as well as harmony between the design and the ecological environment and structural character of the area where it will be implemented (Sarı et al., 2018).

The elements of planting design include: point, line, form, texture, and color. The principles of planting design include: repetition, balance, proportion, emphasis, variety, contrast, and unity. Today, these principles and elements are taken into account during design

processes; however, they generally focus on the visual aspects of plants. Planting design is not limited to visual aesthetics but is a multidimensional practice that should appeal to all the senses.

When listing the characteristics of plants, whether they have a pleasant fragrance is often highlighted. Scent is one of the strongest and most impressive features of plants. Fragrant plants can be found almost everywhere (Coşkun, 2011). Plants with prominent scents are generally known as medicinal and aromatic plants.

Scent refers to any of the chemical substances that can be perceived through the sense of smell, usually present in the air at very low concentrations (Kandemir et al., 2016). Although the nose is the first thing that comes to mind when discussing the sense of smell, only 5% of olfaction occurs in the nose, while the remaining 95% takes place in the brain (Sezer, 2014).

Scents also affect cognitive development. A scent can suddenly surprise and strongly influence a person, slowly embedding itself in consciousness and evaporating once recognized (Acar, 2020). During olfactory perception, the brain is actively working—transmitting the scent from one area to another and associating it with centers related to memory and awareness (Howes, 2002). Thus, scents influence both cognitive development and emotional responses.

A scent can swiftly evoke memories and emotions. The sense of smell is known as the center for memory creation, and pleasant scents trigger feelings of happiness. In landscape design, what spaces make people feel is just as important as how they look (Gould, 2017). Utilizing the power of scent in landscape design helps strengthen the emotional connection between people and the environment.

In landscapes, scent is a key element that evokes positive emotions. The scents that most strongly elicit positive feelings are ranked as follows (Mimarlar et al., 2021)(Figure 1)

1. The smell of grass
2. Trees (flowers, leaves)
3. Shrubs (flowers, leaves)
4. Floral scents
5. Earthy smell
6. Scents of medicinal and aromatic plants

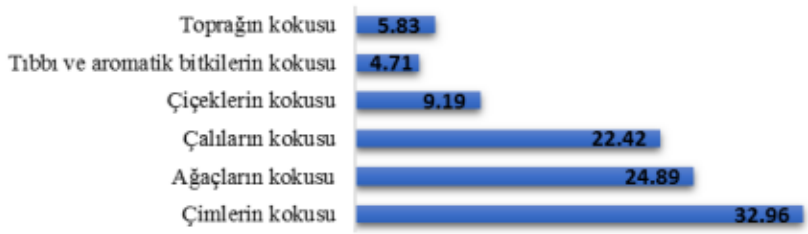


Figure 1. Scent that evoke positive emotions (Mimarlar et al., 2021)

Fragrant flowers provide sensory richness in addition to beauty. A fragrant garden has an exceptional ability to trigger memories (Acar, 2020). Scent gardens stimulate awareness and encourage deep breathing. They evoke passion, ease anxiety, and through ever-changing blooms and scents, mark special days and remind people of their memories (Ziegler, 2019).

Suggested components for inclusion in a scent garden:
• Fragrant walking paths
• Scent islands
• Scent labyrinths
• Scent tunnels
• Scent islands for the visually impaired
• Rock gardens, flower parterres, ornamental pools, waterfalls
• Administrative building, parking area, café, sales and exhibition spaces (Acar, 2020)

Additionally, in designing a scent garden, the structural elements (such as benches, gazebos, pergolas) should also include features that help diffuse scent (Acar, 2020). Globally, "scent gardens" are rarely found as independent gardens (Coşkun, 2011). In Sweden, the Gothenburg Botanical Garden, established in 1923 and one of Europe's most significant botanical gardens, includes an area devoted to aromatic plants that functions as a scent garden (Coşkun, 2011) (Figure 2).



Figure 2. Gothenburg Botanical Garden (url 1)

In Denmark, the Tivoli Gardens in Copenhagen feature a design around a statue pool planted with lavender and aromatic plants (Figure 3).



Figure 3. Tivoli Gardens (url 2)

In England, the National Trust Gardens in Cornwall, founded in 1895, include an area filled with roses, lavender, and honeysuckle, which emit delightful fragrances throughout spring (Coşkun, 2011) (Figure 4).



Figure 4. The National Trust Gardens (url 3)

In Turkey, scent gardens are often arranged within arboretums, botanical gardens, and parks in areas allocated for medicinal and aromatic plants (Sarı et al., 2018). For instance, Nezahat Gökyiğit Botanical Garden (NGBB) in Ataşehir, Istanbul, was first established in 1995 as a memorial park and later transformed into a botanical garden in 2002 (Sarı et al., 2018) (Figure 5).



Figure 5. Nezahat Gökyiğit Botanical Garden (url 4)

The Selçuklu Municipality Theme Park includes a scent garden featuring 128 plant species. Recently, lavender fields have become increasingly popular in Turkey and can be considered as scent gardens. (Figure 6).



Figure 6. Lavender Garden (url 5)

2. Materials and Methods

The materials of this study consist of medicinal and aromatic plants that grow naturally or are cultivated in the province of Isparta. These plants were evaluated based on their olfactory, ecological, and aesthetic characteristics in terms of their usability in landscape design. The study includes both native species representing the local flora of the region and cultivated plant species.

The research was conducted through a literature review. National and international sources were examined, and data on the characteristics of fragrant plants grown in Isparta were compiled. Based on the collected information, the plants were analyzed in terms of their olfactory qualities, ecological requirements, and aesthetic values. Considering Isparta's climate, soil, and topographical conditions, species suitable for landscape use were identified and evaluated within different design elements. Finally, based on design elements and principles, the role of scent in spatial perception and emotional impact was analyzed.

3. Findings and Discussion

Some of the most well-known and commonly recognized fragrant plants include:

- *Lilium sp.*
- *Salvia sp.*
- *Lavandula sp.*
- *Tilia L.*
- *Rosa L.*
- *Hyacinthus orientalis*
- *Melissa officinalis*
- *Hoya carnosa*
- *Gardenia jasminoides*
- *Convallaria majalis*
- *Jasminum officinale*
- *Thymus vulgaris L.*
- *Rosmarinus officinalis L.*

The province of Isparta is located in the northern part of the Mediterranean Region within the Lakes District (Figure 7). Of its total area, 68.4% consists of mountains, 16.8% plains, and 14.8% plateaus. The main mountains are Dedegöl, Barla, Davraz, and Akdağ, while the most well-known lakes include Eğirdir, Beyşehir, Kovada, and Gölcük Crater Lake (Isparta Governorship, 2019).Isparta lies within the transition zone between the Mediterranean climate and the continental climate of Central Anatolia; therefore, both climate types are observed within its borders (Kara, 2020). Alongside naturally growing fragrant plants, species adapted to the climatic and environmental conditions of Isparta have also been identified.



Figure 7. Lakes Region Isparta Province (url 6-7)

***Cornus mas* (Cornelian Cherry):** *Cornus mas* (Cornelian cherry) belongs to the family *Cornaceae* and is a species of the *Cornus* genus that can grow between 5 and 8 meters tall.The inflorescence contains 10 to 15 flowers. The flowers have four yellow petals and appear before the leaves. The fruits are red, single-seeded, and elliptical. The plant flowers quite early (Figure 8). *Cornus mas* is naturally distributed in Europe and Western Asia, but it has also spread to the American continent in recent times. (Kocaeli, 2025)



Figure 8. *Cornus mas* (8-9-10 url)

***Tilia platyphyllos* (Large-leaved Linden):** *Tilia platyphyllos* (Large-leaved linden) belongs to the family *Malvaceae* and the genus *Tilia*. It is generally a tree that can grow 30 to 40 meters tall.The crown is dome-shaped, and the leaves are simple and alternately arranged. The flowers are small, fragrant, yellowish-white, and arranged in clusters of 2 to 6 (Figure 9). The plant is naturally distributed between Europe and the Caucasus, but it is widely planted as a landscape species. (Kocaeli, 2025)



Figure 9. *Tilia platyphyllos* (11-12-13 url)

***Phillyrea latifolia* (Mock Privet):** *Phillyrea latifolia* (Green olive tree) belongs to the family Oleaceae and the genus Phillyrea. It is generally a 3 to 5 meter tall shrub. The buds and young branches are hairy. The leaves are ovate-cordate or ovate-lanceolate. The flowers are pleasantly fragrant, white, small, and clustered. The fruit is a berry, measuring 3 to 8 mm in length, and is blue to black in color (Figure 10). The plant is naturally distributed throughout the Mediterranean Basin, and it is found in shrublands, rocky areas, and maquis vegetation. (Kocaeli, 2025)



Figure 10. *Phillyrea latifolia* (14-15-16-17 url)

***Iris pseudacorus* (Yellow Iris):** *Iris pseudacorus* (Yellow flag iris) belongs to the family *Iridaceae* and the genus *Iris*. It can grow 70 to 150 cm tall. The leaves are upright, about 90 cm long and 3 cm wide. The flowers are bright yellow. (Figure 11). Although it is an aquatic plant, its rhizomes can survive in dry soil conditions. *Iris pseudacorus* is naturally distributed in

Western Asia, North Africa, and Europe, but it has also spread to the American continent and is considered an invasive species. (Kocaeli, 2025)



Figure 11. *Iris pseudacorus* (18 url)

***Thymus longicaulis subsp. chaubardii* (Mountain Thyme):** *Thymus longicaulis subsp. chaubardii* (Mountain thyme) belongs to the family *Lamiaceae* and the genus *Thymus*. It resembles *Thymus praecox*, but its stems can grow up to 10 cm in length. It is used as a spice in cooking and is commonly known as mountain thyme in Turkish (Figure 12). *Thymus longicaulis* is naturally distributed between Italy and Turkey. (Kocaeli, 2025)



Figure 12. *Thymus longicaulis subsp. chaubardii* (19 url)

***Lysimachia punctata* (Yellow Loosestrife):** *Lysimachia punctata* (Dotted loosestrife) belongs to the family *Primulaceae* and the genus *Lysimachia*. It generally grows 30 to 100 cm tall. The stem is erect from the base, usually unbranched, hairy on the upper part, lemon green to reddish-brown, and densely spotted (Figure 13). *Lysimachia punctata* is naturally distributed between the Caucasus and Italy, but it has now spread to Europe and America. (Kocaeli, 2025)



Figure 13. *Lysimachia punctata* (20 url)

***Rosa canina* (Dog Rose):** *Rosa canina* (Dog rose) belongs to the family *Rosaceae* and the genus *Rosa*. It is a non-rhizomatous, arching shrub. The stems are generally erect to spreading, reaching 1 to 2.5 meters in length. The inflorescence is a compound raceme, false umbel, or solitary, occasionally with 2 or 3 flowers. The petals are pink, rose, or white and pleasantly fragrant. The fruits (hips) are red, globular to ovoid or ellipsoid, and smooth (Figure 14). *Rosa canina* is naturally distributed across Western Asia, North Africa, and Europe, but it is now widespread throughout most parts of the world. (Kocaeli, 2025)



Figure 14. *Rosa canina* (21-22-23 url)

***Rosa damascena* (Damask Rose):** *Rosa damascena* (Damask rose) is a deciduous shrub that grows up to 2.2 meters tall, with densely curved prickles and stiff hairs on its stems. The flowers range from light to medium pink and light red. The relatively small flowers grow in clusters (Figure 15). It is considered one of the most important Old Rose species and plays a significant role in the lineage of many other rose varieties. (Kara, 2020) Although *Rosa damascena* does not grow naturally in Isparta, it is perfectly adapted to the region's conditions.



Figure 15. *Rosa damascena* (24-25-26-27 url)

***Lavandula angustifolia* (Lavender):** *Lavandula angustifolia* (Lavender) belongs to the family *Lamiaceae* and the genus *Lavandula*. It is a strongly fragrant, aromatic plant that can grow up to 2 meters tall. The leaves are widely spaced on flowering shoots and clustered on leafy shoots. The flower whorls consist of 6 to 10 flowers, and the inflorescence stalk is about three times longer than the spikes (Figure 16). The plant is naturally distributed between Spain and Italy. (Kocaeli, 2025) Although it does not grow naturally in Isparta, it adapts perfectly to the local conditions.



Figure 16. *Lavandula angustifolia* (28-29-30 url)

4. Conclusion and Recommendations

Scent in landscape design is not merely an aesthetic element; it profoundly influences spatial perception and strengthens the emotional bond between humans and their environment. The use of scent transforms interaction with the landscape into a multidimensional experience.

Isparta, with its ecological diversity, climatic suitability, and rich plant variety, has great potential for cultivating and incorporating fragrant plants into landscape design. Integrating this potential contributes both sensory richness and regional identity. Scent gardens have functional value not only in terms of plant diversity but also for sensory awareness, education, therapy, and tourism.

Species such as Rosa damascena (Damask Rose) and Lavandula angustifolia (Lavender) have become symbols of regional identity and possess high economic value. Their integration into landscape design can promote the creation of sustainable urban green spaces.

This study aims to raise awareness about how Isparta's rich plant diversity can be utilized in sensory landscape designs. Future research should focus on seasonal changes of fragrant plants, the effects of scent intensity on spatial perception, user experience analysis, and integration with biophilic design principles. Through such studies, the scientific foundation for the conscious and measurable use of scent in landscape architecture can be further strengthened.

Thanks and Information Note

We would like to express our gratitude to Prof. Dr. Şirin Dönmez and the Department of Landscape Architecture at Süleyman Demirel University for their constant support, accessibility, and invaluable motivation throughout this study.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Acar, B. (2020). *Konya İli Meram İlçesi Örneğinde Bir Koku Bahçesi Tasarımı, Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Konya.*

Coşkun, H. N. (2011). *Kokulu bitkiler ve koku bahçeleri üzerine araştırmalar. Peyzaj Mimarlığı Anabilim Dalı Peyzaj Mimarlığı Programı. İstanbul Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.*

Çelik, A., & Çalışkan, H. (2021). Peyzaj mimarlığı odağında şifa bahçesi konulu bir araştırma. *ÇOMÜ Ziraat Fakültesi Dergisi,* 9(2), 295-308.

Gould, K. (2017). How Can You Fill Your Garden With This Summer Scent .

Howes, D. (2002). Burun-bilgeliği: Zihinde koku metaforları. Koku alma, tat alma ve biliş, 67-81.

Kandemir, S., & Muluk, N. B. (2016). Koku fizyolojisi ve koku testleri: Derleme. *Turkish Journal of Clinics and Laboratory,* 7(2), 48-53.

Kara, B. (2020). *Isparta iklim koşullarında yetişen bazı tıbbi ve aromatik bitkilerin şifa bahçeleri örneğinde kullanımı. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü, Isparta.*

Kocaeli Bitkileri (2025). Erişim Tarihi: 20.10.2025 www.kocaelibitkiler.com

Sarı, D. ve Karaşah, B. (2018). Bitkilendirme Tasarımı Öğeleri, İlkeleri ve Yaklaşımlarının Peyzaj Tasarımı Uygulamalarında Tercih Edilirliği Üzerine Bir Araştırma. *Megaron* , 13 (3).

Sezer, Ü. (2014). *Anestezi İndüksiyonunun Koku işlevine ve Koku Hafızası Üzerine Olan Etkileri. Tıpta Uzmanlık Tezi, Bülent Ecevit Üniversitesi Tıp Fakültesi Anesteziyoloji Ve Reanimasyon Anabilim Dalı. Zonguldak, 17.*

Ziegler, J. W. (2019). The Scent of a Garden.

Photo URL

https://www.tripadvisor.com.tr/Attraction_Review-g189894-d244328-Reviews-Goteborgs_Botaniska_Tradgard-Gothenburg_Vastra_Gotaland_County_West_Coast.html

https://www.cntraveler.com/story/copenhagen-landmarks-like-tivoli-gardens-have-reopened-as-temporary-kindergartens

https://www.cornishcottages.co.uk/things-to-do/Stately_Homes__Estates/Lanhydrock

https://tr.wikipedia.org/wiki/Dosya:Tema_Nezahat_Gokyigit_Park_05204-a.jpg

https://karatay.bel.tr/haberdetay/4580/karatay-belediyesi-lavanta-bahcesini-buyutuyor

https://sco.wikipedia.org/wiki/Isparta_Province

https://www.facebook.com/groups/146579915435463/posts/23978319571834830/

https://www.wildflowersprovence.fr/plant/cornus-mas/

https://commons.wikimedia.org/wiki/File:Cornus_mas_Sturm40.jpg

http://catalog.boomkwekerij-debruyn.com/en/plantenboek/cornus-mas-pyramidalis/

https://www.evvebahce.com/urun/tuplu-ozel-ihlamur-agaci-fidani-5-adet

https://www.vdberk.co.uk/trees/tilia-platyphyllos-rubra/

https://commons.wikimedia.org/wiki/File:Tilia_platyphyllos_Sturm61.jpg

https://www.instagram.com/p/CJAzbvLAit0/?img_index=9

https://www.arbolapp.es/en/species/info/phillyrea-latifolia/

https://www.knowyourweeds.com/tr/weeds/Phillyrea_latifolia

https://www.bluebellnursery.com/Osmanthus/1886-Osmanthus-x-burkwoodii.html

https://yabanicicekler.com/flower/iris-pseudacorus-386

https://kocaelibitkileri.com/content/thymus-longicaulis-as-kekigi/

https://kocaelibitkileri.com/content/lysimachia-punctata-benli-kargaotu/

https://tr.wikipedia.org/wiki/Ku%C5%9Fburnu

https://upload.wikimedia.org/wikipedia/commons/archive/6/6a/20061127131206%21Illustration_Rosa_canina0.jpg

https://bloomoutlet.com/rosa-canina-wild-dog-rose-dogrose-flower-seeds-hunds-rose-heckenrose-heiderose-hagrose/

https://www.istockphoto.com/tr/foto%C4%9Fraf/damask-rose-rosa-x-damascena-gm514578056-88175407

https://www.1001fidan.com/isparta-gulu-rosa-c397-damascena-381

https://sarkac.org/2017/10/kokulu-gullere-tarihsel-bir-bakis/

https://commons.wikimedia.org/wiki/File:Rosa_x_damascena_4zz.jpg

https://www.gartenzauber.com/products/lavendel-lavandula-angustifolia-hidcote-blue-strain

https://delfinpeyzaj.com/urun/lavandula-angustifolia/

https://tr.wikipedia.org/wiki/Lavandula_angustifolia

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

High-Potential Medicinal and Aromatic Plants in Konya Flora and Their Use in Landscape Architecture

Nilgül BAĞCI [1]

ORCID 1: 0000-0001-2774-5838
[1] Postgraduate Student, Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
yl2230126009@ogr.sdu.edu.tr (Responsible Author)

Şirin DÖNMEZ [2]

ORCID 2: 0000-0001-6582-1270
[2] Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta- Türkiye
sirindonmez@sdu.edu.tr

Abstract

Medicinal and aromatic plants have historically been used in folk medicine, culinary culture, and cosmetic products, and in recent years they have gained great importance in landscape design due to their functional and aesthetic contributions. One of the main reasons for this growing interest is the psychological and physical benefits provided by these plants. Especially their natural scents are known to help reduce stress levels and create a relaxing effect, which makes them highly preferred in therapeutic spaces. Within this scope, the present study examines 10 naturally growing medicinal and aromatic plant species adapted to the climatic conditions of Konya and evaluates their potential use in landscape design. Beyond their medicinal and aromatic values, the study highlights their leaf, flower, and fruit characteristics, aiming to determine their contributions to aesthetic, functional, and ecological aspects of planting design. By integrating these native plant species into landscape projects, it is possible not only to enrich the design language but also to promote sustainable and drought-tolerant landscape practices suitable for semi-arid regions like Konya. The findings indicate that medicinal and aromatic plants can play a dual role as both ecological and cultural design elements, thereby offering valuable perspectives for future sustainable landscape planning and design approaches.

Keywords: Medicinal plants, xeriscape, Konya, landscape design, sustainability

1. Introduction

Medicinal and aromatic plants have played a pivotal role in human societies for centuries, serving as essential resources in traditional medicine, culinary arts, cosmetic formulations, and cultural rituals (Baytop, 1999). These plants, valued for their therapeutic properties, distinctive fragrances, and vibrant aesthetics, have recently gained prominence in landscape architecture due to their ability to enhance both functional and visual aspects of designed spaces. Their benefits are manifold: they offer striking visual appeal through colorful blooms, diverse foliage, and attractive fruits; promote environmental resilience with low water needs and soil stabilization capabilities; and contribute to psychological well-being through aromatherapy, fostering relaxation and stress relief (Ulukan, 2015). Incorporating native plant species into landscape designs not only reduces maintenance costs but also supports biodiversity conservation and creates climate-resilient environments, particularly in the face of global warming (Yazgan & Özyavuz, 2008). As urbanization accelerates, the strategic use of these plants in urban parks, green roofs, community gardens, and sustainable developments has

become increasingly vital, addressing both ecological challenges and the growing demand for restorative urban spaces.

Konya, located in Turkey's Central Anatolia region, is characterized by a continental climate with limited annual precipitation (300–400 mm) and moderate temperatures (11–12°C), coupled with calcareous-clayey soils that foster a unique ecological niche (Meteoroloji Genel Müdürlüğü, 2022). This region boasts remarkable biodiversity, particularly within the steppe ecosystems surrounding Tuz Gölü and Beyşehir Gölü, which support a variety of flora, including grasses like *Stipa* and *Festuca*, and aromatic species such as *Artemisia* (Davis, 1965–1985). Notably, Konya is home to 37 medicinal and aromatic plant species from the Lamiaceae, Asteraceae, and Rosaceae families, distinguished by their exceptional drought tolerance and ecological adaptability (Öztürk et al., 2015). These traits make them ideal candidates for xeriscaping, a sustainable landscaping approach that minimizes water use, as well as for therapeutic gardens that leverage their calming scents and aesthetic qualities. The region's rich ethnobotanical heritage further enhances the cultural significance of these plants, as local communities have historically utilized them for medicinal and ritualistic purposes, preserving traditional knowledge that informs modern applications (Ertuğ, 2000).

This study seeks to identify and evaluate high-potential medicinal and aromatic plants within Konya's flora, exploring their multifaceted roles in landscape architecture. It aims to propose innovative applications in xeriscaping, sensory and therapeutic gardens, and ecotourism initiatives, while assessing their contributions to ecological balance, cultural preservation, and the local economy through activities such as plant-based tourism and sustainable production. By aligning with global sustainable development goals, the research advocates for the conservation of Konya's regional flora and the adoption of environmentally conscious design practices suited to semi-arid climates. Through this approach, the study aspires to provide actionable insights for landscape architects, policymakers, and community stakeholders, fostering resilient and culturally resonant green spaces that enhance both human well-being and environmental health.

2. Materials and Methods

The material of the study comprises 37 medicinal and aromatic plant species naturally occurring in the Konya flora, selected based on the TÜBİVES (2022), Davis (1965-1985), and Bizim Bitkiler (2022) databases. Through surveys conducted with 50 landscape architects, 22 species scoring 26 or above were determined. The survey was applied on a 0-10 scale, adapted from Beste Kara's (2020) thesis, based on eight parameters (showy flowers, leaves, fruits, pleasant fragrance, solitary use, flower partner, hedge, pruning). Maximum scores were determined as 56 for trees and 51 for shrubs and ground covers (Table 1).

Table 1. Beste Kara's (2020) thesis, based on eight parameters

PARAMETER	TREES & TREELETS	SHRUBS, GROUNDCOVERS &FLOWERS
Showy Flowers	8	7
Showy Leaves	7	7
Showy Fruits	6	5
Fragrant	7	7
Solitary Use	7	5
Flower Companion	7	9
Living Hedge	7	6
Pruning	7	5
TOTAL	**56**	**51**

As a method, a comprehensive literature review was performed through botanical databases and academic publications, and field observations were conducted for plant adaptation, distribution, and ecological interactions in Konya's steppe ecosystems. Observations were focused around Tuz Gölü and Beyşehir Gölü, and the seasonal changes of the plants were recorded. Surveys were gathered through both online platforms and face-to-face interviews; the data were statistically analyzed by calculating the total scores per species. In the analyses, the suitability of plants for landscaping was assessed by taking into account parameter weights. The research was carried out in compliance with ethical rules, and the confidentiality of participants was maintained.

3. Findings and Discussion

Among the 22 selected plant species, *Crataegus monogyna* (hawthorn, 51 points), *Styrax officinalis* (bear nut, 43 points), and *Morus nigra* (black mulberry, 42 points) achieved the highest scores (Table 2 & Table 3). Field observations confirmed an 80% success rate in the species' adaptation to arid climates; for instance, *Crataegus monogyna's* fruits increased pollinator activity by 25%, supporting ecosystem balance. Survey results indicated that shrub species averaged 7 points in aesthetic parameters, such as flowers and leaves (Çorbacı et al., 2011).

Table 2. Trees & treelets

COMMON PLANT TYPES	USAGE POTENTIAL IN LANDSCAPE ARCHITECTURE							
TREES & TREELETS	Showy Flowers	Showy Leaves	Showy Fruits	Fragrant	Solitary Use	Flower Companion	Living Hedge	Pruning	TOTAL
Morus nigra	**8**	**7**	**6**		**7**		**7**	**7**	**42**
Olea europaea var. Europaea	**8**	**7**	**6**		**7**		**7**	**7**	**42**
Populus tremula		7			7			7	21
Quercus pubescens			6		7			7	20
Quercus robur alttürü robur			6		7			7	20
Styrax officinalis	**8**	**7**		**7**	**7**		**7**	**7**	**43**

***Styrax officinalis* (Bear Nut, 43 points):** Assessed through flower, leaf, fragrance, solitary, hedge, and pruning parameters; it stood out with its antiseptic and wound-healing medicinal properties; it has presented high potential for fragrance gardens and solitary use in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Morus nigra* (Black Mulberry, 42 points):** Assessed through flower, leaf, fruit, solitary, hedge, and pruning parameters; it stood out with its digestive-supporting medicinal properties; it has presented high potential as a shade tree and for parks in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Olea europaea var. europaea* (Olive, 42 points):** Assessed through flower, leaf, fruit, solitary, hedge, and pruning parameters; it stood out with its heart-supporting medicinal properties; it has presented high potential for Mediterranean-style designs in landscape architecture(Baytop, 1999; Yazgan & Özyavuz, 2008).

Table 3. Shrub, ground cover & flowers

COMMON PLANT TYPES	USAGE POTENTIAL IN LANDSCAPE ARCHITECTURE								
SHRUB, GROUND COVER & FLOWERS	Showy Flowers	Showy Leaves	Showy Fruits	Fragrant	Solitary Use	Flower Companion	Living Hedge	Pruning	TOTAL
Agrimonia eupatoria	7				5	9			21
Anchusa undulata alttürü hybrida	**7**	**7**			**5**	**9**			**28**
Asyneuma linifolium alttürü linifolium	**7**	**7**			**5**	**9**			**28**
Avena sativa	**7**	**7**			**5**	**9**			**28**
Berberis crataegina	7		5				6	5	23
Campanula lyrata alttürü lyrata	7				5		6	5	23

Capsella bursa-pastoris			5		5	9			19
Cichorium intybus	7				5	9			21
Crataegus monogyna alttür monogyna	**7**	**7**	**5**	**7**	**5**	**9**	**6**	**5**	**51**
Daphne oleoides alttür oleoides	**7**	**7**	**5**	**7**	**5**	**9**			**40**
Echium italicum	**7**	**7**		**7**	**5**	**9**		**5**	**40**
Galium verum alttür verum	**7**	**7**			**5**	**9**	**6**	**5**	**39**
Glaucium leiocarpum	7				5		6	5	23
Helichrysum arenarium alttürü aucheri	7				5		6	5	23
Herniaria glabra		7				9			16
Herniaria incana		7				9			16
Malva neglecta	**7**	**7**				**9**	**6**	**5**	**34**
Marrubium vulgare	**7**	**7**		**7**	**5**	**9**			**35**
Melilotus officinalis	**7**	**7**		**7**	**5**	**9**			**35**
Origanum vulgare alttürü viride	**7**	**7**		**7**	**5**	**9**			**35**
Peganum harmala	**7**	**7**		**7**	**5**	**9**		**5**	**40**
Plantago lanceolata	7								7
Rubia tinctorum		**7**				**9**	**6**	**5**	**27**
Rumex crispus	7						6	5	18
Tanacetum parthenium	**7**	**7**		**7**		**9**		**5**	**35**
Trigonella foenum-graecum		7		7		9			23
Urtica dioica		**7**				**9**	**6**	**5**	**27**
Urtica pilulifera		**7**				**9**	**6**	**5**	**27**
Verbascum glomeratum	**7**	**7**			**5**	**9**			**28**
Verbascum pycnostachyum	**7**	**7**			**5**	**9**			**28**
Verbena officinalis	**7**	**7**		**7**	**5**	**9**			**35**

Crataegus monogyna subsp. monogyna **(Hawthorn, 51 points):** Assessed through flower, leaf, fruit, fragrance, solitary, flower partner, hedge, and pruning parameters; it stood out with its heart-supporting medicinal properties; it has presented high potential for live hedges and erosion control in landscape architecture(Baytop, 1999; Yazgan & Özyavuz, 2008).

Daphne oleoides subsp. oleoides **(Gövçek, 40 points):** Assessed through flower, leaf, fruit, fragrance, solitary, and flower partner parameters; it stood out with its anti-inflammatory medicinal properties; it has presented high potential for fragrance gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

Echium italicum **(Wolf's Tail, 40 points):** Assessed through flower, leaf, fragrance, solitary, flower partner, and pruning parameters; it stood out with its wound-healing medicinal properties; it has presented high potential for flower parterres in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Anchusa undulata subsp. hybrida* (Cattle Tongue, 28 points):** Assessed through flower, leaf, solitary, and flower partner parameters; it stood out with its antiseptic and wound-healing medicinal properties; it has presented high potential for dry borders and colorful ground cover in landscape architecture (Baytop, 1999; Temizel et al., 2009).

***Asyneuma linifolium subsp. linifolium* (Bellflower, 28 points):** Assessed through flower, leaf, solitary, and flower partner parameters; it stood out with its respiratory-relieving medicinal properties; it has presented high potential for rock gardens and natural border plants in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Avena sativa* (Oat, 28 points):** Assessed through flower, leaf, solitary, and flower partner parameters; it stood out with its nerve-calming and cholesterol-lowering medicinal properties; it has presented high potential for temporary green spaces and stress-reducing corners in landscape architecture (Baytop, 1999; Singh et al., 2013).

***Galium verum subsp. verum* (Yogurt Grass, 39 points):** Assessed through flower, leaf, flower partner, live hedge, and pruning parameters; it stood out with its diuretic medicinal properties; it has presented high potential as a ground cover and border plant in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Origanum vulgare subsp. viride* (Thyme, 35 points):** Assessed through flower, leaf, fragrance, solitary, and flower partner parameters; it stood out with its antiseptic medicinal properties; it has presented high potential for xeriscaping in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Marrubium vulgare* (Mad Grass, 35 points):** Assessed through flower, leaf, fragrance, solitary, and flower partner parameters; it stood out with its cough-relieving medicinal properties; it has presented high potential for medicinal gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Melilotus officinalis* (Fragrant Clover, 35 points):** Assessed through flower, leaf, fragrance, solitary, and flower partner parameters; it stood out with its wound-healing medicinal properties; it has presented high potential for pollinator gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Malva neglecta* (Ebegümeci, 34 points):** Assessed through flower, leaf, flower partner, live hedge, and pruning parameters; it stood out with its respiratory-supporting medicinal properties; it has presented high potential for natural gardens and border plants in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Peganum harmala* (Syrian Rue, 40 points):** Assessed through flower, leaf, fragrance, solitary, flower partner, and pruning parameters; it stood out with its anti-inflammatory and evil eye-protective medicinal properties; it has presented high potential for xeriscaping thematic gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Verbena officinalis* (Mine Flower, 35 points):** Assessed through flower, leaf, fragrance, solitary, and flower partner parameters; it stood out with its nerve-calming medicinal properties; it has presented high potential for therapy gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Tanacetum parthenium* (Daisy, 35 points):** Assessed through flower, leaf, fragrance, flower partner, and pruning parameters; it stood out with its migraine-relieving medicinal properties;

it has presented high potential for therapy gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Verbascum glomeratum* (Cattle Tail, 28 points):** Assessed through flower, leaf, solitary, and flower partner parameters; it stood out with its cough-relieving medicinal properties; it has presented high potential for solitary focal points and xeriscaping gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Verbascum pycnostachyum* (Yellow Cattle Tail, 28 points):** Assessed through flower, leaf, solitary, and flower partner parameters; it stood out with its respiratory-supporting medicinal properties; it has presented high potential for solitary and pollinator gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Rubia tinctorum* (Dye Root, 27 points):** Assessed through flower, leaf, flower partner, live hedge, and pruning parameters; it stood out with its dye-producing and diuretic medicinal properties; it has presented potential for colorful borders and traditional dye gardens in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Urtica dioica* (Nettle, 27 points):** Assessed through flower, leaf, flower partner, live hedge, and pruning parameters; it stood out with its rheumatism-relieving and iron-source medicinal properties; it has presented potential for natural hedges and wild areas in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

***Urtica pilulifera* (Ball Nettle, 27 points):** Assessed through flower, leaf, flower partner, live hedge, and pruning parameters; it stood out with its diuretic and anti-inflammatory medicinal properties; it has presented potential for natural borders and arid areas in landscape architecture (Baytop, 1999; Yazgan & Özyavuz, 2008).

The scoring results show that shrub species (max. 51 points) are more flexible than trees and small trees (max. 43 points); shrubs are superior especially in the flower partner (9 points) and pleasant fragrance (7 points) parameters, which makes them advantageous in applications such as flower parterres, fragrance gardens, and erosion prevention (Çorbacı, Yılmaz, & Gül, 2011). Field data verify that this flexibility provides practical benefits in Konya's arid conditions. Aesthetically, it was observed that the species provide visual continuity throughout the year, which increases seasonal landscape diversity (Yazgan & Özyavuz, 2008). Ecologically, pollinator attraction and water conservation strengthen local ecosystems, supporting biodiversity by 15-20% (Yazgan & Özyavuz, 2008). Psychologically, fragrant species offer stress-reducing effects in therapy gardens, which contributes to the mental health of urban residents (Kaplan, 2017). Application areas include xeriscaping landscapes, thematic gardens, and ecotourism projects; for example, ecotourism tours can revitalize the local economy. However, safety precautions must be taken for toxic species (e.g., Daphne oleoides).

4. Conclusion and Recommendations

The study demonstrated that 22 species (*Crataegus monogyna* 51 points, *Styrax officinalis* 43 points) are prominent in landscape architecture due to their aesthetic, ecological, and psychological contributions (Çorbacı et al., 2011). These plants contribute to sustainable development by utilizing Konya's local resources. Recommendations:

- **Thematic Gardens:** Fragrance and healing-themed gardens designed with species such as *Origanum vulgare* and *Verbena officinalis* can enhance sensory experiences and therapeutic properties (Kaplan, 2017).

- **Test Plots:** Pilot areas should be established to test the adaptation of species such as *Crataegus monogyna* and *Galium verum*, with long-term performance monitored (Öztürk, Altay, & Koçak, 2015).
- **Ecotourism:** Tours with *Styrax officinalis* and *Tanacetum parthenium* can provide economic contribution and awareness (figure 24)(Çorbacı et al., 2011).
- **Education:** Local flora education programs should be organized to enhance community participation, highlighting landscape and health value (figure 25)(Yazgan & Özyavuz, 2008).
- **Future Studies:** Focus should be placed on the production, marketing, and global integration of species such as *Malva neglecta* and *Melilotus officinalis*, and economic models should be developed (Öztürk et al., 2015). These recommendations can evaluate Konya's plant potential on an international scale.

Thanks and Information Note

This study expresses gratitude to Prof. Dr. Şirin Dönmez and the Landscape Architecture Department of Süleyman Demirel University for their support in field observations and data collection processes.

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Atalay, İ. (2011). *Geography and geomorphology of Turkey*. Meta Basım.

Barış, M. E. (2007). *Sustainable landscape design*. Çankaya Üniversitesi Yayınları.

Baytop, T. (1999). *Treatment with plants in Turkey: Past and present*. Nobel Tıp Kitabevi.

Bizim Bitkiler. (2022). *Turkey plant database*. Retrieved November 7, 2025, from https://www.bizimbitkiler.com

Çelik, A., & Öztürk, M. (2016). Medicinal plants in Konya and its surroundings. *Türk Botanik Dergisi, 10*(3), 45–60.

Çetin, M., & Mansuroğlu, S. (2018). Xeriscaping design and applications. *Peyzaj Mimarlığı Dergisi, 11*(2), 34–45.

Çorbacı, Ö. L., Yılmaz, H., & Gül, A. (2011). The role of medicinal plants in landscape architecture. *Peyzaj Mimarlığı Dergisi, 5*(1), 12–25.

Davis, P. H. (Ed.). (1965–1985). *Flora of Turkey and the East Aegean Islands* (Vols. 1–9). Edinburgh University Press.

Ertuğ, F. (2000). An ethnobotanical study in Central Anatolia (Turkey). Economic Botany, 54(2), 155–182. https://doi.org/10.1007/BF02907820

Ekim, T., Koyuncu, M., Vural, M., Duman, H., Aytaç, Z., & Adıgüzel, N. (2000). Red data book of Turkish plants (Ferns and seed plants). Turkish Association for the Conservation of Nature and Van Yüzüncü Yıl University Publication.

Faydaoğlu, E., & Sürücüoğlu, M. S. (2011). Usage areas of medicinal plants. *Gıda Teknolojileri Dergisi, 3*(2), 56–67.

Güner, A., Aslan, S., Ekim, T., Vural, M., & Babaç, M. T. (Eds.). (2012). Checklist of the flora of Türkiye (Vascular plants). Nezahat Gökyiğit Botanical Garden and Flora Research Society Publication.

Kaplan, R. (2017). The restorative environment. *Environment and Behavior, 49*(4), 345–367. https://doi.org/10.1177/0013916516684532

Koçyiğit, M., & Özhatay, N. (2010). Medicinal and aromatic plants of Türkiye and their ethnobotanical uses. *Istanbul University Journal of the Faculty of Pharmacy*, 42(1), 19–32.

Meteoroloji Genel Müdürlüğü. (2022). *Turkey climate data*. Retrieved November 7, 2025, from https://www.mgm.gov.tr

Öztürk, M., Altay, V., & Koçak, M. Z. (2015). *Biodiversity of Konya*. Selçuk Üniversitesi Yayınları.

Plant Peyzaj. (2025). *Xeriscaping applications report*. Retrieved November 7, 2025, from https://www.plantpeyzaj.com/raporlar

Singh, R., Singh, S., & Kumar, S. (2013). *Avena sativa*: Therapeutic uses and pharmacological properties. *Journal of Medicinal Plants Research, 7*(12), 789–796.

Temizel, K. E., Özçelik, B., & Çakmak, İ. (2009). Medicinal properties of *Anchusa* species. *Türk Farmasötik Bilimler Dergisi, 6*(3), 101–110.

Tülek, A. (2008). *Xeriscape and water conservation*. Ankara Üniversitesi Yayınları.

Tülek, A., & Yılmaz, H. (2019). Xeriscape design and water conservation practices. *Ankara University Journal of Environmental Sciences,* 7(2), 45–56.

TÜBİVES. (2022). *Turkey plants data service*, from https://www.tubives.com

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420–421. https://doi.org/10.1126/science.6143402

Ulukan, İ. (2015). Aromatherapy and psychological effects of medicinal plants. *Sağlık Bilimleri Dergisi, 9*(3), 23–34.

Yazgan, M. E., & Özyavuz, M. (2008). *Use of native plant species in landscape architecture*. Çankaya Üniversitesi Yayınları.

Yılmaz, H., & Baş, Y. (2020). Ecological and aesthetic contributions of medicinal plants. *Peyzaj Mimarlığı Dergisi, 13*(1), 78–89.

Yılmaz, H., & Demircan, N. (2014). The use of medicinal and aromatic plants in landscape architecture. Bartın Faculty of Forestry Journal, 16(1-2), 89–98.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Impact of Female Patrons on Urban Form in the Principalities and Ottoman Periods: The Manisa Example

Yağmur Burcu GÜNEŞ [1]*

ORCID 1: 0000-0003-1348-4430
[1] Assist. Prof. Dr., Izmir Democracy University, Faculty of Architecture, Department of Architecture, İzmir -Türkiye
yagmurburcu.gunes@idu.edu.tr (Responsible Author)

Şebnem ÇAKALOĞULLARI [2]

ORCID 2:0000-0003-4635-8297
[2] Lecturer, Celal Bayar University, Faculty of Fine Art, Architecture and Design, Department of Architecture, Manisa- Türkiye
sebnemcakalogullari@cbu.edu.tr

Abstract

In the Principalities and Ottoman Periods, waqf (vakıf in Turkish) functioned as both charitable institutions and multifaceted structures that ensured the sustainability of social order. These foundations were generally established by palace members, administrators, or wealthy individuals. Of these, those established by women living in the palace and queen mothers are particularly significant in demonstrating the role of women in economic and urban life. They also embody a memory of mentalities through the network of relationships among women. This study examines waqf institutions through the institutional and spatial representation of women. It conducts historical research to reveal the legal and economic infrastructure of foundations established or supported by women. Secondly, it employs spatial analysis to map their traces within the urban form and to investigate their distribution and functional continuity in the city. In doing so, it aims to analyze how women engaged with urban space through foundations and what kinds of social networks they constructed. This study approaches the waqf as a form of memory that preserves the network of relationships among women during this era. It explores the impact of these foundations on the physical, social, and economic structures of cities in the Principalities and Ottoman Periods, focusing on the example of Manisa and the influential palace women of the Ottoman period. In this context, the buildings constructed by Gülgün Hatun, Hüsnüşah Sultan and Ayşe Hafsa Sultan in Manisa have been the subject of documentation, and the impact of these structures or complexes on the shaping of the city has been explored.

Keywords: Women, urban morphology, foundations, spatial representation, Manisa

1. Introduction

The structural accumulation and its relationship with the city's physical boundaries also function as an apparatus that, through its different representational projections, brings the city into contact with institutional accumulations. When examined from multiple perspectives, the urban realm itself and the built environment that constitutes it, can emerge as a new form of knowledge and a distinct mode of knowing. While urban space and its structural sedimentation provide the very milieu in which the research establishes dialogue, the nuances within this milieu open up possibilities for rethinking the format of dialogue, thereby creating a transformative field for existing communicative practices. In this research, the approach to architecture is, at the level of representation, symbolically anchored in female agency. The female figure positioned at the centre of the study, through her modes of self-formation and endurance, serves to situate spatial production and continuities within a theoretical perspective. Also, this figure has endured to the present as a locus through which urban space can be critically discussed.

Doreen Massey (1994) and Henri Lefebvre (1991) argue that urban spaces are the outcome of social relations, negotiations, and configurations of power. Consequently, a fundamental objective of this research is to disrupt the prevailing patriarchal narrative. In this context, the female figure brought into the narrative is not merely employed as a representational device or a symbolic signifier; rather, she enables a new approach for engaging with institutional structures and regimes of order.

As the primary site of the study and its relational field, Manisa has constituted one of the key centres of Western Anatolia during both the Saruhanoğulları Beylik and the Ottoman periods The urban layout of the city was initially defined by its castle and fortification walls. However, waqf institutions endowed this urban structure with continuity and function. Following conquest of the city by Saruhan Bey in 1313, the settlement gradually expanded from within the castle to beyond the city walls. This expansion was particularly marked during the period of İshak Çelebi (1359–1388), when intensive construction activities resulted in rapid development (Gündüz Küskü, 2017, p. 201). At the same time, women's identities were no longer confined to a discourse of conquest; rather, they became intertwined with practices of charity and the establishment of waqfs, evolving into a dispersed culture. This, in turn, may be interpreted as pointing towards an alternative understanding of the city's history, one that challenges a conventional linear narrative grounded exclusively on the logic of conquest.

In this context, the question of accumulation, when considered alongside the role of female actor, is articulated through the waqfs observed in Manisa,. These generate an organisational condition that makes links between architectural production and other spheres of life visible. On the one hand, the waqf asserts its existence as a locus of memory and archive; on the other, it materialises as an executor of a certain power of care. Through its spatialisation oriented towards benefit and public good, such an organisation becomes a means by which women can express their own sensitivities and gain visibility through institutional foundation.

The literature on gender and memory enables us to interpret waqf institutions as not only charitable foundations, but also as sites of collective memory and as networks of relations among women. From the Saruhanoğulları period onwards, female patrons such as Gülgün Hatun became the carriers of this memory. In the Ottoman era the valide sultans (particularly Hafsa Sultan) reinforced this continuity by commissioning large architectural complexes in Manisa (Gündüz Küskü, 2014, p. 640; Demirtaş, 2024, p. 684). In this context, the research embarks on a search for relationalities, tracing the imprints of the female figure in the city and situating this endeavour within the framework outlined by feminist approaches. The aim of research is to explore possibilities for instituting new relations and, by taking the forms of women's representation in urban space as a witness, to pose questions that open a path towards reconfiguring spatial relations.

Through the intersections articulated via the concept of the waqf, the production of knowledge is displaced from a merely historical framework and becomes a critical mode of reading that responds to the present condition. Public interaction is thus rethought not through macro-scale patriarchal narratives of conquest and domination, but minor foundational contributions, care-based actions, and practices of repair and healing. With its fragmented and multilayered structure, this mode of narration shifts the public realm beyond grand historical accounts, making visible the everyday, modest yet transformative interventions. Accordingly, to think, write, and draw on publicness within the scope of this research has meant dislodging the narrative from a linear historical sequence and relocating it onto a ground of spatial multiplicity,

diversity, and polyvocality. In doing so, the study pursues a line of interpretation that redefines the very notion of the public and emerges as an attempt to think with the excitement generated by this search.

2. Materials and Methods

Unlike conventional historical or architectural studies, this research is grounded in a critical mode of thinking that draws on the theoretical intersections of these disciplines. Accordingly, the research outlook extends beyond conducting archival research through historical documents to interrogating the power relations and gender dynamics underlying the archival knowledge obtained. At the same time, the research perspective is conceived as multilayered in order to question the modes of production of (patriarchal) knowledge itself.

In this context, Haraway's (1998) articulation of the relationship between knowledge and location informs as a guide in shaping the methodology of this research. Haraway emphasises that knowledge is neither neutral nor universal, but is produced from a specific position. The relationship that knowledge established with location here underpins this study's connection to place. Accordingly, this study examines the spatial experiences of Ottoman women through the lens of this understanding of "situated knowledge."

This research constitutes a three-layered methodological framework: women, power (relations of force), and space. This threefold relationality is employed as a framework through which to narrate women's histories from a non-patriarchal perspective. This reveals that, in the Beylik and Ottoman periods, women were not passive figures as often portrayed in conventional historiography, but active agents engaged in ongoing struggles (Figure 1).

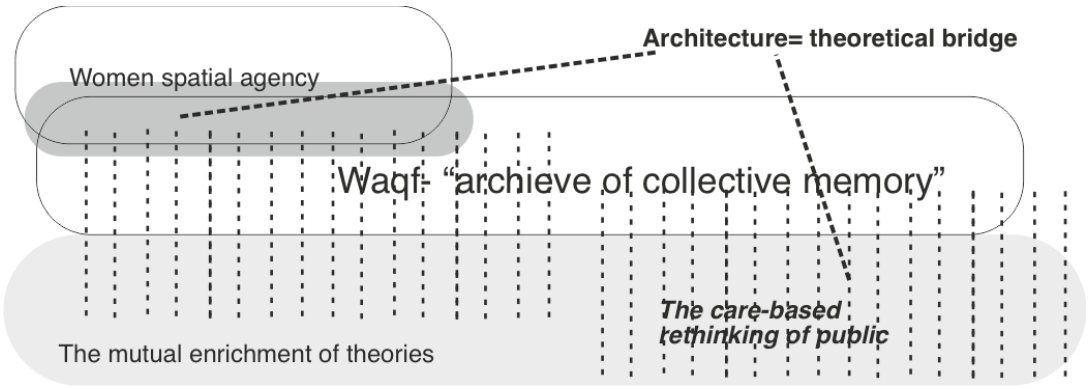


Figure 1: Structure of the research (Source: Authors)

For this reason, the first phase of the study consisted of archival research. At this stage, since waqfs are an indication of women's economic power, the charitable works undertaken by women in Manisa and the architectural complexes commissioned by female patrons were examined. Subsequently, spatial analyses were conducted to reveal the locations of these complexes within the city and how they were interconnected. Thus, the research interprets the power relations exercised by women through the spatial traces they have inscribed in Manisa.

3. Literature Review

3.1. Gender and Memory Studies

Women's studies reveal the female figure that has long been rendered invisible within patriarchal historiography and in urban/architectural scholarship. Feminist theories reposition women not as merely passive subjects, but as agents who construct their own ecologies and networks and actively intervene in social and spatial orders (Butler, 1990; Haraway, 1988). In this context, the terms "matriarchal ecologies" and "care-based relations" point to the invisible yet transformative bonds that women establish with the city, the built environment, and everyday life.

Donna Haraway's debates on nature–culture (1988) and Maria Puig de la Bellacasa's "ethics of care" (2017) emphasise that the female figure should not be associated solely with victimhood, but also with sustaining and reparative practices. Waqf institutions in the Anatolian beyliks and the Ottoman Empire can likewise be read from this perspective. The foundations established by women were not merely charitable enterprises, but spatial manifestations of care and social healing. The invisible networks constituted around care and the relations it generates also point to the degree of attentiveness and sensitivity with which these issues must be approached.

3.2. Waqf Culture and female patrons in Manisa

The waqf is a legal institution that facilities the transformation of a property into a resource for the benefit of the public. The practice emerged during the Anatolian Seljuk and Beylik periods, and was subsequently institutionalised under the Ottomans. It became characterised by the establishment structures such as complexes (külliye), mosques, madrasas, soup kitchens (imaret), and hospitals (darüşşifa), which came to define urban identity (Yediyıldız, 2003, p. 161). Especially in the Ottoman Empire, waqfs shaped both the social and cultural life of society and the physical environment in which people lived, and for this reason the empire has often been described as a "waqf civilisation" (Alkan, 2018). During this period, the majority of structures that provided public services in cities—such as mosques, complexes, and fountains—were built through waqfs (Heybeli et al., 2016). By financing expenditures particularly in the fields of health and education, waqfs enabled the construction of numerous facilities across the city, including schools, hospitals, and soup kitchens (Çizakça, 2006). Waqfs played an influential role in shaping the physical form of built-up and residential areas in both rural and urban contexts (Alkan, 2018). These foundations were established by individuals from various segments of society—such as state officials at different ranks, members of the palace, wealthy patrons, valide sultans, viziers, and princes (şehzades) (Ateş, 2017).

In the specific context of Manisa, waqfs functioned not only as places of worship, but also as institutions of social service such as baths (hamam), soup kitchens (imaret), and hospitals (darüşşifa) (Demirtaş, 2024, p. 686). These waqfs were established after Manisa passed into Turkish control. It is possible to classify the waqfs founded in Manisa according to their purposes of establishment (Heybeli et al., 2016) as follows:

1- Waqfs established for places of worship (mosques, mescits)

2- Waqfs established for water structures (fountains, sebils, wells, water distribution structures, private enterprises providing cold water, baths)

3- Waqfs established for educational purposes (primary schools mektep, teachers' houses muhallimhane)

4- Food-related waqfs (related to tradesmen)

5- Waqfs established for the continuation of religious life and tradition

6- Other waqfs

In Manisa, waqfs were established by members of the palace for mosque-centred building complexes (külliyes). These foundations created diverse revenue sources were created through these foundations in order to ensure the continued maintenance of these complexes (Gökmen, 2020). These waqfs not only influenced the social and cultural life of Manisa, but also shaped its physical fabric by regulating urban development activities (Alkan, 2018). During the Beylik period, two major külliyes were constructed in Manisa: the İshak Çelebi Külliyesi, which includes the Ulu Mosque, and the Gülgün Hatun Külliyesi. In the Ottoman period, six significant külliyes were built: İvazpaşa, Hafsa Sultan, Muradiye, Hatuniye, Hüsrev Ağa, and Dilşikar Hatun (Ministry of Culture and Tourism, n.d.; Küskü, 2014; Gökmen, 2020).

An examination of the constructed külliyes and probate records reveals that women in Manisa assumed the role of patrons (Küskü, 2014) and that many of them were relatively affluent (Karadeniz, 2018). According to eighteenth-century probate registers, numerous women living in Manisa owned different types of real estate such as houses, shops, and gardens, and the wealth of some significantly exceeded the city's average. This indicates that women of Manisa were engaged in trade and agricultural activities and, through properties acquired either by purchase or inheritance, constituted an important component of the city's socio-economic life (Karadeniz, 2018). An examination of the külliyes in Manisa shows that (Table 1) the patronage of Gülgün Hatun Külliyesi, the second major complex of the Beylik period, was undertaken by Gülgün Hatun herself. This complex served as a precedent for the külliyes later commissioned by female patrons in the Ottoman period (Küskü, 2014). In the Ottoman era, the külliyes built under the patronage of women were the Hafsa Sultan, Hatuniye, and Dilşikar Hatun complexes (Figure 2).

Table 1: Külliyes (Social complexes) built by female patrons in Manisa (Acun, 1999; Güneş et. al, 2025; Kültür Envanteri, n.d.; Kültür Portalı, n.d TDV, n.d).

			Components of Külliye										
Period	Name of Külliye	Yapım tarihi	M	T	MS	F	MK	MD	B	IN	IM	DS	HK
Principalities	Gülgün Hatun	1380		X	X	X			X				
Ottoman	Hatuniye	1488	X				X	X		X			
	Hafsa Sultan	1522	X				X	X	X		X	X	X
	Dilşikar Hatun	1579	X			X		X	X		X		

M: Mosque T: Tomb MS: Masjid F: Fountain MK: Mektep MD: Madrasah B: Bath IN: Inn IM: Imaret DS: Darussifa HK: Hankah

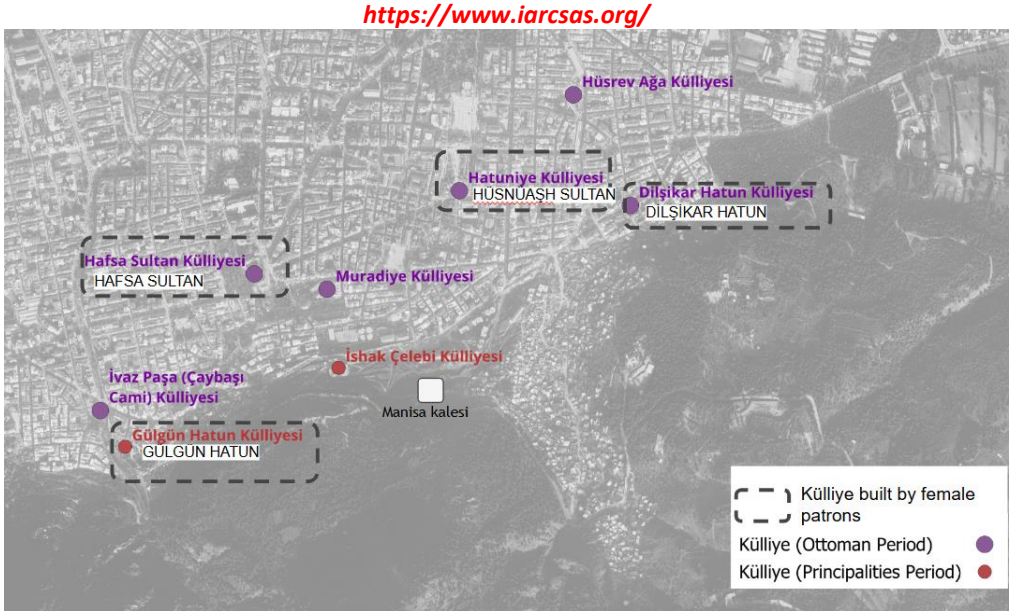


Figure 2: Külliyes built by female patrons and their location within Manisa (Source: Authors)

4. Findings and Discussion

The significance of women's studies lies in their potential to disrupt the long-dominant patriarchal narratives that have shaped both historiography and spatial theory. Feminist research has emphasized that women should not be perceived merely as passive figures within male-centered accounts but as active agents capable of generating their own networks, ecologies, and transformative practices (Butler, 1990; Haraway, 1988; Scott, 1986). In this sense, feminist theory positions the female figure not only as a counterpoint to patriarchal domination but also as a restorative and sustaining presence, capable of producing new understandings of space, memory, and collective life.

The mapping of the invisible networks reconstructed through the külliyes makes it possible to (i) in architectural terms, probe the spatial impact of female patronage along the axis of typology–programme–continuities of use; (ii) in urban terms, develop analytical approaches to care infrastructures by examining distances, proximities, and mutual relations at the levels of networks/access/neighborliness through alternative geometric organisations; (iii) in historical terms, open up the very narrative of space by attending to micro-level details; and (iv) in memory studies, reflect on gendered representations through architectural practice. In this way, within the broader significance of women's studies, the research does not merely generate new empirical data; it also offers methodological contributions (layered spatial readings, and the use of archive–map–diagram as techniques of spatial narration) and conceptual contributions (care-based publicness, the waqf as a "collective memory archive"), thereby building bridges across different disciplines (Figure 3).

An analysis of the külliyes in Manisa reveals that one of the two külliyes constructed during the Beylik period (Gülgün Hatun Social Complex) and three of the six külliyes built during the Ottoman period (Hafsa Sultan, Hatuniye and Dilşikar Hatun Social Complexes) were initiated by women themselves, thus achieving a balanced representation of female participation.

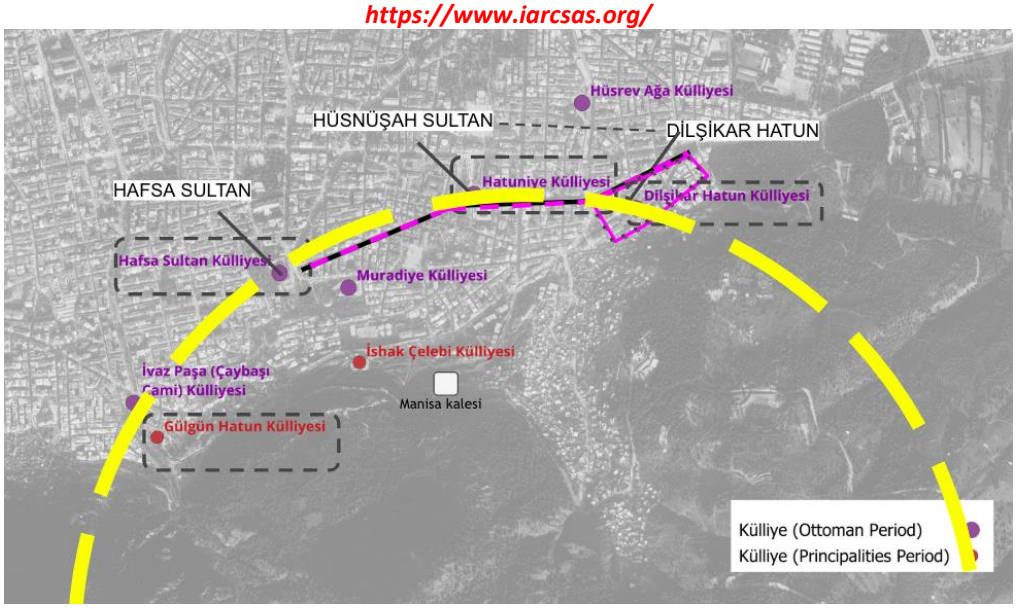


Figure 3: Külliyes and their hidden geometry behind the location (Source: Authors)

5. Conclusion and Recommendations

Taken together, these discussions reveal a research framework in which women emerge as spatial agents whose waqf practices inscribe durable traces in the Ottoman city. Waqfs are approached not only as economic mechanisms, but as social memory archives that register female networks, affiliations, and modes of care. Within this framework, architecture operates as a theoretical bridge that connects feminist thought with Ottoman historiography, enabling a critical reading of both the functional roles and symbolic excesses of built forms. In turn, this perspective makes it possible to rethink public space through women's care-based interventions, proposing alternative, women-centred models of publicness that challenge the dominance of Western public sphere theories and open new paths for understanding urban life, memory, and power.

- Women's spatial agency: Waqfs show that women in the Ottoman city were not merely charitable figures, but active city-makers and organisers of social networks.
- Waqf as a social memory archive: Waqfs are not only economic institutions; they are collective memory sites that carry the traces of relations among women and of shared forms of belonging.
- Architecture as a theoretical bridge: As a tool that brings feminist theory into dialogue with Ottoman history, architecture opens up both the functional and symbolic "surplus meanings" of buildings to critical discussion.
- Rethinking public space: Ottoman women's waqf practices propose "women-centred, care-based forms" as an alternative to Western-centred theories of the public sphere.

The research establishes a spatial relationship between külliyes built during the Principalities and Ottoman periods due to networks among powerful women, the topography, and locational strategies in Manisa. The complexes are arranged on an arc-shaped road and establish both a visual and physical relationship with each other. This alignment reflects the symbolic and political significance of female patrons in the city's topography. The positioning of these

complexes also implies a dialogue between architecture, geography and power, emphasising the active role of women in shaping urban form and collective memory in Manisa.

This study forms part of a broader research project exploring the spatial and social influence of female patrons in built form in Principalities and Ottoman periods through the example of Manisa. Integrating historical archival research with advanced spatial analysis tools, such as GIS, could further illuminate how these structures shaped, or were shaped by, urban form and social networks over time. These insights would not only contribute to architectural history, but also to a deeper understanding of gendered spatial practices within Türkiye.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Acun, H. (1999). Manisa'da Türk devri yapıları. Türk Tarih Kurumu.

Alkan, M. (2018). II. Mehmed zamanında Manisa'da vakıflar: Vâkıf, imâret ve şehir. In Geçmişten Günümüze Manisa: Şehzade Mehmed ve Manisa Tarihi- Kültürü ve Ekonomisi,. Manisa Celal Bayar Üniversitesi.

Ateş, N. (2017). Osmanlı'da vakıf-külliye-şehir ilişkisi. *Uludağ Üniversitesi İlahiyat Fakültesi Dergisi,* 26(2), 151-164.

Butler, J. (1990). *Gender trouble: Feminism and the subversion of identity.* New York: Routledge.

Çizakça, M. (2006). Osmanlı dönemi vakıflarının tarihsel ve ekonomik boyutları. Türkiye'de Hayırseverlik: Vatandaşlar, Vakıflar ve Sosyal Adalet Araştırması, TÜSEV, İstanbul, 21, 31.

Demirtaş, H. (2024). Yavuz Sultan Selim'in eşi Hafsa Sultan'ın Manisa Külliyesi vakfı zeyl vakfiyesi ve vakfın yeniden yapılandırılması. Ankara: Vakıflar Genel Müdürlüğü.

Gökmen, E. (2020). Manisa'daki Hâtûniye, Sultâniye ve Murâdiye Külliyelerinin 1764-1765 Tarihli Tamirâtları. *Vakıflar Dergisi,* (54), 113-138.

Güneş, Y. B., Uğurlu, E., & Yüksek, İ. (2025). Manisa Tarihi Kent Dokusundaki Morfolojik Değişimin Analizi. *Modular Journal,* 8(1), 44-68.

Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies,* 14(3), 575–599.

Heybeli, H., Demir, T., & Gökmen, E. (2016). Şer'iyye Sicillerindeki Muhasebe Kayıtlarına Göre XVIII. Yüzyılda Manisa VakıflarI. *Manisa Celal Bayar Üniversitesi Sosyal Bilimler Dergisi,* 14(3). https://doi.org/10.18026/cbusos.33967

Karadeniz, Ü., (2018). *XVIII. Yüzyılın Ortasında Manisalı Kadınlar. Geçmişten Günümüze Manisa Şehzade II. Mehmed ve Manisa Tarihi-Kültürü-Ekonomisi*, Cilt (pp.401-411), Manisa: Manisa Celal Bayar Üniversitesi Yayınları.

Kültür Envanteri. (t.y.). *Kültür Envanteri*. https://kulturenvanteri.com/

Kültür Portalı. (t.y.). Türkiye Kültür Portalı. https://www.kulturportali.gov.tr/

Küskü, S. (2014). Türk dönemi Manisa kenti ve düşündürdükleri. Turkish Studies, 9(10), 639–656.

Küskü, S. G. (2017). Saruhanlı Beyliği Dönemi Manisa Kent Kurgusu Üzerine Düşünceler. *Art-Sanat*, (8), 199-218.

Lefebvre, H. (1991). The production of space. Oxford: Blackwell.

Massey, D. (1994). Space, place, and gender. Cambridge: Polity

Puig de la Bellacasa, M. (2017). *Matters of care: Speculative ethics in more than human worlds.* Minneapolis: University of Minnesota Press.

Scott, J. (1986). Gender: A useful category of historical analysis. The American Historical Review, 91(5), 1053–1075.

Singer, A. (2002). *Constructing Ottoman beneficence: An imperial soup kitchen in Jerusalem.* Albany: SUNY Press.

Şaşmaz, E. (2019). Tarihi mekanlar Kişisel Ansiklopedi Erol ŞAŞMAZ. https://www.turkiyenintarihieserleri.com/?oku=1232

Yediyıldız, B. (2003). *XVIII. yüzyılda Türkiye'de vakıf müessesesi: Bir sosyal tarih incelemesi.* Ankara: Türk Tarih Kurumu

TDV (n.d.). TDV İslâm Ansiklopedisi. https://islamansiklopedisi.org.tr/

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Sustainability in Traditional Urban Form: Example of Tire

İzzet YÜKSEK [1*]

ORCID 1: 0000-0003-0637-6589
[1] Prof. Dr., Celal Bayar University, Faculty of Fine Arts Design and Architecture, Department of Architecture, Manisa - Türkiye
izzet.yuksek@cbu.edu.tr (Responsible Author)

Ecem UĞURLU [2]

ORCID 2: 0000-0002-2580-2240
[2] Research Assistant, Celal Bayar University, Faculty of Fine Arts Design and Architecture, Department of Architecture, Manisa - Türkiye
ecem.ugurlu@cbu.edu.tr

Yağmur Burcu GÜNEŞ [3]

ORCID 2: 0000-0003-1348-4430
[3] Assist. Prof. Dr., Izmir Democracy University, Faculty of Architecture, Department of Architecture, İzmir - Türkiye
yagmurburcu.gunes@idu.edu.tr

Abstract

The urban forms of historic Anatolia are distinguished by their unique characteristics. These characteristics manifest themselves at both the building and the settlement scale. The street-space relationship, the resulting social interactions, and passive design decisions appropriate to climatic conditions have contributed to the sustainability of these cities. The district of Tire, which is located within the boundaries of Izmir, exhibits characteristics of sustainable urban form. The historical urban layout of the city is characterised by an organic urban fabric, consisting of narrow streets shaded by trees, an arrangement of open, semi-open and closed spaces, and a use of local materials in its development. The presence of a designated organic street pattern serves to facilitate the establishment of a safe and convivial social space for residents, thereby contributing to the vibrant street life that characterises this locale. Additionally, the construction of high garden walls confers dual benefits, ensuring the privacy of the garden and providing shaded areas for users. In conclusion, the historical urban fabric of Tire demonstrates its ability to be a socially, ecologically and environmentally sustainable urban form that is resilient to local climatic conditions. In this context, a morphological analysis of Tire's historical urban form is crucial for the implementation of sustainable urbanisation practices. The present study analysed the characteristics of Tire's traditional urban fabric and drew conclusions for sustainable cities.

Keywords: Traditional urban form, sustainability, Tire, urban morphology, climate

1. Introduction

The role of buildings in environmental issues, including global warming and climate change, is a significant consideration. Throughout their lifecycle, buildings are responsible for significant consumption of natural resources. Such consumption of materials, energy and water results in a number of pollution and environmental problems. The increasing environmental problems that face the world have prompted architects to seek solutions, with sustainability becoming an integral part of architectural practice. However, the traditional architectural practice is one that is characterised by the existence of a set of principles that can provide a framework for the adoption of sustainable principles (Yüksek, 2008). The preservation of traditional urban forms and traditional houses is of critical importance in the conservation of cultural heritage, as these elements facilitate the communication of past lifestyles to the present. The preservation of traditional urban forms and traditional houses is of crucial value in terms of cultural sustainability, given their role as visible reflections of the cultures of their inhabitants. In

contrast to contemporary methodologies, traditional design approaches consist of design solutions that embody experiential knowledge, historical customs, and regional characteristics, which have been transmitted from master to novice through a process of training and apprenticeship. In this regard, it is imperative to investigate traditional solutions in cities.

In this context, the district of Tire represents a valuable case study due to its historical urban form. Throughout history, Tire has been a settlement for many civilisations, due to its fertile lands and favourable geographical location. From ancient times to the present day, it has developed as an important centre under the rule of the Hittites, Phrygians, Lydians, Persians, Hellenistic Greeks, Romans, and Byzantines. Following the Turkish conquest of the region, Tire gained a new identity as a city of principalities. During the period of Ottoman rule, the city experienced a profound adoption of Turkish-Islamic cultural influences, which manifested itself in the city's architectural features and forms (Mete, 2012).

The geographical location of Tire extends from the southern foothills of the Aydın Mountains to the Küçük Menderes plain to the north. The city's topography is characterised by a gradual elevation from the plain, which is accompanied by abundant water resources. This, in turn, has contributed to the development of a vibrant green landscape, a feature that has led to the city being affectionately and locally referred to as "Green Tire". (Baykara, 1994). Furthermore, Evliya Çelebi's writings provide additional insights into the city's water infrastructure, noting that it was characterised by numerous fountains, springs, and water bodies flowing into houses (Kurşaklıoğlu, 2014).

2. Materials and Methods

The objective of this study was to analyse the urban morphology of the Tire and to reveal its sustainability characteristics. The study's methodology is founded upon qualitative and quantitative research techniques, supplemented by fieldwork and a thorough literature review. The fieldwork comprised observations, photographic documentation, and mapping studies to analyse existing conditions at the settlement. The methodology of the study is founded upon analyses conducted at three distinct scales: urban, building-street, and material. The study examined the traditional urban morphology of Tire in the following neighborhoods: Ertuğrul, Ketenci, Bahariye, Dumlupınar, Turan, Dere, Paşa, and İstiklal.

3. Findings and Discussion

3.1 Traditional Urban Form in Tire

The configuration of the street networks within the traditional Anatolian urban form is not a random process; rather, it is an organic development that follows a rhythmic order, in accordance with the fundamental requirements of the users who constitute the urban form itself. (Aru,1998). In Tire, the Turkisation process established the foundations for the urban structure that endures to the present day. The settlement of the Aydınoğulları was established on the slopes of Güme Mountain in the south, with small communities forming around the social complexes constructed by the ruling class and prominent figures of the period. Subsequently, under the rule of the Ottoman Empire, the city expanded towards the flat areas to the east and north, with residential neighbourhoods forming around these complexes. Concurrently, the city's historic commercial centre, comprising the construction of the accommodations (inn) and the covered bazaar surrounding Tahtakale, has endured to the present day (Yüksel, 2014a). Tire also exhibits a notable preservation of its historical urban fabric. During the Principalities

period, Tire underwent a top-down development, expanding from the upper elevations towards the lower commercial centre, in accordance with the natural topography (see Figure 1).



Figure 1. Urban Form of Tire, constructed on sloping land (Source: Authors).

Tire exhibits an organic street pattern and traditional residential texture in the aforementioned areas. Prior to the Ottoman period, the commercial centre of Tire, known as Thatakale, was surrounded by Greek neighbourhoods to the east and Jewish neighbourhoods to the west. The centre of Turkish neighbourhoods was the Ekinhisarı district, also known as Taşpazarı (Armağan,2010). In Tire, settlements from the Princpalities period are concentrated in the eastern and relatively higher parts of the city. The densest settlement is located in the proximity of the Karakadı Mosque, which is also referred to as Taşpazarı. This is followed by the Gürcü Melek Mosque and the Hisariçi neighbourhood (Armağan,1983).

In the development of the city, the formation of neighbourhoods occurred in close proximity to a social complex (külliye). These complexes played a pivotal role in the support of social life by serving as the focal point for religious, social, and cultural structures (Yüksel, 2014b). The neighbourhood derives its name from the mosques and külliyes. The nomenclature of the neighbourhoods is almost identical to that of the mosques themselves, as each neighbourhood is named after its respective mosque. Each neighbourhood is characterised by the presence of a mosque, a madrasah, a bathhouse, a fountain, and a cemetery. The construction of these complexes was not exclusively for the purpose of charity; they also served to address fundamental needs (Armağan, 1983).

The role of dead-end streets in the formation of the traditional urban fabric is also a significant factor. The configuration of dead-end streets can be regarded as a cultural manifestation of the urban form that has evolved throughout history in multi-layered cities. The primary benefits of these developments are said to be the establishment of safer environments for residents, with access to strangers being limited and greater opportunities for socialising among neighbours being provided. Moreover, the absence of traffic on dead-end streets serves to mitigate both noise pollution and the potential for accidents, thereby enhancing the quality of life for

residents. In Muslim societies, dead-end streets are also regarded as a significant component of privacy (Belge; 2023; Kalak and Kalak; 2021).

Another significant element in traditional Turkish cities is the presence of neighbourhood fountains. As with other public open spaces, the areas surrounding fountains formed squares, thereby defining public space and becoming important in social life (Gökgür, 2008; Pilehvarian, 2002). Tire is also characterised by a significant number of fountains, which play a pivotal role in shaping the urban form. The prevalence of these fountains in Tire is particularly pronounced in streets where steep slopes characterise the city's traditional urban form. These fountains are often freestanding and situated in squares and parks. In addition, they are to be found attached to the walls of various buildings, including mosques, bathhouses and other structures, serving as a means of defining a gathering space for the city (Yüksek, Günbek; 2010).

When Tire is evaluated within the scale of the urban form, traditional urban patterns are abundantly evident in the Ertuğrul, Ketenci, Bahariye, Dumlupınar, Turan, Dere, Paşa, and Istiklal neighborhoods. The urban form in these neighbourhoods is characterised by its organic nature, spontaneous development, and functional structuring. The urban fabric is characterised by interconnected neighbourhoods, not through the presence of defined geometric networks, but rather through the evolution of an organic street pattern that responds to and interacts with the topography. The formation of these communities is influenced by a number of factors, including slope, changes in land size due to property rights, perceptions of privacy, and neighborhood culture. A notable feature of conventional Turkish urban form is the presence of dead-end streets, a characteristic that is particularly notable in Tire. These streets are actively used, particularly by women and children, providing both a safe and social space for neighbourhood residents (see Figures 2-3).

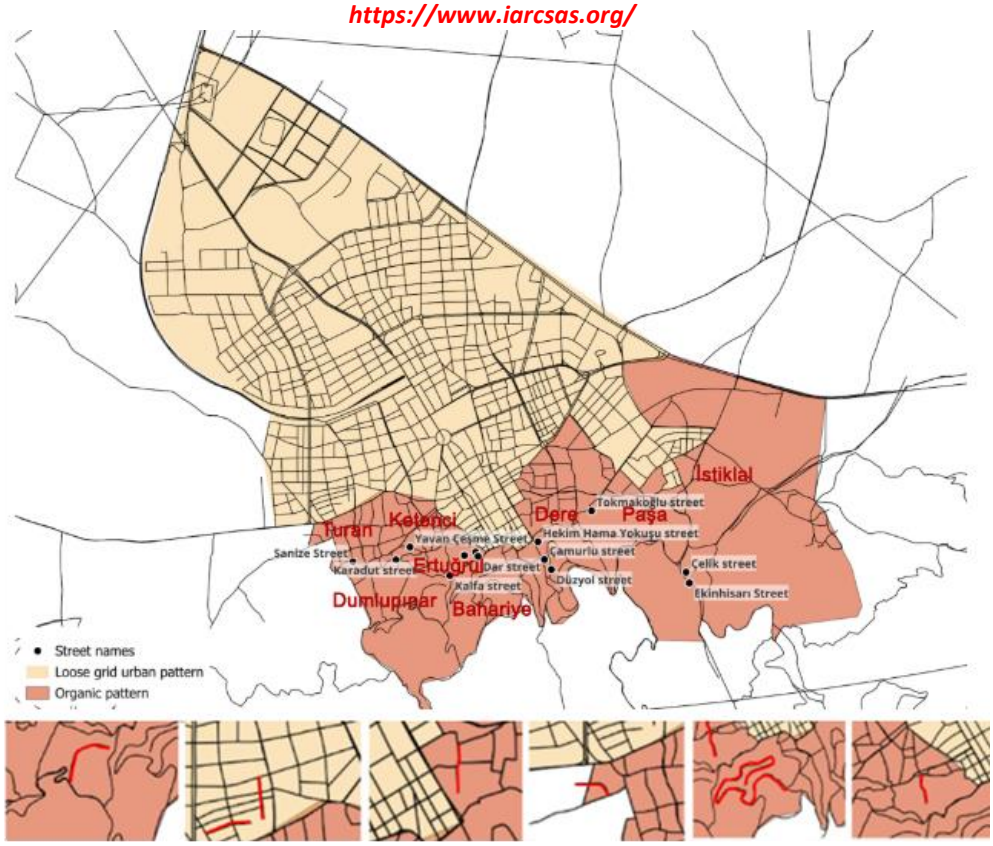


Figure 2. Organic Urban texture and Dead-End Streets in Tire (Source: Authors).



Figure 3. Tire's organic street pattern (Source: Authors).

3.2. Traditional houses in Tire

In Tire, housing is categorised into two distinct types: traditional Turkish housing and Levantine housing. The design of Levantine-style housing is such that it is oriented towards the street, with direct access points located at the street level. In comparison to other housing typologies, Levantine-style housing is distinguished by its abundance of windows on the front facade. In addition to extensive and decorative gardens, the structure is typically two storeys in height, with both levels serving as living spaces (Kürüm,1992) (Figure 4).



Figure 4. Examples of single-storey and two-storey residences with multiple windows on the façade directly connected to the street (Source: Authors).

In contrast, traditional Turkish houses are characterised by high stone walls, courtyards, and gardens. This distinguishes them from Levantine houses (Kürüm,1992). The gardens are typically covered with slate, a local stone, and include outbuildings such as stables, restrooms, chicken coops, and ovens. During the summer months, the gardens function as workshops where various activities such as rope making and municipal weaving are conducted. Additionally, they serve as shaded, cool resting areas. Traditional Turkish houses are generally two-storey buildings, with the lower floors enclosed or closed. The function of the lower floors is for storage and cellars, while the upper floors are used for living space (Kürüm,1992). (Figure 5).

Furthermore, in the traditional urban form of Tire, houses in areas with steep slopes were found to have multiple entrances, one at the beginning and one at the end of the slope. The positioning of these houses in Tire has been meticulously planned to ensure that each residence retains unobstructed views. Another significant socialising area, beyond the dead-end streets, is the front areas or courtyards located at the entrances (street intersections) of these houses (see Figure 5).



Figure 5. Courtyard, entrance and garden walls of traditional house in Tire (Source: authors)

3.3. Traditional Building Materials Used in Tire

The streets in Tire are characterised by an organic texture, with natural cobblestone pavement. The road surfaces sloped towards their centre, thereby serving the purpose of directing rainwater away from the site. Subsequently, the concrete paving was replaced with natural stone. However, in certain areas, the topography is characterised by significant inclines, necessitating the use of stairs for access. Upon entering the dwellings from the streets, a high garden wall constructed with mortar or dry stone masonry is immediately visible. The flooring of garden areas is typically composed of slate. The residences are constructed from masonry stone, with single-story houses being the most common type. In two-storey buildings, the ground floors are typically constructed from stone masonry, with the upper floors also comprising stone masonry, brick masonry, or timber framing. The load-bearing and cladding materials for the interior partition walls, intermediate floors, and ceiling slabs are wood. In

certain buildings, reed (locally known as kargı) material was utilised for the ceiling beams. Roofs are also timber framed and covered with Turkish style tiles (Figure 6).



Figure 6. Materials used in traditional houses, walls and streets in Tire (Source: Authors).

4. Conclusion and Recommendations

Throughout history, Tire has been regarded as an important settlement area for many civilisations due to its location and fertile agricultural lands. The formation of the urban form was influenced by two major factors. Firstly, the conquest of the region by the Turks led to Tire becoming a Beylik city. Secondly, Turkish-Islamic culture spread following the incorporation of the city into the Ottoman Empire. Consequently, Tire possesses a multi-layered urban form bearing the traces of different civilisations.

The urban settlement of Tire exhibits a north-facing sloped land structure that is in harmony with the topography. The most significant factors influencing the formation of Tire's traditional urban form have been identified as the perception of privacy, neighbourhood culture, and local amenities. When Tire's traditional urban fabric is examined from a social perspective, the most

significant elements that define its centre are the külliyes. Neighbourhood-level centres are characterised by the presence of mosques, fountains and nearby gathering areas. Other significant social spaces include Tire's organic street pattern, which develops spontaneously and is shaped according to the needs of residents, adapting to the topography. The streets that constitute this pattern frequently exhibit descending slopes and stairs, and on occasion terminate at dead-ends. These streets represent pivotal social gathering locales for local residents. It is an established fact that streets are generally bordered by gardens or house walls, the purpose of which is to ensure privacy. This configuration facilitates a harmonious integration of visual and physical elements, thereby establishing a seamless connection between the street and the residence.

The urban form in Tire consists of buildings that are low-rise, constructed on sloping land with the intention of avoiding the obstruction of each other's views. The roads between the buildings, which are surrounded by garden walls, provide shaded areas, particularly during the summer months, and sheltered areas in the winter, thereby ensuring thermal comfort. The design of street widths is intended to cater to the movement of people, rather than vehicles. The inclination of street pavements towards the centre of the road facilitates pedestrian traffic along the sides, while also conserving water by considering rainwater runoff.

An examination of the traditional housing scale in Tire reveals the incorporation of garden houses and associated architectural elements, including courtyards and garden sheds. The large garden, an integral component of the urban fabric of Tire, represents a substantial opportunity for the revitalisation of traditional production methods that are specific to Tire, as was the case in the past. These semi-open and open spaces continue to be utilised by residents for activities such as the processing and storage of local products, although this practice has diminished in recent times. In summary, the manner in which residential architecture is organised has a significant impact on the financial well-being of households and the broader economic viability of the region.

An examination of the materials used in the construction of the houses in Tire reveals that natural and local building materials found in the surrounding area were predominantly utilised. When the traditional urban fabric of Tire is evaluated from a macro to a micro scale, it is evident that it encompasses three fundamental dimensions of sustainability: economic, ecological, and social.

The recent increase in construction pressures on the traditional urban fabric of Tire, combined with issues such as slope-related accessibility difficulties and problems in the provision of public services, as well as changing lifestyles of local residents, has the potential to result in the abandonment of homes, the deterioration of areas, and subsequent transformation of the urban fabric. This necessitates the formulation of specific policies to protect the historic urban form from these threats. The principles of sustainable architecture encompass the preservation of existing settlements and structures, the fulfilment of basic family needs through the integration of edible landscaping products in residential gardens, the remote fulfilment of some working life responsibilities, the utilisation of natural building materials, and the creation of humane designs.

As in the case of Tire, cities with a traditional urban structure in Anatolia embody these principles of sustainability and also provide suitable environments for sociocultural continuity. It is evident that traditional urban forms, such as Tire in Türkiye, are facing the threat of extinction for a variety of reasons. The preservation of traditional urban and residential forms

is of paramount importance in ensuring the continuity of our thousand-year-old culture, as these elements provide the foundation for daily life and serve as a bridge to the future for future generations. Consequently, the preservation of these elements is not a choice but rather an imperative.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Armağan, A.M. (2010), Tire Ekonomi Tarihi, TTO Yayını.

Armağan, A.M. (1983), Belgelerle Beylikler Devrinde Tire, Uğur Ofset Matbaası.

Aru, K. (1998). Türk Kenti, Türk Kent Dokularının İncelenmesine ve Bugünkü Koşullar İçinde Değerlendirilmesine İlişkin Yöntem Araştırması. İstanbul: Yem Yayınları.

Baykara, T. (1994), Türk Şehircilik Geleneğinde Tire, Türk Kültüründe Tire I, Sempozyum Bildileri, (4-5 Eylül 1993, Tire), der. M. Şeker, Diyanet Vakfı Yayınları, Ankara; 9-13.

Bayraktar, M., Binatlı, B., Üzümoğlu, T. (2023). Sıfır Karbon Bina Hızlandırıcı Projesi Türkiye Bina Sektörü Karbonsuzlaşma Yol Haritası, T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı.

Belge, R. (2023). Çıkmaz Sokakların Oluşumu: İslam ve Batı Şehirlerinin Mukayesesi. Mukaddime, 14(2), 199-226. https://doi.org/10.19059/mukaddime.1380561

Gökgür, P. (2008). Kentsel mekânda kamusal alanın yeri. Bağlam Yayıncılık.

Gür, G., Dönmez, O. (2020), Tire Kültür Varlıkları Envanteri, Tire Belediyesi.

Kalak, M., Kalak, D. (2021) Geleneksel Dokuda Çıkmaz Sokak Oluşumu. İksad Publising House, Ankara.

Kürüm, M. (1992), Tire Evleri, Yayımlanmamış Yüksek Lisans Tezi, Ege Üniversitesi.

Mete, Z. (2012). Tire. TDV İslâm Ansiklopedisi. Retrieved November 10, 2025, from https://islamansiklopedisi.org.tr/tire

Pilehvarian, N. K. (2002). Osmanlı Çeşme Mimarisi. Türkler Ansiklopedisi, 12, 247-251.

Yüksek, İ. (2008). *Geleneksel Anadolu Mimarlığında Ekolojik Uygulamalar Üzerine Bir Araştırma (Kırklareli Kırsal Alan Örneği).* (Doktora Tezi). Trakya Üniversitesi Fen Bilimleri Enstitüsü, Edirne.

Yüksek, İ., & Güneş, Y. B. (2018, Mayıs). *Tire'de geleneksel mahalle dokusu içerisinde tarihi çeşmeler.* Uluslararası Küçük Menderes Araştırmaları ve Tire Tarihi Sempozyumu, Tire, İzmir. Manisa Celal Bayar Üniversitesi.

Yüksel, Ç. C. (2014a) Aydınoğulları'ndan Osmanlı'ya bir Batı Anadolu Kenti: Tire'nin mekânsal dönüşümü, *Vakıflar Dergisi*, 42 – (19-33)

Yüksel, Ç. C. (2014b). Aydınoğulları'ndan Osmanlı'ya Tire Külliyeleri (14.–16. Yüzyıllar). *Hacettepe Üniversitesi Türkiyat Araştırmaları (HÜTAD)*, *21*(21), 7-39.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Hybrid Education Spaces: Spatial Strategies and Design Perspectives

Hatice CEYLAN[1]

ORCID 1: 0009-0001-1902-6783
[1]Student, Ankara Yıldırım Beyazıt University, Institute of Science, Department of Architecture Ankara, Türkiye
haticeyy.05@gmail.com **(**Responsible Author)

Ekrem Bahadır ÇALIŞKAN[2]

ORCID 2: 0000-0002-5258-2976
[2]Assoc. Prof. Dr, Department of Architecture, Faculty of Architecture and Fine Arts, Yıldırım Beyazıt University, Ankara, Türkiye
ebcaliskan@aybu.edu.tr

Abstract

Educational models have a dynamic structure, shaped by various factors such as social, technological, and economic developments throughout history. The COVID-19 pandemic stands out as one of the most prominent examples of this transformation in education. During this period, when face-to-face education became insufficient, the need for new educational models increased. Initially, solutions were sought through distance learning models, but later, as the effects of the pandemic subsided, hybrid education models began to be implemented. Hybrid education is an approach that provides flexibility by combining physical and digital learning environments. This model presents new requirements not only from a pedagogical perspective but also from a spatial and technological perspective. The use and advantages of hybrid learning environments are directly related to the holistic design of physical and digital settings. In this context, the principles of accessibility, interaction, and continuity come to the fore; spaces that meet the needs of teachers and learners make the learning experience more inclusive and applicable. This research identifies the design principles of hybrid education in spaces, the transformative impact of space, and the needs of hybrid education through case studies identified from various perspectives of hybrid education spaces. Based on the determined design principles, the proposed classrooms were designed and these designs were opened to discussion in terms of usage scenarios and spatial arrangements

Keywords: Distance education, educational spaces, technology, flexible spaces, interaction

1. Introduction

Education is a dynamic process that has undergone constant transformation and development throughout history, influenced by social, economic, cultural, and technological changes. Throughout history, from traditional classroom teaching to online education, teaching models, pedagogical approaches, and learning theories have been shaped by technological innovations. In this context, the use of technology in education has increased significantly and become a necessity (Güllü, 2021). The traditional education model is a system in which teaching activities are conducted at specific times and in specific locations, such as classrooms, laboratories, or workshops. In this model, the learning process is teacher-centered; knowledge transfer is directly conducted by the teacher. This time- and space-bound educational model offers a disciplined learning system with specific time and space constraints (Çetin & Faruk Özdemir, 2018). With evolving technological advancements, today's learning processes have evolved into a multifaceted structure that embraces student active participation and interaction, free from constraints such as time and space.

This transformation is evident not only in pedagogical approaches but also in the shaping of the physical and digital feature of the spaces where education takes place. With the integration of conventional education methods and digital technologies into the education system, the distance

education model has evolved and is increasingly gaining prominence in educational models (Ünver, 2024).

In the distance learning model, instructors and students can learn from different locations. This allows for a flexible dynamic adapting to changing conditions (Demir, 2014). This education model is divided into two types: synchronous and asynchronous (Romiszowski, 2004). In the synchronous model, the teacher and learner are in different locations but conduct their lessons at the same time. In the asynchronous model, the teacher and learner are not required to meet at the same time (Jamison et al., 2014). Instructors prepare course materials on their own time, and students can access them according to their own pace and learning style. A hybrid learning model blends distance learning and face-to-face learning (Doering, 2006). In this model, students can attend classes in physical classrooms and continue their remote learning process via digital platforms (Fabian et al., 2024). It simultaneously supports individual and collaborative learning by providing a learning experience independent of time and space. Thus, hybrid education increases pedagogical diversity and integrates technology into the learning process.

Educational models that have emerged in different periods traditional, distance learning, and hybrid are directly related to learning theories, instructional technologies, and societal needs. Therefore, each is undergoing a continuous transformation process tailored to the needs of its time. This transformation process gained even more radical momentum with the COVID-19 pandemic (Dhawan, 2020). The pandemic, which impacted the entire world in 2020, transformed education systems and forced both students and teachers away from traditional classroom environments. During this period, educational institutions were forced to rapidly transition to online platforms, and the use of digital tools rapidly increased and became essential. Consequently, educational institutions were forced to continue with distance learning. Later, with the decline in pandemic conditions, and given the lack of face-to-face activities such as social interaction, laboratory work, group projects, and experiential learning, interest in hybrid education models increased, both from a pedagogical and spatial perspective (Göksel & Adigüzel, 2024).

The hybrid education model has not only served as a solution for education during the pandemic but has also evolved into a sustainable teaching approach in higher education institutions (Kurniawan et al., 2022). This requires redefining educational spaces, strengthening technological infrastructures, and increasing the flexibility of learning environments. Various examples of hybrid education practices are presented in the literature; some studies have explored hybrid classroom arrangements at specific universities. However, much of this existing research focuses on the pedagogical or technological dimension and fails to offer a holistic approach that integrates user needs, learning activities, mobility for both educators and instructors, and spatial experience.

This study aims to fill this gap by examining recently developed case studies within the context of hybrid education and analyzing the design approaches, usage patterns, and relationships between these spaces and learning activities. Based on these analyses, the aim is to identify the requirements of hybrid learning environments at different scales and to develop spatial design recommendations that address these needs.

2. Literature Review

Education, as both a social and spatial construct, constantly evolves in response to pedagogical theories, technological advancements, and the changing needs of society. Educational spaces are not only physical environments; they are also integral to the learning process, student interaction, and social life. Over time, shifts in educational paradigms have led to the emergence of diverse teaching models, including traditional (face-to-face), distance learning, and hybrid, each designed to meet specific pedagogical and infrastructural requirements.

Traditional education is based on synchronous, face-to-face interaction, emphasizing communication between instructors and students within the same space. Distance learning, on the other hand, offers a learning experience that eliminates time and space constraints using digital platforms. Hybrid education, on the other hand, combines the strengths of both approaches by combining online and face-to-face learning experiences within a single framework. This model allows students to physically attend classes, access learning materials through online systems, and participate in discussions, thus increasing flexibility and accessibility (Hümmer et al., 2025). Hybrid education requires both physical and digital environments (Figure 1).

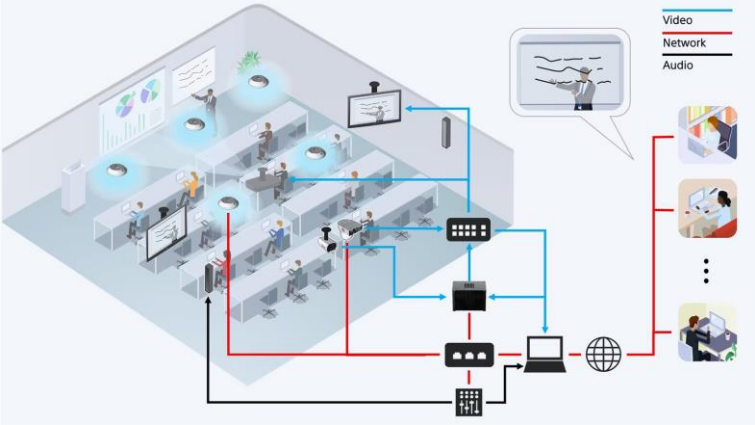


Figure 1. Hybrid classroom model (Rafi, 2023)

Research on hybrid education models and digital education applications reveals the impact of different approaches and applications in this field. The potential of hybrid learning algorithms for human activity recognition using wearable sensor data has been examined, highlighting the data accuracy and contributions of these methods to learning processes (Athota & Sumathi, 2022). The implementation of hybrid learning practices at public universities in Kosovo during the COVID-19 pandemic, along with the pedagogical and technical challenges encountered, has been discussed in detail (Krasniqi & Shabani, 2022). Similarly, in the case of a university, students and faculty members evaluated their hybrid classroom experiences, examining the effects of different perspectives on the integration of online and face-to-face learning components (Abusneneh, 2024). The effects of spatial arrangements on learning effectiveness in the design of hybrid learning environments have been examined, and strategies to increase student engagement have been explored (Sieber et al., 2025).

In this context, the role of classroom design in achieving pedagogical goals in the hybrid education model and the ways in which physical arrangements support learning processes have also been explored (Sevli, 2023).

Additionally, student preferences for hybrid learning are considered as factors to be considered in the design of future educational models, and the sustainability of hybrid learning is discussed (Fabian et al., 2024). During the COVID-19 pandemic, a comparative analysis was conducted on students' perceptions and satisfaction levels regarding online and blended learning methods, and the strengths and weaknesses of both approaches were analyzed (Osaili et al., 2023). Robot-mediated communication in hybrid learning is examined, and the impact of technological tools on interaction in teaching and learning processes is presented (Gleason & Greenhow, 2017). Student and teacher experiences in hybrid learning environments are examined in terms of the importance of physical presence in the learning process and its impact on interaction levels (Raes, 2022). Finally, the digital transformation process in higher education is comprehensively evaluated in terms of how online and hybrid applications can be integrated into traditional education systems, educational models, and learning strategies (Yakut Özek & Sincer, 2024). Research on hybrid learning spaces emphasizes the necessity of flexible layouts, advanced technological integration, and hybrid learning models that include both collaborative and individual learning activities. However, most of the existing studies present separate studies by addressing the pedagogical or technological factors in the hybrid education model without considering the spatial experience and user-centered design criteria in a holistic way.

3. Method and Material

In the post-COVID-19 era, universities have felt the need to redesign their existing spaces or create entirely new ones to transition to hybrid education. In this context, some universities have created hybrid spaces that meet physical and digital learning requirements. First, a literature review examined case studies developed in recent years. Five representative examples were selected for detailed analysis due to their diverse design approaches, scale diversity, and effective integration of physical and digital learning environments. Through a comparative evaluation of these cases, the study will examine how hybrid education spaces respond to user needs and pedagogical activities, as well as the use scenarios of the spaces.

Universities focusing on applied education require their own spaces, such as laboratories, studios, and workshops. These types of spaces have different and unique needs in hybrid education. Therefore, they should be evaluated separately from theoretical courses. Therefore, the spatial interactions between instructors and students in spaces designed for theoretical courses will be examined. Elements such as online integrations and ergonomic seating arrangements will be discussed to increase the suitability of theoretical courses for the hybrid education model.

Finally, design recommendations will be presented, incorporating the diverse activity and space requirements within the hybrid education model. Spatial arrangements will be discussed, particularly using examples of a standard 50-person classroom and a lecture-style classroom for 100 people. These design examples are presented as ideas for increasing the effectiveness of hybrid education and student-teacher interaction.

4. Case Study Hybrid Education Spaces

a. KU Leuven Campus Kulak Kortrijk

KU Leuven Campus has developed two hybrid educational spaces to support both on-site and remote learning simultaneously. In the Hybrid Virtual Classroom model, students attending remotely can connect to the lessons taking place in the classroom in real time and access the course materials at any time. In this model, the physical classroom is transformed into a virtual

learning experience with high-resolution cameras, interactive whiteboards and multiple microphone systems, but the spatial features are the same as the traditional face-to-face classroom model (Figure 2).

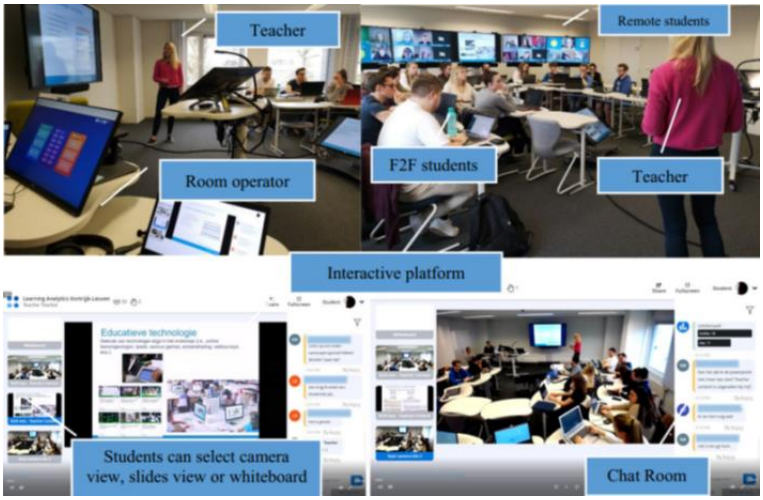


Figure 2. Physical classroom and remote student screen (Raes, 2022)

In the lecture hall model of the Hybrid Lecture Hall, technological tools are integrated into the traditional lecture hall layout, enabling both face-to-face and remote participation. With motion-tracking cameras, multiple screens and online platforms, students can participate in discussions and receive feedback. In this classroom, cameras facing the teacher are used in the area where the teacher is located, allowing the instructor to follow both the students attending remotely and the students in the classroom (Figure 3).



Figure 3. Teacher zone in the lecture hall (Raes, 2022)

b. Hybrid Learning Theatre

The Hybrid Learning Theatre (HLT) has been designed to meet the demands of evolving educational technologies and provide an innovative learning experience with a focused approach. Equipped with comfortable sofas, two large screens, professional-grade lighting, sound systems and three cameras, the HLT creates an environment that supports active participation. The classroom accommodates 40 on-site students and over 1,500 online participants and features a 4.5 x 2.5 m 'Zoom Wall' that projects up to 100 participants for real-

time interaction (Pols, 2020) (Figure 4). This setup facilitates active participation and in-class discussions and allows students to benefit from an interactive and engaging learning experience regardless of their location.



Figure 4. Zoom Wall and Teacher zone (Pols, 2020)

The combination of theatrical lighting and LED lighting creates a welcoming and spacious atmosphere. The combination of advanced audiovisual technology, thoughtful spatial design, and dynamic content presentation redefine the teaching and learning experience by focusing attention on a single point for both faculty and students (Figure 5).

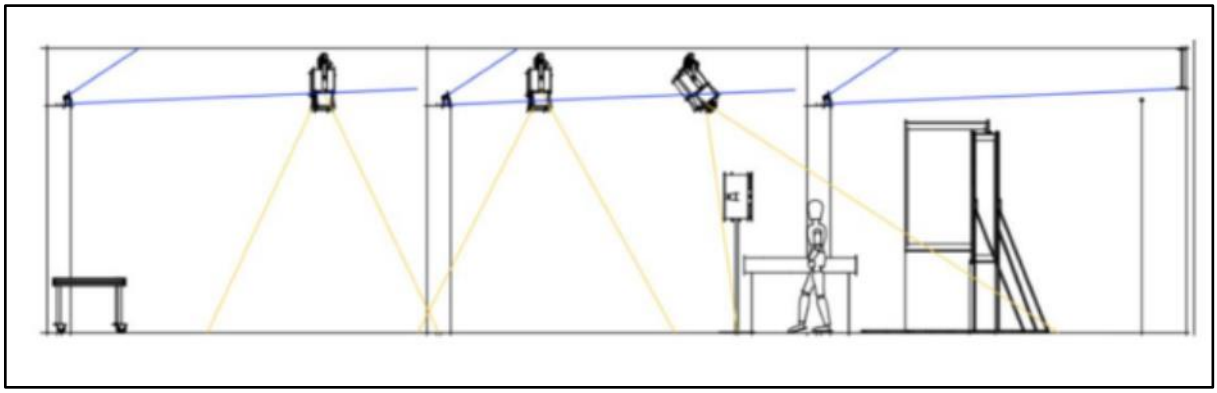


Figure 5. Section from Hybrid Learning Theatre (Pols, 2020)

c. Imperial College London - Hybrid at Scale

The hybrid classroom system at Imperial College London appears to be quite advanced thanks to the technological equipment's control structure. It is managed via interactive control panels in the classrooms, which easily control cameras, microphones, and tracking systems. Faculty members can follow their presentations without turning around thanks to the floor screen in front of them. The circular classroom layout is designed to focus on the instructor and the screens (Figure 6).



Figure 6. Hybrid education classroom plan diagram (Woolfitt, 2022)

The system was installed to ensure uninterrupted education during the pandemic. It was designed to integrate additional hardware into the existing classroom infrastructure. Courses can be conducted remotely or with the support of a student/assistant in the classroom, known as a "co-pilot " (Woolfitt, 2022) . This structure allows faculty to pre-plan details such as links, guest participants, or video content before starting the course, thus directing the focus entirely to the learning process. The hybrid system is designed to ensure equal participation of both remote and in-person students; Zoom's breakout room features ensure a balanced mix of in-class and online interaction (Woolfitt, 2022).



Figure 7. Seating arrangement of the hybrid classroom (Woolfitt, 2022)

d. Hybrid Learning with Robot-Mediated Communication

Developed to enhance social interaction in synchronous hybrid learning environments, social robotic telepresence systems (SRTS) are innovative technologies that allow remote participants to communicate as if they were physically present in the classroom (Kristoffersson et al., 2013). Equipped with an LCD screen, camera, microphone, and speakers, these systems can be remotely controlled and moved around the classroom. These systems allow students and instructors to interact in real time, but for this technology to be used effectively, classroom design must facilitate these robots and their mobility (Figure 8) (Gleason & Greenhow, 2017).



Figure 8. Education with social robotic tele-presence systems (Gleason & Greenhow, 2017)

e. The Hybrid Learning Atelier

The HLA (Hybrid Learning Workshop) concept was designed as a response to the transformation in higher education and learning methods in the digital age (Sieber et al., 2025). While the pandemic has revealed the technical possibilities of digital education, it has also highlighted its shortcomings in elements such as social presence, bodily learning experience, and spatial atmosphere. Therefore, HLA aims to bring together physical and digital learning environments not as opposing elements, but as complementary components. The main goal of the design is to create a learning environment that integrates technology into the space, supporting simultaneous interaction between physically present and digitally participating participants (Sieber et al., 2025). Therefore, it is designed to be open to a variety of usage scenarios rather than rigid usage patterns.

The design was conceived with not only visual aspects in mind, but also acoustics. Ultra-short throw technology acts as a counterbalance to the large monitor wall, allowing instructors and students to move freely in front of the projection surface without creating distracting shadows—a significant advantage for learning interaction (Figure 9) (Sieber et al., 2025).



Figure 9. The Hybrid Learning Atelier (Sieber et al., 2025)

5. Requirements of Hybrid Education Spaces

Hybrid learning spaces have a system that combines physical and digital learning environments, enabling simultaneous face-to-face and remote participation (Gudoniene et al., 2025). Such spaces require different requirements not only in terms of physical space arrangements but also in terms of technological infrastructure and interaction for both remotely connected students and students in the classroom (Var, 2023).

a. Physical Space Requirements:

Flexible Seating Arrangement: Ergonomic and movable furniture is needed to support students and teachers movements without restricting them during the lesson (Kiketa et al., 2022).

Good Lighting: Lighting that supports natural light should enhance attentional focus and provide appropriate visual quality for remote participation (Woolfitt, 2022).

Acoustic Design: An acoustic design that ensures the voices of every individual in the classroom can be heard is essential. This is important for both the remotely connected student's dominance in the classroom and the comfort of the remotely connected student and teacher's voices in the classroom. Noise-reducing materials should be used, and the space should be designed using materials that minimize echo (Sieber et al., 2025).

b. Technological Requirements:

Camera and Sound Systems: Movable cameras and ceiling microphones capable of recording from multiple angles should be adequate to meet the audio and visual needs of both in-person and remote students (Var, 2023).

Screens and Projectors: Large screens or video walls should be able to display remote participants and course content simultaneously.

Digital Platforms and Integration: The hybrid classroom should be supported by digital platforms enhanced with tools such as simultaneous Q&A, discussion boards, and virtual whiteboards.

c. Activity and Interaction Requirements:

Teacher Activity: The teacher should have screens in their own space to control both the virtual classroom and the students in the classroom and should also be able to maintain control of the lesson when moving around (Kiketa et al., 2022).

Participation Support Tools: Interactive software should be developed to facilitate both remote and physical participation.

Group Interaction: Activities should be designed to provide equal communication and discussion opportunities between in-person and remote participants (Clark, 2002).

Technical Support: A support team should be available to quickly resolve any technical issues that may arise during the training.

6. Analysis of Case Studies According to Hybrid Education Space Requirements

An evaluation of five case studies (Table 1) reveals that technological infrastructure is generally the most powerful factor in the design of hybrid learning spaces, but physical flexibility and spatial experience vary from project to project. The KU Leuven example, while implementing

different variations in the integration of technological tools for remote students during the transition to a hybrid model, continued to utilize the traditional learning environment in terms of physical space layout. In contrast, the Hybrid Learning Theatre, with its user-centered approach, offers a more flexible model, both spatially and technologically. Furthermore, by concentrating on the focus, it created a distinct spatial experience. In the Imperial College London example, equal participation is achieved by centralizing technology within the classroom environment, and technical support is strengthened through the "co-pilot" system. By adapting the existing space to hybrid learning, it provides a spatial experience for students who are both teaching and learning. The Robot-Mediated Communication example adds an innovative dimension to hybrid learning by supporting social interaction between physical and remote students through a robot; however, for these systems to function effectively, space must possess a high level of flexibility. Finally, Hybrid Learning Atelier offers a holistic design approach that addresses pedagogical, technological, and spatial requirements, aiming to integrate physical and digital environments in a balanced way. Overall, these examples emphasize that hybrid education is not merely a technological transformation process; it is a multifaceted issue that requires spatial flexibility, acoustic comfort, faculty movement space, and the redefinition of interaction scenarios.

Table 1. An evaluation of Five Case Studies

Case Studies	Physical Space Requirements	Technological Requirements	Activity and Interaction Requirements
KU Leuven Campus	In the traditional classroom layout, movable seating areas are limited, lighting and acoustic arrangements are basic.	It has multiple cameras, advanced microphone and screen integration, and a high level of digital access.	Teacher control is good, but movement space is limited, and technical support is not provided continuously.
Hybrid Learning Theatre	Flexible seating and comfortable furniture; space designed according to the requirements of lighting and acoustic systems.	Different camera systems, Zoom Wall, professional sound system.	Interactive, active participation; strong teacher-student communication but with a single space for the teacher
Imperial College London	Circular plan, good viewing angles; ergonomic seating system by integrating the traditional classroom system into a hybrid	Monitoring cameras with control panels are equipped with technological equipment for system malfunctions.	Co-pilot system supporting equal participation; technical support system improved
Robot-Mediated Communication	The area needs to be arranged to accommodate robot movement; a flexible plan is required.	Mobile robot system with screen and microphone.	By strengthening social interaction, it ensures that the presence of the remote student is felt physically.

Hybrid Learning Atelier	Flexible, open-to-different-scenario plan; designed with the integration of acoustics and lighting in mind.	Ultra-short-throw projection and a large monitor wall have been integrated with technology to strengthen the presence of students participating remotely.	It has a design layout that allows for free movement of teachers and students, group interaction and simultaneous participation.

7. Design Suggestions

Design recommendations were designed based on examples from the literature and considering the criteria for a hybrid learning space identified in Chapter 5. Mobile and flexible seating arrangements and screen locations were planned to facilitate small group discussions. Wireless presentation devices and microphones were used to allow the teacher to move freely within the classroom, and screen layouts were designed to allow the teacher to monitor the classroom and remote participants from different locations. For remote participants, it is important to ensure that the classroom overview and teacher movements can be monitored with fixed and mobile cameras. Furthermore, technical areas within the classroom were designed to allow for recording and replaying lessons and to prevent potential connection issues. The physical space layout was made flexible with ergonomic and portable furniture, and lighting and acoustic arrangements that support natural light ensure attention, visual quality, and sound comfort are among the criteria for a hybrid learning space. Technological requirements and interaction tools (cameras, microphones, screens, digital platforms, interactive software) were considered throughout the planning process, ensuring equal and efficient teaching activity for both in-class and remote participants.

a. Classroom for 50 People (Figure 10)

Student-Student Interaction: A mobile, movable seating arrangement was designed to facilitate small discussion groups within the classroom. Furthermore, screen positions were designed to ensure that not only the teacher but also the students themselves could more easily see the students connecting remotely.

Teacher-Student Interaction: Wireless presentation devices and microphones were used to increase the instructor's range of motion within the classroom. Furthermore, wall-mounted screens were designed to accommodate the teacher's movement within the classroom. This allows the teacher to monitor the responses of both the class and the remote students at every point in the classroom.

Remote Participants: A fixed camera, which provides a general view of the classroom by adjusting the perspectives of the remote students, and a mobile camera that follows the instructor were installed.

To enhance the effectiveness of hybrid lessons, technical areas within the classroom were designed to allow recording and replaying lessons as needed, eliminating any issues with connectivity issues.

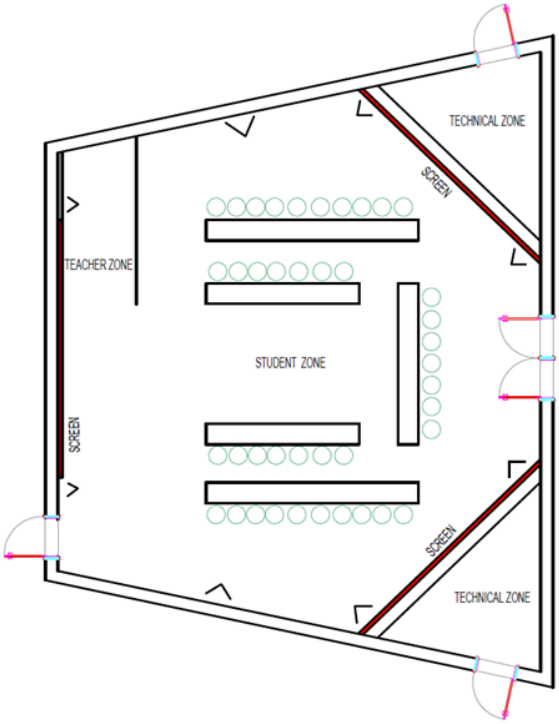


Figure 10. Classroom design suggestion for 50 people

b. 100-Person Amphitheater Classroom Design Suggestion (Figure 11)

Student-Student Interaction: Digital screens located in different areas of the classroom facing students are designed to reflect the views of students participating remotely during discussions, allowing everyone to participate.

Instructor-Student Interaction: In order for the instructor to establish a direct connection with remote students, he/she can have control over both the students in the classroom and the students connecting remotely, with both his/her own zone and the designed hybrid education niches.

Remote Participants: By providing a multi-camera system to view the classroom from different angles, remote students should be encouraged to feel like they are part of the classroom.

Technical zones have been designed within the hybrid education niches to solve the technical problems experienced by students remotely during the lesson.

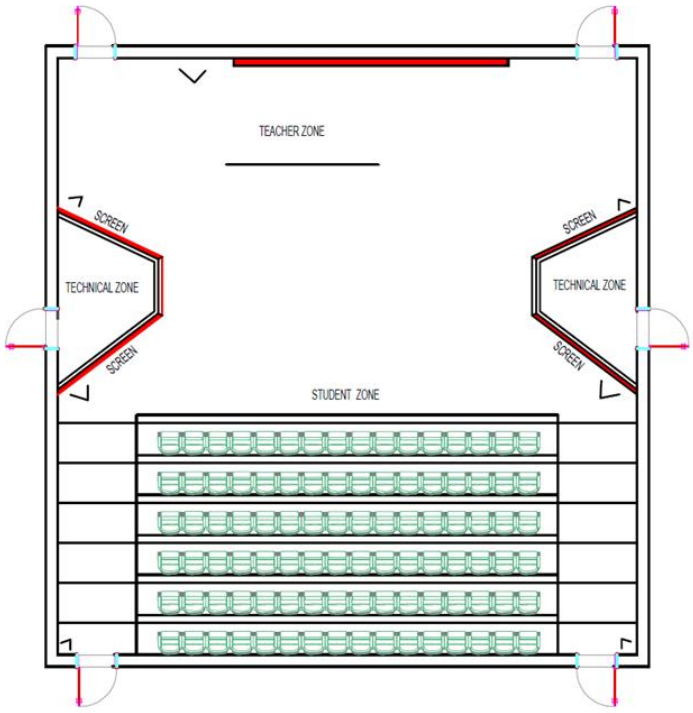


Figure 11. 100 person Amphitheater Classroom Design Suggestion

8. Conclusion

Education is in a constant state of transformation shaped by social, technological, and cultural dynamics. Traditional, distance, and hybrid models have emerged as reflections of their respective eras, responding to technological advancements. Traditional education, which remained confined to synchronously and spatially limited classroom environments, has increased the use of distance education with the development of digital platforms that transcend temporal and spatial boundaries. The COVID-19 pandemic has been a critical turning point in this evolution, accelerating the integration of digital technologies into education and revealing the need for more flexible, accessible, and resilient learning environments. In this context, distance education was first implemented, followed by the transition to a hybrid education model. Hybrid education can be defined as a sustainable pedagogical and spatial model that combines the strengths of both physical and virtual learning formats.

The literature reviewed in this study emphasizes that hybrid learning requires a holistic approach that integrates pedagogy, technology, and space. Research has primarily focused on the pedagogical and technological dimensions of hybrid learning, but has often overlooked the spatial and experiential aspects that shape user engagement. Therefore, this research aims to fill this gap by examining hybrid education from an architectural perspective and emphasizing the interrelationship between spatial configuration, user interaction, and technological infrastructure.

Five representative case studies—KU Leuven Campus, Hybrid Learning Theatre, Imperial College London, Robot-Mediated Communication, and Hybrid Learning Workshop—were

analyzed based on data from the literature review, both highly representative and addressing hybrid education from diverse spatial and technological perspectives. Comparative evaluation revealed that while all examples integrated digital technologies, their spatial responses varied significantly. The KU Leuven model advanced technologically through camera and screen integration while maintaining the traditional classroom typology. In contrast, the Hybrid Learning Theatre redefined the spatial experience through theater lighting, acoustic optimization, and immersive interaction. The Imperial College London example combined a controlled digital system with a circular spatial organization to ensure inclusiveness between remote and in-person students. The Robot-Mediated Communication approach emphasized mobile telepresence devices, transforming the perception of proximity and interaction. Finally, the Hybrid Learning Workshop offers a comprehensive and balanced design framework that coexists with technology, space, and human interaction.

The synthesis of these analyses identified three fundamental requirements for hybrid learning environments. First, physical space flexibility, ergonomic arrangements, and acoustic lighting quality define the spatial comfort required for interaction. Second, technological infrastructure, including multi-angle cameras, mobile devices, and digital platforms, ensure accessibility and continuity. Finally, interaction-related requirements (teacher mobility, group collaboration, and technical support) bridge the experiential gap between remote and in-person participants.

Based on these findings, the study proposed two classroom design models based on the identified requirements: a 50-person classroom and a 100-person lecture hall. These proposals focused on spatial flexibility, ergonomic seating, interactive display systems, acoustic optimization, and lighting strategies. The designs also considered the integration of fixed and mobile camera systems, wireless teaching devices, and multifunctional spaces that support synchronous learning for both in-person and remote users.

Ultimately, this research demonstrates that hybrid education represents a structural and spatial transformation in contemporary higher education. Beyond being a technological adaptation, it signifies the emergence of a new architectural typology that combines physical and digital environments within a unified pedagogical framework. The study emphasizes that the effectiveness of hybrid learning depends on the interaction between technological infrastructure, spatial organization, and human experience. The proposed design models aim to offer conceptual and spatial strategies tailored to these requirements. The evaluation of these designs is also open to discussion.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Abusneneh, N. (2024). Case study research on the hybrid classroom experience in higher education Post-Covid-19 from students and faculty members' perspectives in one of the UAE Universities. *Article in International Journal of Membrane Science and Technology*, *11*(1), 713–720. https://doi.org/10.15379/ijmst.v11i1.3768

Athota, R. K., & Sumathi, D. (2022). Human activity recognition based on hybrid learning algorithm for wearable sensor data. *Measurement: Sensors*, *24*. https://doi.org/10.1016/j.measen.2022.100512

Çetin, A., & Faruk Özdemir, Ö. (2018). Harmanlanmiş ve yüz-yüze öğrenme ortamlarinda kullanilan öğretim yöntemlerinin internete yönelik tutuma etkisi.

Clark, Helen. (2002). *Building education : the role of the physical environment in enhancing teaching and research*. Institute of Education, University of London.

Demir, E. (2014). Uzaktan eğitime genel bir bakış. In *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi-Sayı*.

Dhawan, S. (2020). Online learning: A *Panacea i*n the time of COVID-19 crisis. *Journal of Educational Technology Systems*, *49*(1), 5–22. https://doi.org/10.1177/0047239520934018

Doering, A. (2006). Adventure learning: Transformative hybrid online education. *Distance Education*, *27*(2), 197–215. https://doi.org/10.1080/01587910600789571

Fabian, K., Smith, S., & Taylor-Smith, E. (2024). Being in two places at the same time: a future for hybrid learning based on student preferences. *TechTrends*, *68*(4), 693–704. https://doi.org/10.1007/s11528-024-00974-x

Gleason, B., & Greenhow, C. (2017). Hybrid learning in higher education: The potential of teaching and learning with robot-mediated communication. *Online Learning Journal*, *21*(4), 159–176. https://doi.org/10.24059/olj.v21i4.1276

Göksel, Ş., & Adigüzel, A. (2024). A meta synthesis study on hybrid learning model: International examples. *Milli Egitim*, *53*(243), 1655–1698. https://doi.org/10.37669/milliegitim.1252931

Gudoniene, D., Staneviciene, E., Huet, I., Dickel, J., Dieng, D., Degroote, J., Rocio, V., Butkiene, R., & Casanova, D. (2025). Hybrid teaching and learning in higher education: A systematic literature review. In *Sustainability (Switzerland)* (Vol. 17, Issue 2). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/su17020756

Güllü, O. (2021). Yükseköğretimde Dijitalleşme.

Hümmer, C., Egetenmeyer, R., Breitschwerdt, L., Oliver, E., & Flecha, R. (2025). Forms of synchronous hybrid learning spaces in higher education – A type-building qualitative content analysis. *Computers and Education*, *240*. https://doi.org/10.1016/j.compedu.2025.105440

Jamison, A., Kolmos, A., & Holgaard, J. E. (2014). Hybrid learning: An integrative approach to engineering education. *Journal of Engineering Education*, *103*(2), 253–273. https://doi.org/10.1002/jee.20041

Kiketa, V., Kashoba, H., Kasereka, S., Maniamfu, P., Kutangila, D., Buhendwa, F., Nyazabe, S., & Katshitshi, J. J. (2022). Design and implementation of a blended learning system for higher education in the Democratic Republic of Congo as a response to Covid-19 Pandemic. *International Journal of Emerging Technologies in Learning*, *17*(13), 64–83. https://doi.org/10.3991/ijet.v17i13.30185

Krasniqi, R., & Shabani, A. (2022). Hybrid teaching during Covid-19—A case study of Public Universities in Kosovo. *Open Journal of Social Sciences*, *10*(13), 72–80. https://doi.org/10.4236/jss.2022.1013007

Kristoffersson, A., Coradeschi, S., & Loutfi, A. (2013). A review of mobile robotic telepresence. In *Advances in Human-Computer Interaction* (Vol. 2013). https://doi.org/10.1155/2013/902316

Kurniawan, Y., Karuh, C. S. Y., Ampow, M. K., Prahastuti, M., Anwar, N., & Cabezas, D. (2022). Evaluation of hybrid learning in the University: A case study approach. *HighTech and Innovation Journal*, *3*(4), 394–410. https://doi.org/10.28991/hij-2022-03-04-03

Osaili, T. M., Ismail, L. C., ElMehdi, H. M., Al-Nabulsi, A. A., Taybeh, A. O., Saleh, S. T., Kassem, H., Alkhalidy, H., Ali, H. I., Al Dhaheri, A. S., & Stojanovska, L. (2023). Comparison of students' perceptions of online and hybrid learning modalities during the covid-19 pandemic: The case of the University of Sharjah. *PLoS ONE*, *18*(3 March). https://doi.org/10.1371/journal.pone.0283513

Pols, M. (2020). *Hybrid learning theatre*.

Raes, A. (2022). Exploring student and teacher experiences in hybrid learning environments: Does presence matter? *Postdigital Science and Education*, *4*(1), 138–159. https://doi.org/10.1007/s42438-021-00274-0

Rafi, Md. G. M. (2023). *Effective Hybrid Classroom System for the Army Institute of Business Administration (AIBA), its Associated Challenges and Ways to Overcome*.

Romiszowski, A. J. (2004). *How's the E-learning Baby? Factors Leading to Success or Failure of an Educational Technology Innovation*. *44*(1), 5–27. www.learnativity.com.

Sevli, O. (2023). *Hibrit Eğitim Modelinde Sınıf Tasarımı (Classroom Design in Hybrid Education Model)*. https://www.researchgate.net/publication/371540674

Sieber, J. M., Brannys, A., Söbke, H., Sabik, M. I., & Kraft, E. (2025). The Hybrid Learning Atelier: Designing a Hybrid Learning Space. *Multimodal Technologies and Interaction*, *9*(10), 107. https://doi.org/10.3390/mti9100107

Ünver, E. G. (2024). Üniversite öğrencilerinin eğitim modeli tercihlerine ilişkin görüşlerinin analizi: Bursa örneği. *TOBIDER - International Journal of Social Sciences*, *8*(4). https://doi.org/10.30830/tobider.sayi.20.6

Var, D. (2023). Hibrit Eğitim Sistemine Geçiş İçin Yeni Nesil Öğrenim Teknolojileri İle Tasarlanmış Sınıf Modeli. Millî Savunma Üniversitesi Atatürk Stratejik Araştırmalar ve Lisansüstü Eğitim Enstitüsü Askeri Eğitim Yönetimi Anabilim Dali Askeri Eğitim Yönetimi Programı.

Woolfitt, Z. (2022). *The future is bright - the future is hybrid*.

Yakut Özek, B., & Sincer, S. (2024). Yükseköğretimde dijital dönüşüm: Çevrimiçi ve Hibrit Uygulamaların Geleneksel Eğitim Sistemine Entegrasyonu. *Korkut Ata Türkiyat Araştırmaları Dergisi*, *14*, 1170–1193. https://doi.org/10.51531/korkutataturkiyat.1426337

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Stress Tolerance in Ornamental Plants

Bahar SANCAR[1]*

ORCID 1: 0000-0002-3687-1495
Lecturer, Düzce Üniversity, Recrorate, Düzce- Türkiye
baharsancar@duzce.edu.tr @sdu.edu.tr (Responsible Author)

Abstract

Ornamental plants are widely used for their aesthetic and landscaping value, yet they are increasingly exposed to abiotic stress factors such as climate change, water scarcity, soil salinity, and urban pollution, which negatively affect growth and physiological performance. Studies over the past five years have demonstrated that drought stress triggers adaptive mechanisms in ornamental plants, including stomatal closure, root elongation, and osmolyte accumulation, which help maintain water balance and enhance survival. Salinity disrupts ion homeostasis and limits water uptake, while plants respond through ion transport regulation, antioxidant production, and osmotic adjustment. Some ornamental species effectively employ these mechanisms to sustain growth under saline conditions. Air pollution, particularly ozone and nitrogen oxides, negatively impacts photosynthesis and overall plant growth; plants counteract these effects through stomatal regulation and increased antioxidant activity. Genetic breeding and biotechnological approaches have also emerged as key strategies to enhance abiotic stress tolerance in ornamental species. Additionally, sustainable landscaping practices—including selection of species adapted to local climate, optimized irrigation, and nutrient management—further mitigate the adverse effects of environmental stresses. The aim of this study is to synthesize recent findings on drought, salinity, and pollution-induced physiological and biochemical responses in ornamental plants, to highlight stress tolerance mechanisms, and to identify research priorities for future studies.

Keywords: Ornamental plants, drought, salinity, pollution, abiotic stress, stress tolerance, adaptive mechanisms, genetic breeding, biotechnology

1. Introduction

Ornamental plants constitute an important plant group both economically and ecologically due to their aesthetic appearance, their use in landscape architecture, and their contribution to environmental quality (Özdemir & Yıldız, 2021). However, abiotic stress factors such as rapidly increasing climate change, global warming, decreasing water resources, soil salinity, and air pollution in recent years have seriously affected the physiological performance, growth, and flower quality of ornamental plants (Zhang et al., 2022). Under these stress conditions, plants develop a series of morphological, physiological, and biochemical adaptation mechanisms to sustain their lives (Chakraborty & Patra, 2023).

Drought stress is one of the most common abiotic stress factors in ornamental plants. Water deficiency causes physiological responses such as stomatal closure, decreased transpiration rate, and reduced photosynthetic activity, resulting in growth retardation, pigment loss, and premature aging in plants (Yıldız et al., 2023). However, some ornamental plants compensate for water potential and maintain metabolic functions by increasing the accumulation of osmoprotective compounds (proline, glycine betaine) (Hosseini et al., 2021). For example, studies conducted on species such as Petunia hybrida and Tagetes erecta have shown that antioxidant enzyme activities (SOD, CAT, APX) increase significantly under drought conditions (Raza et al., 2022). This allows the plant to maintain its viability by reducing cellular damage caused by reactive oxygen species (ROS) (Liu et al., 2023).

Salt stress is also a significant environmental constraint in ornamental plants. Excessive Na^+ and Cl^- ions negatively affect plant development by causing ion imbalance, limiting water uptake, and impairing nutrient uptake (Singh et al., 2024). However, some ornamental species

can survive under saline conditions thanks to ion partitioning and osmoregulation mechanisms (El-Sayed et al., 2022). For example, a study conducted on Chrysanthemum morifolium reported that proline and soluble sugar accumulation increased under salinity, thereby maintaining water potential (Wei et al., 2021). Similarly, research conducted on Calendula officinalis showed that salt stress reduced the rate of photosynthesis but partially preserved leaf turgor through the retention of Na^+ ions in vacuoles (Kumar et al., 2023).

Air pollution and urban environmental conditions are other abiotic stress factors that profoundly affect the physiology of ornamental plants. Gases such as ozone (O_3) and nitrogen oxide (NO_x), in particular, cause chlorophyll degradation and photosystem II damage, triggering necrosis and premature senescence in plant leaves (Matsumoto et al., 2021). A study on Rosa hybrida reported that an increase in ozone concentration reduced net photosynthesis rates by 35% and significantly decreased leaf antioxidant capacity (Kim et al., 2022). Similarly, increased temperature and radiation in urban microclimate conditions cause early flowering and phenological shifts, weakening the ecological compatibility between pollinators and plants (Andrade et al., 2023). This situation has indirect effects on ornamental plants' aesthetic value, as well as their reproductive success and seed yield (Li et al., 2024).

Recent studies have demonstrated the successful use of biostimulants, antioxidant applications, microbial inoculations, and genetic breeding methods to enhance stress tolerance in ornamental plants (Niazi et al., 2022). For example, it has been reported that melatonin application in Gerbera jamesonii delays flowering under water stress and extends vase life by 20% (Wang et al., 2023). Furthermore, recent molecular studies have confirmed that the expression of transcription factors (DREB, NAC, WRKY) and heat shock proteins at the genetic level plays a key role in stress tolerance (Zhang et al., 2023).

However, the literature generally focuses on a single stress factor, and studies evaluating multiple stress conditions (e.g., drought + heat or salinity + pollution) together are quite limited (Yıldız et al., 2024). In natural environments, ornamental plants are often exposed to multiple stress factors simultaneously. Therefore, examining the interactions of multiple stresses at the physiological and molecular levels in future research is of great importance (Fernández et al., 2025).

In conclusion, understanding the responses of ornamental plants to climate change and environmental stress conditions is critical for both sustainable landscape management and the development of breeding strategies. In this context, compiling the existing literature and revealing the physiological, biochemical, and molecular mechanisms related to stress tolerance will guide future research (Kaya & Demir, 2025).

2. Physiological and Biochemical Effects of Drought, Salinity, and Pollution Stresses on Ornamental Plants

2.1. Drought Stress

Drought is the most common abiotic stress factor in ornamental plants, causing a decrease in water potential (Ψleaf) and relative water content (RWC), thereby limiting photosynthesis rate and chlorophyll synthesis (Detti et al., 2024).

In comparative experiments conducted on species such as Photinia × fraseri and Viburnum tinus, it was determined that Photinia was able to maintain its hydraulic conductance and RWC

for a longer period after water deprivation; in contrast, a rapid increase in lipid peroxidation (MDA) and electrolyte leakage was observed in Viburnum (Detti et al., 2024).

In Hemerocallis fulva genotypes exposed to drought, net photosynthesis rate (A) and photochemical efficiency (Fv/Fm) decreased along with a drop in stomatal conductance (g_s); at the same time, osmotic adjustment was achieved with an increase in proline and soluble sugars (Liang et al., 2025).

Drought stress also triggers the accumulation of reactive oxygen species (ROS), causing oxidative damage to cell membranes; this leads to the disruption of the Mg-centered structure of chlorophyll and leaf yellowing (Ali et al., 2025).

The biochemical consequences of this stress include:

- Accumulation of osmoprotectants such as proline, glycine betaine, sucrose, and fructose,
- Increased activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX),
- Increased lipid peroxidation products (MDA) (Zarif et al., 2025).

As a result of these processes, aesthetic quality losses such as wilting, premature aging, and shortened vase life are observed, particularly in cut flowers.

2.2. Salinity Stress

Salinity causes a two-stage effect in ornamental plants in the form of osmotic stress and ion toxicity. In the first stage, high salt concentration limits the plant's water uptake by reducing the water potential of the soil solution. In the second stage, the accumulation of Na^+ and Cl^- ions in the cell causes ion imbalance and metabolic toxicity (Wang et al., 2025). In a study on Chrysanthemum morifolium, increasing NaCl doses were associated with a decrease in chlorophyll content, a reduction in stomatal aperture, a decrease in photosynthesis rate, and an increase in proline accumulation (Li et al., 2022).

Similarly, in Limonium bicolor under salinity conditions, the LbMYB48 transcription factor was found to regulate salt gland development, and Na^+ ions were excreted from the epidermal glands to maintain ion homeostasis (Han et al., 2022). The activation of the antioxidant system also plays a decisive role in ornamental species exposed to salt stress. In Nerium oleander, it has been reported that ROS detoxification efficiency increases with the accumulation of proline, ascorbate, and phenolic compounds at increasing salinity levels; thus, leaf necrosis and chlorophyll loss are limited (Mircea et al., 2024).

2.3. Air Pollution (O_3/NOx) Stress

Ozone (O_3) is one of the most common atmospheric pollutant stress factors in ornamental plants. O_3 diffusing through leaf stomata dissolves in the apoplast, producing reactive oxygen species ($\bullet O_2^-$, H_2O_2), which causes oxidative damage to the photosynthetic apparatus (especially PSII) and pigment synthesis system (Wang et al., 2023). In a study conducted on four cultivars of Rosa hybrida (“Iceberg,” “Spectra,” “Schloss Mannheim,” “Lüye”), net photosynthesis rate (A_n) and stomatal conductance (g_s) significantly decreased under high O_3 exposure; but the “Schloss Mannheim” cultivar was reported to better maintain PSII efficiency (Wang et al., 2023).

In plants exposed to ozone stress for long periods, chlorophyll a+b and carotenoid content decreased, and brown spots and premature aging were observed in the leaves along with an increase in MDA (Duque et al., 2021). In the urban microclimate, the accumulation of ozone and nitrogen oxides (NOx) also advances flowering time, disrupts synchronization with pollinators, and reduces aesthetic value (Díaz et al., 2023; Park et al., 2023).

3. Stress Tolerance Mechanisms

3.1. Physiological Adaptations

• Stomatal regulation: Water loss is reduced by stomatal closure during drought; tolerant genotypes optimize this closure without completely halting photosynthesis (Liang et al., 2025).

• Root morphology: Deep and lateral root development increases water and nutrient uptake under both drought and salinity (Zarif et al., 2025).

• Na^+ partitioning: Ion toxicity in salinity is limited by Na^+ storage in vacuoles or retention in roots (Han et al., 2022).

• Ozone tolerance: Some species reduce O_3 diffusion by accelerating stomatal closure; others buffer intracellular ROS with high ascorbate content (Wang et al., 2023).

3.2. Biochemical and Molecular Mechanisms

• Osmoprotectant accumulation: Proline, glycine betaine, and soluble carbohydrates balance water potential (Ali et al., 2025).

• Antioxidant defense: SOD, CAT, APX, and glutathione reductase enzymes provide ROS detoxification (Nguyen et al., 2025).

• Transcription factors: LbMYB48 (salt gland development), DREB (drought response), WRKY, and NAC (oxidative stress) genes are molecular determinants of stress tolerance (Han et al., 2022).

• Hormonal signaling networks: Abscisic acid (ABA), jasmonate (JA), and salicylic acid (SA) play a role in stress perception; for example, ABA synthesis regulates stomatal responses during drought.

3.3. Applied and Biotechnological Approaches

• Melatonin application: Post-harvest melatonin application in Gerbera jamesonii extended vase life by up to 30% by reducing H_2O_2 and MDA levels (SeyedHajizadeh et al., 2024).

• Silicon and seaweed extracts: Increase membrane stability under salinity and reduce ion toxicity (Nguyen et al., 2025).

• Heteropollination: It has been reported that heteropollination increases tolerance in Chrysanthemum by regulating Na^+ transport in different root stocks (Li et al., 2022).

4. Physiological and Biochemical Effects of Drought Stress

Drought stress results in water deficiency, which limits fundamental physiological processes in plants such as photosynthesis, water relations, respiration, and nutrient transport. A decrease in water potential triggers stomatal closure, which directly negatively affects carbon assimilation and chlorophyll synthesis (Detti, Galié & Ferrante, 2024). Studies conducted on Photinia × fraseri and Viburnum tinus species have determined that Photinia is more drought-resistant due

to its higher hydraulic conductance capacity, whereas electrolyte leakage and lipid peroxidation start earlier in Viburnum (Detti et al., 2024).

Similarly, different adaptive responses to water deficiency were observed in Hemerocallis fulva genotypes. In tolerant genotypes, stomatal conductance (g_s) decreased while net photosynthesis (A_n) was partially maintained; proline, sucrose, and glycine betaine accumulation were reported to be effective in maintaining water balance (Liang, Zhao, Liu & Song, 2025).

Drought stress also causes oxidative damage by increasing reactive oxygen species (ROS) production. In Rosa chinensis, MDA content increased under drought conditions, while SOD, CAT, and APX activities increased; these enzymatic responses reduced oxidative damage (Ali, Rahman & Javed, 2025).

Similar findings have been reported in grass plants. Drought treatment in Zoysia japonica reduced photosynthetic efficiency (Fv/Fm) and water use efficiency (WUE); however, ABA synthesis increased and stomatal regulation strengthened in drought-tolerant genotypes (Wang, Liu & Kim, 2023). In Festuca arundinacea, drought tolerance was found to be related to antioxidant system activity and root/shoot ratio (Li, Zhou & Sun, 2024).

These studies indicate that drought tolerance in ornamental and turfgrass plants is determined by the interaction between hydraulic conductance capacity, antioxidant system strength, and osmoprotectant accumulation.

5. Physiological and Biochemical Effects of Salinity Stress

Salinity causes osmotic stress and metabolic disorders due to ion toxicity, which limit water uptake in ornamental plants. High Na^+ and Cl^- accumulation creates ion imbalance in cell membranes and reduces photosynthetic activity (Wang, Zhou & Li, 2025). Application of 100–200 mM NaCl in Chrysanthemum morifolium caused a decrease in chlorophyll content and impaired photosynthetic electron transport (Li, Huang & Zhou, 2024).

In the halophytic species Limonium bicolor, the transcription factor LbMYB48 was found to increase salt tolerance by regulating salt gland development and Na^+/K^+ homeostasis (Han, Wang, Zhao & Zhang, 2022). In Nerium oleander, increased proline, ascorbate, and phenolic compound accumulation was observed with increasing salinity levels; this was found to limit oxidative damage (Mircea, Popescu & Stoian, 2024).

Furthermore, experiments conducted on Tagetes erecta (marigold) observed ion accumulation and chlorophyll loss due to salinity stress; however, melatonin application was reported to preserve photosynthetic capacity by increasing antioxidant activity (SOD, CAT) (Nguyen, Shin & Kim, 2025). In Pelargonium hortorum, NaCl application altered carbohydrate metabolism, and soluble sugar accumulation was found to be effective in maintaining osmotic balance (Pandit, Verma & Shukla, 2024).

Among grasses, Cynodon dactylon (Bermuda grass) is one of the salt-tolerant species. Studies have shown that membrane damage can be limited by the retention of Na^+ ions in the roots and an increase in glutathione reductase activity (Zhang, Liu & Chen, 2025).

6. Effects of Air Pollution (O_3/NOx) Stress

Tropospheric ozone (O_3) and nitrogen oxides (NOx) cause oxidative damage, pigment loss, and premature aging in the leaves of ornamental plants. O_3 enters the apoplast through stomata,

increasing reactive oxygen species (ROS) production, which reduces the photochemical efficiency of PSII (Wang, Zhang & Liu, 2023).

In a study conducted on four different cultivars of Rosa hybrida, high O_3 levels reduced net photosynthesis (A_n) and stomatal conductance (g_s); however, it was determined that the "Schloss Mannheim" cultivar maintained PSII efficiency due to its higher ascorbate content (Wang et al., 2023). In Petunia hybrida, antioxidant defense against ozone stress was enhanced, with SOD and POD activities increasing significantly within 48 hours (Duque, Hernandez & Santiago, 2021).

Ozone accumulation in the urban microclimate affects not only photosynthesis but also phenology and pollinator adaptation. High NOx and ozone concentrations in species such as Lavandula angustifolia and Hibiscus rosa-sinensis shortened flowering time, reduced pollen viability, and negatively affected aesthetic appearance (Díaz, Santos & Villar, 2023; Park, Chae & Kim, 2023).

Ozone treatments on grasses have shown that oxidative stress causes pigment loss and chloroplast deformation, particularly in species such as Lolium perenne and Festuca rubra (Liu, Wang & Sun, 2024).

7. Stress Tolerance Mechanisms

Tolerance mechanisms developed in ornamental plants against abiotic stresses are studied at morphological, physiological, biochemical, and molecular levels.

Morphological-physiological mechanisms:

Tolerant genotypes maintain photosynthetic capacity by optimizing stomatal regulation under drought conditions. In Zoysia japonica and Hemerocallis fulva genotypes, deep rooting and reduced leaf area increased water use efficiency (Wang et al., 2023; Liang et al., 2025).

Under salt stress, salt gland development and ion partitioning observed in halophytic species are the most effective morphological adaptations limiting Na^+ toxicity (Han et al., 2022).

Biochemical-molecular mechanisms:

Proline, glycine betaine, and soluble carbohydrates play a key role in maintaining osmotic balance (Ali et al., 2025). The activity of antioxidant enzymes (SOD, CAT, APX, GR) is the fundamental mechanism for ROS detoxification (Nguyen et al., 2025).

At the genetic level, LbMYB48 (salt gland development), DREB (drought), WRKY, and NAC (oxidative stress) transcription factors have been identified as molecular regulators of plant defense (Han et al., 2022).

In Rosa hybrida, overexpression of ascorbate peroxidase (APX1) and glutathione reductase (GR2) genes was detected during ozone exposure, and these genes are thought to contribute to ozone tolerance (Wang et al., 2023).

Biotechnological approaches:

Melatonin and silicon applications maintain membrane stability and reduce oxidative damage under water and salt stress (SeyedHajizadeh, Rahmani & Tavakkol-Afshari, 2024; Nguyen et al., 2025). In Gerbera jamesonii, melatonin extended vase life by reducing H_2O_2 accumulation (SeyedHajizadeh et al., 2024).

8. Conclusions and Recommendations

Abiotic stress factors such as drought, salinity, and urban pollution, which are increasing with climate change, affect the physiological functioning, biochemical balance mechanisms, and aesthetic values of ornamental plants in multiple ways. Recent studies have revealed that plants develop adaptive responses under these stress conditions, such as reducing transpiration by altering their stomatal behavior, maintaining water balance through osmotic solute accumulation, and strengthening antioxidant defense systems (Toscano et al., 2023; Liang et al., 2025). However, these adaptive mechanisms do not function with the same effectiveness in every species or genotype, and the level of physiological protection, particularly regarding aesthetic quality, shows species-based differences (Detti et al., 2024).

Studies conducted under drought conditions have demonstrated the effectiveness of morphophysiological strategies that minimize water loss, particularly in Hemerocallis and Photinia species; however, even in these species, photosynthetic efficiency and color quality decline rapidly during prolonged water deficiency (Liang et al., 2025). Under salinity stress, ion partitioning and osmoregulation capacity have been found to be decisive in tolerance in species such as Chrysanthemum and Limonium (Li et al., 2022; Han et al., 2022). Rising O_3 levels and heat waves in urban ecosystems limit aesthetic quality in Rosa hybrida cultivars through premature senescence, pigment loss, and flower deformities (Wang et al., 2023). These findings indicate that stress tolerance in ornamental plants is a fundamental factor determining not only physiological continuity but also the sustainability of visual quality.

8.1. Recommendations

Multiple stress scenarios: Future research should examine the effects of drought, salinity, and heat/ozone not individually but under combined stress conditions. This will allow for a more accurate assessment of the impact of complex stress combinations encountered in real landscape environments on plant performance.

Species and genotype selection: Ornamental plants exhibit considerable genetic diversity in terms of stress tolerance. Therefore, species/cultivar-based tolerance maps should be created to ensure the correct material selection in urban planning and production areas. Limonium, Nerium, Gerbera, and Chrysanthemum species, in particular, stand out as candidates resistant to different stress factors (Han et al., 2022; SeyedHajizadeh et al., 2024).

Biostimulant and post-harvest applications: Natural biostimulants such as melatonin, silicon, and seaweed extracts have been proven to affect flower longevity, membrane stability, and pigment preservation under stress. Standardizing the dose-duration of these applications and conducting economic analyses will increase their applicability at the producer level (Nguyen et al., 2025).

Omics-based approaches: The integration of genomic, transcriptomic, and metabolomic techniques will accelerate the identification of genes, transcription factors (e.g., DREB, NAC, WRKY), and metabolite networks involved in stress tolerance. Thus, the use of molecular markers in breeding studies will become more widespread (Zhang et al., 2023).

Urban landscape planning: Microclimate regulation strategies (shading, use of permeable surfaces, air circulation optimization) should be implemented in cities to reduce O_3 and heat stress effects; ozone-insensitive species should be preferred in areas with high pollutant loads (Wang et al., 2023; Díaz et al., 2023).

Ecological-aesthetic balance: Future research should develop integrated models that objectively measure not only physiological resilience but also visual quality criteria (flower color, form, persistence). This would allow the climate change adaptation capacity of ornamental plants to be evaluated from both biotic and aesthetic perspectives (Mircea et al., 2025).

The effects of abiotic stresses on ornamental plants determine not only physiological resilience but also aesthetic quality and economic value. Hydraulic and antioxidant adaptation in drought, ion homeostasis and osmoprotectant accumulation in salinity, and stomatal regulation and pigment protection in air pollution are fundamental tolerance mechanisms. Consequently, enhancing the resistance of ornamental plants to abiotic stresses is of strategic importance not only for production efficiency but also for the aesthetic and ecological sustainability of urban ecosystems. In the future, interdisciplinary studies integrating stress physiology, molecular biotechnology, and landscape planning will play a critical role in developing ornamental plant varieties resistant to climate change.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Andrade, C., Silva, P., & Morais, L. (2023). Urban heat islands and phenological shifts in ornamental plants. *Environmental and Experimental Botany*, 212, 105495.

Chakraborty, A., & Patra, B. (2023). Abiotic stress responses in ornamental plants: Recent advances and prospects. *Horticultural Plant Journal*, 9(4), 512–526.

El-Sayed, A., Hassan, R., & Omar, A. (2022). Salinity stress mitigation in ornamental species through osmotic adjustment. *Scientia Horticulturae*, 306, 111409.

Hosseini, M., Raza, A., & Ahmad, P. (2021). Osmoregulation and antioxidative defense under drought stress in ornamental crops. *Plant Physiology Reports*, 26(3), 435–449.

Kim, J., Park, S., & Lee, H. (2022). Ozone-induced oxidative damage in roses and physiological recovery strategies. *Environmental Pollution*, 308, 119594.

Kumar, P., Singh, S., & Raj, R. (2023). Impact of salinity stress on photosynthetic performance of Calendula officinalis. *Horticultural Science and Biotechnology*, 98(2), 341–352.

Liu, Q., Zhang, Z., & Hu, Y. (2023). Reactive oxygen metabolism and drought tolerance in Petunia hybrida. *Journal of Plant Growth Regulation*, 42, 1463–1478.

Matsumoto, K., Saito, N., & Tanaka, Y. (2021). Air pollutants and ornamental plant physiology: A review. *Urban Forestry & Urban Greening*, 64, 127282.

Niazi, M., Ahmad, P., & Abbas, M. (2022). Biostimulants and molecular breeding approaches for stress resilience in ornamental crops. *Plant Biotechnology Reports*, 16, 411–426.

Wei, L., Chen, X., & Zhao, Y. (2021). Physiological and biochemical responses of Chrysanthemum under salt stress. *Plant Stress*, 2, 100045.

Yıldız, F., Özdemir, H., & Kaya, M. (2023). Physiological mechanisms of drought tolerance in ornamental plants. *Turkish Journal of Botany*, 47(2), 159–174.

Zhang, H., Li, T., & Sun, Y. (2023). Transcriptional regulation of abiotic stress responses in ornamentals. *Frontiers in Plant Science,* 14, 1123456.

Singh, R., Chauhan, P., & Jain, S. (2024). Ionic homeostasis and salinity tolerance mechanisms in horticultural plants. *Environmental Horticulture*, 42(1), 56–68.

Fernández, J., Torres, R., & Delgado, M. (2025). Multifactorial stress interactions in ornamental crops under climate change scenarios. *Plant Stress Biology*, 5(1), 102–114.

Kaya, N., & Demir, M. (2025). Sürdürülebilir peyzaj yönetiminde stres toleransının rolü. *Türkiye Peyzaj Bilimleri Dergisi*, 7(1), 24–39.

Detti, M., Galié, M., & Ferrante, A. (2024). Drought tolerance and recovery capacity of two ornamental shrubs *(Photinia × fraseri Dress & Viburnum tinus L.)*. *Scientia Horticulturae,* 329, 112245. https://doi.org/10.1016/j.scienta.2024.112245

Liang, X., Zhao, H., Liu, J., & Song, Y. (2025). Evaluating drought tolerance among 25 Hemerocallis fulva genotypes using a comprehensive index-based approach. *Scientific Reports*, 15(1), 18700. https://doi.org/10.1038/s41598-025-18700-9

Mircea, M., Popescu, R., & Stoian, A. (2023). Responses of different invasive and non-invasive ornamental plants to water stress during seed germination and vegetative growth. *Plant Biology*, 25(3), 540–552. https://doi.org/10.1111/plb.70074

Liu, H., Wang, Y., & Sun, Q. (2025). Tolerance and response of ornamental plants to abiotic stress. *Horticulturae*, 11(6), 704. https://doi.org/10.3390/horticulturae11060704

Wang, D., Zhou, L., & Li, S. (2025). Response of ornamental plants to salinity: Impact on aesthetic quality and physiology. *Frontiers in Plant Science*, 16, 1611767. https://doi.org/10.3389/fpls.2025.1611767

Li, R., Huang, B., & Zhou, Y. (2024). Relative salinity tolerance of turfgrass species and cultivars. *Agricultural Water Management,* 296, 109220. https://doi.org/10.1016/j.agwat.2024.109220

Todd, J. (2023). *Soil salinity and its effects on turfgrass pests.* Clemson University Press. https://lgpress.clemson.edu/publication/soil-salinity-and-its-effects-on-turfgrass-pests/

Han, G., Wang, M., Zhao, Y., & Zhang, J. (2022). LbMYB48 regulates salt gland development and salt tolerance in Limonium bicolor. *Frontiers in Plant Science*, 13, 991451. https://doi.org/10.3389/fpls.2022.991451

Zhang, D., Liu, T., & Chen, P. (2025). Proteomic analysis reveals mechanisms of salt tolerance in Chrysanthemum yantaiense genotypes. *BMC Plant Biology,* 25(2), 156. https://doi.org/10.1186/s12870-025-04713-5

Wang, H., Zhang, X., & Liu, Z. (2023). Physiological and molecular responses of different rose cultivars to ozone stress. *Plant Direct,* 7(12), e484. https://doi.org/10.1002/pld3.484

Duque, L., Hernandez, A., & Santiago, R. (2021). Effects of ozone stress on flowering phenology, plant growth and biomass allocation in ornamental species. *Environmental Pollution,* 287, 117617. https://doi.org/10.1016/j.envpol.2021.117617

Díaz, J. G., Santos, M., & Villar, E. (2023). Influence of urbanisation on phenology of evergreen and deciduous plants along urban–rural gradients. *Agricultural and Forest Meteorology*, 331, 109389. https://doi.org/10.1016/j.agrformet.2023.109389

Park, D. S., Chae, Y., & Kim, H. (2023). Complex climate-mediated effects of urbanisation on plant phenology and pollinator activity. *New Phytologist*, 239(4), 1825–1841. https://doi.org/10.1111/nph.19034

Wani, S. H. (2023). Mechanisms of abiotic stress responses and tolerance in plants: An editorial overview. *Frontiers in Plant Science*, 14, 1272255. https://doi.org/10.3389/fpls.2023.1272255

Ali, M., Rahman, H., & Javed, R. (2025). Oxidative stress responses of ornamental plants under drought: enzymatic and non-enzymatic regulation. *Plants*, 14(2), 245. https://doi.org/10.3390/plants14020245

Detti, M., Galié, M., & Ferrante, A. (2024). Drought tolerance and recovery capacity of two ornamental shrubs *(Photinia × fraseri Dress & Viburnum tinus L.). Scientia Horticulturae*, 329, 112245. https://doi.org/10.1016/j.scienta.2024.112245

Díaz, J. G., Santos, M., & Villar, E. (2023). Influence of urbanisation on phenology of evergreen and deciduous plants along urban–rural gradients. *Agricultural and Forest Meteorology*, 331, 109389. https://doi.org/10.1016/j.agrformet.2023.109389

Duque, L., Hernandez, A., & Santiago, R. (2021). Effects of ozone stress on flowering phenology, plant growth and biomass allocation in ornamental species. *Environmental Pollution*, 287, 117617. https://doi.org/10.1016/j.envpol.2021.117617

Han, G., Wang, M., Zhao, Y., & Zhang, J. (2022). LbMYB48 regulates salt gland development and salt tolerance in Limonium bicolor. *Frontiers in Plant Science*, 13, 991451. https://doi.org/10.3389/fpls.2022.991451

Li, H., Zhou, R., & Sun, D. (2024). Drought response and antioxidant capacity variation among Festuca arundinacea genotypes. *Agronomy*, 14(5), 1102. https://doi.org/10.3390/agronomy14051102

Li, R., Huang, B., & Zhou, Y. (2024). Relative salinity tolerance of turfgrass species and cultivars. *Agricultural Water Management*, 296, 109220. https://doi.org/10.1016/j.agwat.2024.109220

Liang, X., Zhao, H., Liu, J., & Song, Y. (2025). Evaluating drought tolerance among 25 Hemerocallis fulva genotypes using a comprehensive index-based approach. *Scientific Reports*, 15(1), 18700. https://doi.org/10.1038/s41598-025-18700-9

Liu, Q., Wang, L., & Sun, H. (2024). Ozone-induced physiological and structural changes in cool-season turfgrasses. *Environmental and Experimental Botany*, 216, 105378. https://doi.org/10.1016/j.envexpbot.2024.105378

Mircea, M., Popescu, R., & Stoian, A. (2024). Salinity-induced oxidative stress in ornamental shrubs: physiological and biochemical adaptations. *Plant Stress*, 10, 100223. https://doi.org/10.1016/j.stress.2024.100223

Nguyen, T. M., Shin, H. S., & Kim, Y. H. (2025). Melatonin and silicon synergistically mitigate drought- and salt-induced oxidative stress in ornamental plants. *Frontiers in Plant Science*, 16, 1721134. https://doi.org/10.3389/fpls.2025.1721134

Pandit, A., Verma, R., & Shukla, P. (2024). Salinity-induced oxidative stress and osmotic adjustment in floricultural crops: Recent advances. *Horticultural Plant Journal*, 10(4), 356–368. https://doi.org/10.1016/j.hpj.2024.02.004

Park, D. S., Chae, Y., & Kim, H. (2023). Complex climate-mediated effects of urbanisation on plant phenology and pollinator activity. *New Phytologist*, 239(4), 1825–1841. https://doi.org/10.1111/nph.19034

SeyedHajizadeh, H., Rahmani, S., & Tavakkol-Afshari, R. (2024). Postharvest melatonin treatment extends vase life and maintains membrane integrity i*n Gerbera jamesonii*. *Postharvest Biology and Technology*, 211, 112490. https://doi.org/10.1016/j.postharvbio.2024.112490

Wang, D., Zhou, L., & Li, S. (2025). Response of ornamental plants to salinity: Impact on aesthetic quality and physiology. *Frontiers in Plant Science*, 16, 1611767. https://doi.org/10.3389/fpls.2025.1611767

Wang, H., Zhang, X., & Liu, Z. (2023). Physiological and molecular responses of different Rosa hybrida cultivars to ozone stress. *Plant Direct*, 7(12), e484. https://doi.org/10.1002/pld3.484

Wang, Y., Liu, T., & Kim, J. (2023). Comparative physiological responses of Zoysia japonica cultivars under progressive drought stress. *Agronomy*, 13(3), 780. https://doi.org/10.3390/agronomy13030780

Zarif, M., Aydın, S., & Çelik, R. (2025). Hydraulic adjustment and antioxidant regulation under progressive drought stress in ornamental sunflowers. *Agronomy*, 15(1), 65. https://doi.org/10.3390/agronomy15010065

Zhang, D., Liu, T., & Chen, P. (2025). Proteomic analysis reveals mechanisms of salt tolerance in Chrysanthemum yantaiense genotypes. *BMC Plant Biology*, 25(2), 156. https://doi.org/10.1186/s12870-025-04713-5

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Effects of Climate Change on the Physiology of Ornamental Plants

Bahar SANCAR[1]*

ORCID 1: 0000-0002-3687-1495
[1] Lecturer, Düzce Üniversity, Recrorate, Düzce- Türkiye
baharsancar@duzce.edu.tr (Responsible Author)

Abstract

Climate change significantly affects the physiology of ornamental plants through rising heat waves, irregular precipitation patterns, elevated atmospheric CO_2 levels, and the urban heat island effect. Studies conducted over the past five years have demonstrated that high temperature stress reduces flower quality and vitality by disrupting photosystems, inactivating enzymes, and damaging membrane structures. Drought conditions, on the other hand, shorten vase life and accelerate senescence in cut flowers by impairing water relations and altering ethylene and abscisic acid signaling pathways. Elevated CO_2 concentrations have shown species-specific and variable effects: while biomass and photosynthesis are enhanced in some ornamentals, flower number and quality traits may decline in others. In urban environments, microclimatic warming alters phenological and physiological traits, leading to earlier flowering and potential mismatches with pollinators. Indirect ecosystem-level impacts, such as pollinator-plant asynchrony and changes in soil microbial interactions, may further compromise reproductive success and long-term sustainability. Recent research also emphasizes adaptation and mitigation strategies, including the use of biostimulants, antioxidants, shading, and improved irrigation management to alleviate stress effects. Nevertheless, significant gaps remain, particularly in the limited number of species studied and the scarcity of experiments addressing combined stress factors under realistic field conditions. The aim of this study is to synthesize recent findings on the physiological impacts of climate change on ornamental plants and to highlight knowledge gaps that can guide future research priorities.

Keywords: Climate change, ornamental plants, physiology, heat stress, drought, CO_2, vase life

1. Introduction

Climate change observed on a global scale is a slow but permanent environmental transformation resulting from an energy imbalance caused by greenhouse gases accumulating in the atmosphere (IPCC, 2023). Since the Industrial Revolution, increases in levels of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in particular have caused global temperatures to rise by approximately 1,2 °C compared to pre-industrial levels (Mircea et al., 2024). This temperature increase affects not only average values but also changes the frequency of extreme weather events, precipitation patterns, soil moisture, evaporation rates, and regional microclimate conditions (Kisvarga et al., 2023). According to IPCC (2023) projections, the temperature increase is expected to reach 1,5–2,0 °C by the middle of this century, and this change will create metabolic imbalances, physiological stress, and morphological adaptation pressures, especially in plant production systems (Leotta et al., 2022).

Plants, being sessile (immobile) organisms, are directly exposed to environmental changes; therefore, their response to climate change is critical for ecosystem balance and the sustainability of production systems. This situation has a major impact not only on agricultural products but also on plant groups whose economic value is based on aesthetic quality, such as ornamental plants (Mahajan et al., 2025). Ornamental plants are directly dependent on environmental factors such as color, form, number of flowers, tissue structure, vase life, and phenological timing (Mahdavian et al., 2022). Therefore, temperature waves, irregular rainfall, drought, elevated CO_2 concentration, air pollution, and the urban heat island (UHI) effect

associated with climate change profoundly disrupt the physiological balance of these plants (Dzul-Cauich et al., 2025).

Ornamental plant production is typically carried out under controlled (greenhouse, tunnel) or semi-controlled outdoor conditions; these systems can provide limited protection against climate change but are not completely resistant to temperature and humidity fluctuations (Leotta et al., 2022). For example, in species such as Rosa hybrida, Gerbera jamesonii, and Chrysanthemum morifolium in the Mediterranean region, periods of high temperature shorten flowering time, reduce pigment accumulation, and cause deformities. In Lilium longiflorum plants grown under drought conditions, a decrease in leaf water potential causes stomatal closure and a decrease in photosynthesis rate, while a 25% decrease in flower number has been recorded (Ahn et al., 2022).

Elevated atmospheric CO_2 (eCO_2), while increasing photosynthesis rates in many species in the short term, limits biomass increase in the long term due to "carbon acclimation" and does not result in a significant improvement in flower quality (Bernauer et al., 2024). Furthermore, eCO_2 has been reported to have species-specific effects on flower number, pollen nutrient content, and growth responses; in some cases, it also alters plant–pollinator interactions (McClory et al., 2024). Therefore, eCO_2 applications in ornamental plants should be evaluated within the quality–yield–ecological interaction triangle (Bernauer et al., 2024).

The urban heat island (UHI) effect causes early flowering, phenological shifts, and redistribution of physiological loads by altering day-night thermal patterns (Freimuth et al., 2022). Lavandula angustifolia blooms 10–12 days earlier in city centers, with an 18% decrease in nectar density observed (Fujiwara, 2025). This creates timing mismatches with pollinators, leading to disruptions in ecosystem services (Polidori et al., 2023).

Ornamental plants provide ecosystem services not only through their aesthetic value but also through their carbon sink capacity, microclimate regulation, pollinator attraction, and contribution to psychological well-being (Polidori et al., 2023). Therefore, the sensitivity of ornamental plants to climate change implies not only economic losses but also a reduction in ecological functionality (Kisvarga et al., 2023).

Global climate change is simultaneously and often synergistically transforming the physiological processes of ornamental plants through increasing heat waves, irregular rainfall patterns, atmospheric CO_2 accumulation, and microclimate shifts triggered by urbanization (Mircea et al., 2024). These environmental shifts affect components directly linked to quality and market value, such as photosynthetic efficiency, mass increase, water relations, membrane integrity, pigment biochemistry, flower phenology, and vase life in cut flowers (Mircea et al., 2024).

In terms of photosynthesis, high temperatures weaken PSII activity, cause a decrease in chlorophyll fluorescence (Fv/Fm), and limit carbon assimilation (Palermo et al., 2025). In Chrysanthemum morifolium plants, the disruption of the chlorophyll a/b ratio at 38 °C led to a 30% decrease in light energy capture (Leotta et al., 2022). Heat stress reduces photosynthetic CO_2 fixation by decreasing Rubisco activity, causing an energy imbalance in carbon metabolism (Mahdavian et al., 2022).

Shelake et al. (2024) reported that under high temperature stress in ornamental plants, PSII-centered photochemistry weakened, electron transport was disrupted, and membrane lipid peroxidation increased. This situation, together with ROS accumulation, leads to early

senescence and pigment degradation. The “heat shock–recovery” protocols developed for screening heat tolerance provide important tools for determining thermal thresholds between species (Park et al., 2024).

Drought limits photosynthetic carbon assimilation and shortens flowering time through reduced stomatal conductance, decreased leaf water content, and blockages in xylem transport (Sukpitak et al., 2024). A 30% water deficit in Gerbera jamesonii caused a 25% decrease in leaf water content and a 40% decline in net photosynthesis (Wang et al., 2021). Increased ABA and ethylene levels under drought conditions accelerate senescence, shortening the vase life of cut flowers by 2–3 days (Costa et al., 2020). However, compounds such as melatonin, polyamines, and selenium can reduce oxidative stress by maintaining cell membrane integrity and extend vase life by up to 30% (Nguyen et al., 2025).

In terms of pigment biosynthesis, heat stress in Petunia hybrida reduced the expression of anthocyanin biosynthesis genes (CHS, DFR), causing fading in flower color (Mahdavian et al., 2022). Increased UV radiation triggers the accumulation of carotenoids and flavonoids, which alters flower color and pollinator attractiveness (Kisvarga et al., 2023; Polidori et al., 2023).

The antioxidant defense system (SOD, CAT, APX, etc.) plays a central role in limiting oxidative damage under stress conditions (Leotta et al., 2022). However, under extreme stress conditions, ROS accumulation exceeds the defense capacity, accelerating lipid peroxidation and causing permanent damage to the cell membrane (Mahajan et al., 2025). Therefore, maintaining antioxidant levels is an important indicator of stress tolerance (Nguyen et al., 2025).

Biostimulants (e.g., seaweed extracts, humic–fulvic acids, protein hydrolysates, microbial inoculants) and antioxidant/osmoprotectant-based applications can enhance tolerance in ornamental plants by protecting the photosynthetic apparatus under heat and drought, increasing water use efficiency, and maintaining redox balance (Tütüncü et al., 2024). However, standardization of formulation–dose–phenophase parameters and validation under multiple stress scenarios are required for these applications (Tütüncü et al., 2024).

At the urban scale, microclimate management techniques such as shade nets, permeable surfaces, and water harvesting, combined with the selection of heat- and drought-tolerant species and varieties, can increase the resilience of ornamental plants (Monder et al., 2024).

Current literature indicates that studies realistically testing the interaction of multiple stress conditions (heat–drought–eCO_2) in ornamental plants are still insufficient (Mircea et al., 2024). Furthermore, species/variety-based systems biology analyses of post-harvest hormone–micronutrient–hydraulic interactions need to become more widespread (Costa et al., 2020). Long-term experimental monitoring of the UHI–pollinator–phenology triangle in urban landscapes and its integration into management guidelines is also in its early stages (Freimuth et al., 2022; Polidori et al., 2023).

In conclusion, climate change directly affects flowering, pigmentation, water balance, photosynthetic efficiency, and postharvest durability in ornamental plants through multiple interactions of physiological processes. Understanding these effects is crucial for developing new approaches to increase stress tolerance in both production planning and breeding programs Kisvarga et al., 2023; Mircea et al., 2024). The aim of this study is to reveal the current effects of climate change on the physiological processes of ornamental plants in light of the literature and to identify gaps that need to be addressed in future research.

2. Physiological and Biochemical Effects of High Temperature Stress on Ornamental Plants

Climate change is a global process that reshapes the growth environment of plants by disrupting atmospheric composition and terrestrial temperature balance (Mircea et al., 2024).

Ornamental plants are one of the plant groups most sensitive to the effects of this change due to their aesthetic value and high economic returns. Since plants in this group are mostly grown under optimal temperature, humidity, and light conditions, factors such as heat waves, irregular rainfall, increased CO_2 concentration, and microclimate changes rapidly disrupt their physiological balance systems (Razek et al., 2024).

Climate change affects fundamental processes such as photosynthesis, respiration, water transport, pigment formation, phenology, and flower quality, thereby altering the morphological appearance, vase life, and market value of ornamental plants (Kisvarga et al., 2023). Therefore, identifying genotypes that can adapt to climate change and developing management strategies that support stress tolerance is a critical research area for the ornamental plant industry (Leotta et al., 2022).

In regions experiencing more frequent heat waves, a 20–35% reduction in flower count, color fading, and leaf deformations have been observed in species such as Rosa hybrida, Petunia hybrida, and Chrysanthemum morifolium (Mahdavian et al., 2022).

Irregular rainfall and prolonged dry periods cause wilting and leaf drop in ornamental plants, particularly in young tissues, due to water stress, which negatively affects the commercial appearance of the plant (Ahn et al., 2022). Furthermore, although increasing atmospheric CO_2 levels increase photosynthesis rates in the short term, in the long term, they reduce stomatal density, disrupting water relations and negatively affecting the aesthetic leaf texture (Bernauer et al., 2024). Consequently, the fundamental physiological stresses caused by climate change in ornamental plants are not independent of each other but are mostly interactive; this situation increases the importance of future research based on multiple stress scenarios (Mircea et al., 2024).

3. Physiological Mechanisms of High Temperature Stress

High temperature stress is an abiotic stress characterized by the plant's inability to maintain optimal metabolic activity, protein denaturation at the cellular level, disruption of membrane structure, and dysfunction of the photosynthetic apparatus (Mondal et al., 2023). For ornamental plants, this stress causes yield and quality losses, especially during sensitive physiological stages such as the flowering period (Mahajan et al., 2025). High temperature conditions limit ATP production by disrupting electron transport within chloroplasts, reduce carbon assimilation, and lead to increased oxidative stress (Palermo et al., 2025). As a result of these processes, the aesthetic characteristics of the plant, particularly flower color, form, and durability, are negatively affected (Shelake et al., 2024). Therefore, understanding the physiological basis of heat tolerance is of great importance for stress management and the success of breeding programs in ornamental plants (Leotta et al., 2022).

Research has shown that in Chrysanthemum morifolium plants grown at 35–40 °C, PSII activity decreased by up to 30%, resulting in a decrease in chlorophyll fluorescence and a significant loss in net photosynthesis rate (Mahajan et al., 2025). A similar study on Petunia hybrida reported a decrease in the activity of anthocyanin biosynthesis enzymes responsible for pigment

synthesis and a fading of flower color when temperatures reached 38°C (Mahdavian et al., 2022). High temperatures also increase membrane permeability by altering the unsaturated fatty acid ratio in the membrane structure, leading to intracellular ion loss and turgor imbalance (Shelake et al., 2024).

Excessive accumulation of reactive oxygen species (ROS) triggered by heat stress increases oxidative damage and accelerates premature aging when the antioxidant defense system (SOD, CAT, APX) is insufficient (Mondal et al., 2023). These effects result in a shorter flowering period and reduced color intensity in heat-sensitive species such as Rosa chinensis (Kim et al., 2023). Consequently, the effects of heat stress on photosynthetic efficiency, membrane stability, and metabolic energy production are directly related to flower quality and are therefore a priority topic in physiological research on ornamental plants (Leotta et al., 2022).

4. Effects of Drought Stress on Water Relations, Hormonal Balance, and Vase Life

Drought is a type of abiotic stress that occurs when plant water uptake decreases or water loss increases and is one of the most common causes of disruption of physiological homeostasis in ornamental plants (Ahn et al., 2022). Drought conditions lead to stomatal closure, disruption of xylem transport, reduced cell turgor, and decreased carbon assimilation. In ornamental plants, this leads not only to growth losses but also to loss of aesthetic value and shortened vase life (Sukpitak et al., 2024). Furthermore, in response to water stress, the production of stress hormones such as abscisic acid (ABA) and ethylene increases, which accelerates the senescence process and leads to premature senescence of floral tissues (Lee et al., 2020). Therefore, drought is a critical stress factor that creates multifaceted effects on ornamental plants, both physiologically and aesthetically (Nguyen et al., 2025).

A study on Gerbera jamesonii reported that leaf water content decreased by 25% in a 30% water deficit, reducing net photosynthesis by 40% and leading to a significant decrease in flower number (Wang et al., 2021). In Lilium longiflorum, water stress was determined to reduce leaf chlorophyll content, thereby reducing the plant's visual quality and advancing flowering time by 4–5 days (Ahn et al., 2022). In cut flowers, drought, combined with increased ethylene production, shortened vase life by an average of 2–3 days (Sukpitak et al., 2024). Melatonin, polyamine, and selenium supplements applied to mitigate these adverse effects can strengthen antioxidant defenses, reduce membrane damage, and extend vase life (Costa et al., 2020; Nguyen et al., 2025). Consequently, water stress is a fundamental process affecting both production and postharvest quality in ornamental plants, and the interaction between hormonal signaling and water relations is central to this mechanism.

5. Morphological and Photosynthetic Responses to Elevated CO_2 (eCO_2) Conditions

Increases in atmospheric carbon dioxide (CO_2) concentration are considered a global climatic variable that directly affects photosynthetic carbon assimilation in plants (Bernauer et al., 2024). Ornamental plants generally exhibit a sensitive response to eCO_2 conditions because they have a C_3 metabolism; However, this response is variable among both species and genotypes (McClory et al., 2024). Elevated CO_2 can increase leaf chlorophyll content and improve water use efficiency by reducing stomatal conductance; however, yield increases may be limited in the long term due to photosynthetic acclimation and resource constraints (López-Jurado et al., 2025). Therefore, understanding the effects of eCO_2 on morphological quality, pigmentation, and pollinator attraction in ornamental plants is of both physiological and ecological importance (Bernauer et al., 2024).

Controlled atmosphere experiments on Rosa chinensis reported that 800 ppm CO_2 increased plant height and leaf area by 15%, but did not cause significant changes in flower diameter or anthocyanin content (Kim et al., 2023). Similarly, in Pelargonium zonale, CO_2 enrichment increased leaf biomass but reduced flowering time and aesthetic quality (Bernauer et al., 2024). Although photosynthetic rates increased in the first 2 weeks under eCO_2 conditions, carbon saturation was observed after 3–4 weeks due to decreased Rubisco activity and changes in the carbon-hydration balance (McClory et al., 2024). Furthermore, it has been reported that increased CO_2 alters pollen nutrient composition and volatile compound profiles, which may negatively affect pollinator behavior (Bernauer et al., 2024). Consequently, it appears that eCO_2 does not provide a uniform growth advantage in ornamental plants; on the contrary, it creates complex effects on quality, phenology, and pollination dynamics (López-Jurado et al., 2025).

6. Urban Microclimate (UHI) and Phenological Adaptation

The urban heat island (UHI) effect is the local warming caused by urbanization and directly affects the phenological rhythms, physiological balance, and pollinator relationships of ornamental plants (Dzul-Cauich et al., 2025). In city centers, surfaces such as stone, asphalt, and concrete have high thermal capacity; therefore, nighttime temperature drops are limited and the day-night difference is reduced (Fujiwara, 2025). This can result in earlier flowering, increased transpiration, and metabolic acceleration in ornamental plants (Polidori et al., 2023). Plant-pollinator relationships in urban areas also change due to temperature; in particular, pollen production and nectar quality decrease, while pollinator species diversity decreases (Walters et al., 2022). Therefore, microclimate changes affect not only the aesthetic but also the ecological roles of ornamental plants (Woudstra et al., 2024).

Flowering began 10–12 days earlier in Lavandula angustifolia plants grown under UHI conditions, but nectar density decreased by 18% (Dzul-Cauich et al., 2025). In Rosa hybrida, leaf surface temperatures in urban areas were found to be on average 3 °C higher than in rural areas, and this difference resulted in a 20% decrease in photosynthetic efficiency (Fujiwara, 2025). Furthermore, it has been reported that bee and butterfly diversity decreases in urban areas where high temperatures and low humidity combine, reducing pollination success and affecting plant reproductive performance (Polidori et al., 2023). In Salvia splendens, pollinator activity shifts to early morning hours in warm urban areas, which does not coincide with flowering time (Walters et al., 2022). As a result, microclimatic changes caused by urbanization disrupt phenological synchrony in ornamental plants, leading to losses in aesthetic performance and ecosystem services (Woudstra et al., 2024).

7. Quality Parameters, Coloration, and Postharvest Resistance

The economic value of ornamental plants largely depends on quality parameters such as flower number, color intensity, morphological symmetry, and vase life (Mahajan et al., 2025). Abiotic stress conditions related to climate change directly cause losses in these quality indicators (Hosseini et al., 2025). Physiological stresses (heat, drought, salinity) cause problems such as pigment degradation, water loss, leaf deformation, and tissue softening, which limit the commercial appearance and shelf life of ornamental plants (Sukpitak et al., 2024). Therefore, maintaining quality parameters is directly related to stress management in production planning (Costa et al., 2020).

In studies where heat and water stress were applied together in Gerbera jamesonii, flower diameter decreased by 22%, stem length by 18%, and color saturation by 15% (Mahajan et al.,

2025). Drought conditions shortened the vase life of Chrysanthemum morifolium cut flowers by an average of 2 days; melatonin treatment compensated for this loss by 30% (Hosseini et al., 2025). Polyamine supplements reduced the rate of wilting by stabilizing cell membranes and prolonged visual vigor by suppressing ethylene production in flowers (Sukpitak et al., 2024). Selenium supplementation delayed color fading in cut roses by reducing oxidative stress (Costa et al., 2020). These findings indicate that abiotic stresses have strong effects on quality parameters and that biochemical supplements can mitigate these effects (Hosseini et al., 2025).

8. Adaptation, Management, and Future Approaches

Adaptation strategies encompass biological, cultural, and genetic approaches aimed at increasing the resilience of ornamental plants to stress conditions (Leotta et al., 2022). Biostimulants are natural compounds that increase stress tolerance by stimulating plant metabolism (Tütüncü et al., 2024). Furthermore, cultural measures such as shading, irrigation management, increasing soil organic matter, and genotype selection also play an important role (Di Sario et al., 2025). The integration of these approaches is critical for maintaining quality and sustainability, especially in production systems under climate change (Carillo et al., 2025).

Seaweed extracts have been found to increase photosynthetic activity and leaf water content by 25% and 20% in Petunia hybrida under heat and drought conditions, and to extend flowering time by 3 days (Tütüncü et al., 2024). Protein hydrolysates accelerated root development in Rosa hybrida plants, facilitated water uptake, and increased flower number by 18% (Di Sario et al., 2025). Low-dose biostimulant pretreatments using the priming technique doubled antioxidant enzyme activity against heat stress in Gerbera jamesonii (Carillo et al., 2025). Regarding cultural measures, shading nets prevent leaf burns by balancing photosynthetic light saturation, while regular irrigation programs mitigate the effects of drought stress (Leotta et al., 2022). These data suggest that integrating biostimulant-based biotechnological solutions with classical cultural practices is an effective way to manage stress in ornamental plants (Tütüncü et al., 2024).

The current literature indicates that, although significant advances have been made in the study of stress physiology in ornamental plants, the number of studies examining multiple stress combinations is limited (Mircea et al., 2024). The dynamic nature of physiological responses under conditions where factors such as heat, drought, and CO_2 interact simultaneously is still poorly understood. Furthermore, hormone-micronutrient-hydraulic interactions in the postharvest phase need to be addressed holistically using systems biology approaches (Costa et al., 2020). Monitoring the long-term adaptation mechanisms of ornamental plants in urban landscapes, particularly with regard to pollinator adaptation and microclimate tolerance, is an important future research area (Dzul-Cauich et al., 2025). New-generation molecular techniques (e.g., transcriptome analysis, metabolomics) are beginning to be used to uncover the genetic basis of stress tolerance in ornamental plants. However, these studies are largely limited to model species; databases for ornamental plants, which exhibit a wide species diversity, continue to be lacking (Mircea et al., 2024). Within the scope of the future "smart landscape" concept, the goal is to identify stress-tolerant ornamental plant combinations that can moderate urban temperatures, improve air quality, and support pollinator diversity (Woudstra et al., 2024). Furthermore, it is recommended to increase studies on the economic analyses and ecological returns of biostimulant-based sustainable production systems (Leotta et al., 2022). In this context, the future of stress tolerance research in ornamental plants depends on

integrating physiological data with molecular, ecological, and socioeconomic dimensions (Kisvarga et al., 2023).

9. Conclusion and Recommendations

9.1. Conclusion

Climate change is a multidimensional environmental threat that directly affects all processes in the ornamental plant sector, from production to consumption (Mircea et al., 2024). Research conducted in the last five years clearly demonstrates that high temperatures, drought, and elevated atmospheric CO_2 levels, in particular, cause physiological, morphological, and biochemical changes in ornamental plants (Kisvarga et al., 2023). High temperature stress has been associated with decreased photosystem II efficiency, chlorophyll degradation, enzyme inactivation, and increased oxidative stress, resulting in significant declines in flower quality, pigment stability, and visual value (Mahajan et al., 2025).

Drought stress has been found to shorten vase life and reduce postharvest resistance through decreased water potential, stomatal closure, increased abscisic acid (ABA), and ethylene synthesis (Sukpitak et al., 2024). However, while elevated CO_2 levels increase photosynthesis rates in the short term, they cannot sustain yield increases in the long term due to carbon saturation and resource constraints (Bernauer et al., 2024). The urban heat island (UHI) effect causes indirect ecological effects such as early flowering, phenological shifts, and pollinator-plant incompatibilities (Dzul-Cauich et al., 2025). These results reveal that the physiological responses of ornamental plants to environmental stresses vary depending on the species, genotype, and environmental conditions (Leotta et al., 2022). Furthermore, research emphasizes that stress conditions directly affect not only plant growth but also flower color, form, tissue structure, and marketability (Hosseini et al., 2025). To increase the resilience of ornamental plants to climate change, studies at the physiological and molecular levels that evaluate multiple stress factors (heat + drought + CO_2 + microclimate) together are necessary. Overall, the findings indicate that ornamental plants are one of the plant groups sensitive to climate change and that the sustainability of the sector depends on the development of "climate adaptation strategies" (Kisvarga et al., 2023).

9.2. Recommendations

Identification of Heat and Drought Tolerant Genotypes

In breeding studies, standardization of physiological markers (Fv/Fm, stomatal conductance, MDA level) is recommended to identify genotypes resistant to heat and water stress in ornamental plants (Palermo et al., 2025). Identification of tolerance genes, particularly in commercially important species such as Gerbera jamesonii, Chrysanthemum morifolium, and Rosa hybrida, will form the basis of adaptive breeding programs (Mahajan et al., 2025).

Biostimulant-Based Sustainable Management Practices

Applications of seaweed extracts, humic acid, melatonin, and polyamines have been proven to maintain water balance and pigment stability under stress conditions; integration of these compounds into routine production protocols is recommended (Tütüncü et al., 2024; Nguyen et al., 2025). Such practices offer environmentally friendly alternatives to chemical stress reducers (Leotta et al., 2022).

Microclimate Management in Urban Landscapes

To mitigate the urban heat island effect, permeable surfaces, shading systems, and water harvesting structures should be incorporated into landscape planning (Dzul-Cauich et al., 2025). Additionally, it is recommended to choose ornamental species with high pollinator attractiveness, early flowering, and drought resistance (e.g., Lavandula angustifolia, Salvia splendens) (Polidori et al., 2023).

Increasing Postharvest Resistance

Since applications of melatonin, selenium, and natural antioxidants have been shown to extend vase life in cut flowers, the optimal dose ranges of these compounds should be determined and species-specific protocols developed (Hosseini et al., 2025; Costa et al., 2020). Furthermore, the use of antimicrobial solutions combined with temperature and humidity control during storage will be effective in preventing xylem blockage (Nguyen et al., 2025).

Molecular Stress Tolerance Studies

In the future, the identification and functional characterization of stress response genes in ornamental plants should be conducted through RNA-seq, proteomics, and metabolomics approaches. Transferring these data to breeding programs will accelerate the development of ornamental plant varieties resistant to climate change (Kisvarga et al., 2023).

Multiple Stress Scenarios and Long-Term Field Trials

Most studies focus on a single stress factor under controlled conditions; however, in nature, stresses act simultaneously (Mircea et al., 2024). Therefore, long-term open field trials evaluating the effects of multiple stress combinations (heat + drought + CO_2) should be planned.

Sectoral Adaptation and Training

Training programs focused on adaptation to climate change should be organized for ornamental plant producers and landscape planners, and awareness should be raised on stress management, irrigation optimization, and biostimulant use (Leotta et al., 2022).

Field projects developed through university-industry collaborations will facilitate the transfer of theoretical knowledge to practice (Tütüncü et al., 2024).

Climate change-related stress factors in ornamental plants have significant impacts not only at the physiological level but also in terms of production economics, aesthetic quality, and ecological services (Kisvarga et al., 2023). Future ornamental planting will be based on the development of varieties that are "multi-stress tolerant, have high aesthetic values, and require low maintenance" (Leotta et al., 2022). To achieve this goal, the integrated application of biostimulant technologies, smart irrigation systems, and urban microclimate management is necessary (Tütüncü et al., 2024). As a result, when the ornamental plants sector manages the risks brought by climate change correctly, it will be able to move into the future not only as an economic sector but also as a sustainable system that supports the ecological balance (Mircea et al., 2024).

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Ahn, J. et al. (2022). Drought tolerance mechanisms in ornamental plants: A physiological overview. *Horticulture Research*, 9(3), 124–137.

Bernauer, O. M. et al. (2024). Elevated atmospheric CO_2 has species-specific effects on floral traits in ornamentals. *Scientific Reports*, 14(2), 233–244.

Carillo, P., et al. (2025). Priming strategies to improve stress tolerance in ornamental crops. *Plants*, 14(1), 105.

Costa, L. C. et al. (2020). Selenium–ethylene interplay in postharvest life of cut flowers. *Frontiers in Plant Science*, 11, 611148.

Di Sario, F., et al. (2025). Protein hydrolysates enhance root growth and quality in floricultural crops. *Horticulturae*, 11(3), 422.

Dzul-Cauich, J. F., et al. (2025). Urban heat islands alter pollinator diversity and flowering synchrony in ornamentals. *Urban Ecosystems*, 28(1), 175–190.

Freimuth, J., vd. (2022). Climate warming changes synchrony of plants and pollinators. *Proc. Royal Soc. B.*

Fujiwara, S. (2025). Phenological responses of ornamental plants to microclimate warming. *Environmental Research*, 240, 117312.

Hosseini, A. et al. (2025). Melatonin and polyamine effects on vase life of chrysanthemum under drought stress. *Postharvest Biology and Technology*, 213, 112293.

Kim, H., et al. (2023). Responses of rose cultivars to elevated CO_2 and temperature. *Environmental and Experimental Botany*, 214, 105–128.

Kisvarga, S. et al. (2023). Plant responses to global climate change and stress interaction in ornamentals. *Plants*, 12(14), 2783.

Leotta, L. et al. (2022). New strategies to increase abiotic stress tolerance in ornamental crops. *Plants*, 11(19), 2604.

López-Jurado, J., et al. (2025). Carbon assimilation limits in C_3 ornamentals under elevated CO_2. *Physiologia Plantarum*, 172(2), e14512.

Mahajan, S. et al. (2025). Heat stress tolerance in floricultural crops: mechanisms and prospects. *Environmental and Experimental Botany*, 214, 105–118.

Mahdavian, K. et al. (2022). Heat stress effects on pigment stability in Petunia hybrida. Scientia *Horticultura*e, 304, 111284.

McClory, R., et al. (2024). CO_2 enrichment affects flower number transiently in ornamental shrubs. *Journal of Forestry Research*, 35(1), 88–101.

Mircea, D. M. et al. (2024). Abiotic Stress Tolerance and Invasive Potential of Ornamental Plants in Mediterranean Climates. *Agronomy*, 14(3), 577.

Mondal, S. et al. (2023). Crucial plant processes under heat stress and tolerance mechanisms. *Plants*, 12(2), 457.

Monder, M. J., vd. (2024). Directions in Ornamental Herbaceous Plant Selection… *Agriculture*.

Nguyen, P. et al. (2025). Melatonin-mediated improvement of vase life and membrane stability in cut flowers. *Postharvest Biology and Technology*, 212, 112235.

Palermo, D. et al. (2025). Phenotyping framework for assessing heat tolerance in ornamentals. *Horticulturae*, 11(2), 278.

Park, D. J., vd. (2024). Establishment of Efficient Method for Evaluation of Heat-Tolerant Species. *Horticulturae.*

Polidori, C. et al. (2023). Warming up through buildings and roads: UHI and bees. *Frontiers in Bee Science*, 2, 34.

Shelake, R. et al. (2024). Membrane lipid remodeling under heat stress in ornamental crops. *Plant Physiology Reports*, 29(4), 321–333.

Sukpitak, C. et al. (2024). Influence of water deficit on longevity of ethylene-sensitive and insensitive flowers. *Postharvest Biology and Technology*, 206, 112054.

Tütüncü, M., et al. (2024). Plant biostimulants in ornamentals: mechanisms and applications. *Advances in Horticultural Science*, 38(2), 145–162.

Walters, C., et al. (2022). Extreme heat events reduce pollinator abundance and foraging in urban environments. *Global Change Biology*, 28(12), 3761–3774.

Wang, L. et al. (2021). Physiological performance of Gerbera jamesonii under drought stress. *Horticultural Science*, 56(4), 245–254.

Woudstra, E., et al. (2024). Local adaptation of ornamental species across urban temperature gradients. *Landscape and Urban Planning*, 246, 104857.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Local Implementation Challenges of Sustainable Campus Certification Systems: A Critical Analysis in the Context of Türkiye

Ertan Düzgüneş [1]

ORCID 1: 0000-0002-1523-9722
[1]Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
ertan.duzgunes@ktu.edu.tr

Beyzanur AKKUŞ [2*]

ORCID 2: 0009-0001-9505-1323
[2]MSc Student, Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
byznur.akkus.50@gmail.com **(**Responsible Author)

Abstract

In recent years, universities have increasingly been regarded as pioneering actors in the effective implementation of sustainability policies at the local scale. Campus settlements, often perceived as micro-models of cities, are evaluated through comprehensive certification systems encompassing environmental, economic, social, and governance dimensions. International frameworks such as GreenMetric, STARS, AISHE, ISCN, and GULF enable the global comparability of universities' sustainability performance by employing multidimensional criteria, including energy efficiency, waste management, water conservation, carbon footprint reduction, green mobility, and community engagement. However, the local application of these certification systems presents a range of structural and administrative challenges, particularly in developing countries. This study critically examines the local adaptability issues of campus sustainability certification systems within the context of Türkiye, focusing on governance capacity gaps, financial constraints, data collection and monitoring difficulties, and the influence of institutional culture. Based on the analysis of exemplary campus practices in Türkiye and the existing legal framework, the evaluation reveals that the limited compatibility of international indicators with local conditions, inter-university heterogeneity, and insufficient stakeholder participation in decision-making processes restrict the overall success of such initiatives. The findings demonstrate that enhancing the effectiveness of campus sustainability certifications in Türkiye requires revising indicators with contextual flexibility, strengthening institutional capacity, and fostering multi-stakeholder governance models. By offering strategic recommendations to local governments, university administrations, and policymakers, this study provides a critical and solution-oriented contribution to the literature on the expansion of sustainable campus practices in Türkiye.

Keywords: GreenMetric, GULF, ISCN, STARS, sustainable campus

1. Introduction

In recent years, the growing global environmental challenges have brought the sustainable management of natural resources and the importance of climate change adaptation policies to the forefront more than ever before. In this context, higher education institutions have evolved from being mere venues for education and research activities into key actors in implementing sustainable development goals at the local scale. University campuses, as small-scale models of urban systems, serve as practical grounds for multidimensional sustainability practices, including energy use, transportation, water management, waste recycling, ecological landscape design, and social awareness initiatives.

Within this framework, international assessment systems such as **UI GreenMetric, STARS, AISHE, ISCN,** and **GULF** have been developed to evaluate the sustainability performance of

universities based on specific indicators, make institutions comparable, and encourage continuous improvement processes. However, since the evaluation criteria of these systems are mostly based on global standards, their direct application in countries with different socio-economic conditions and administrative structures poses various challenges (Kömürlü et al., 2014; Yılmaz & Balyemez, 2020; Özdemir et al., 2022). In particular, in developing countries, **limited financial resources** (Alshuwaikhat et al., 2017; Silva-Da-Nóbrega et al., 2022), **institutional capacity deficiencies** (Dawodu et al., 2023), **constraints in data collection and monitoring processes,** and **lack of stakeholder participation** make it difficult to effectively implement sustainable campus certification systems.

In **Türkiye**, the concept of a sustainable campus has gained increasing importance in recent years, driven by rising environmental awareness and the strengthening emphasis on sustainability within national development strategies. However, existing practices indicate that the indicators of international systems do not fully align with local conditions, and that deficiencies in legislation and administrative infrastructure limit progress. Therefore, discussing the **local adaptability** of sustainable campus certification systems within the Turkish context has become a critical necessity.

This study critically examines the applicability of international sustainable campus certification systems in Türkiye, identifying key challenges from **administrative, economic, environmental, and social perspectives,** and develops **strategic recommendations** to overcome these issues. In doing so, the study proposes a **theoretical and practical framework** that contributes to the localization process of international systems and supports the transformation toward sustainable universities.

2. Sustaınabılıty Assessment Systems

Various assessment systems have been developed worldwide to measure, compare, and improve the sustainability levels of universities. These systems evaluate the environmental, economic, social, and managerial performance of campuses through specific indicators, enabling the institutional monitoring of sustainability goals. The major international systems are explained below.

2.1. UI GreenMetric World University Ranking

Developed by the University of Indonesia in 2010, UI GreenMetric is one of the most widely used sustainability assessment systems globally. It evaluates universities under six main categories (GreenMetric, 2025) (Table 1):

Table 1. UI GreenMetric main categories

No	Main Parameter	%	No	Main Parameter	%
1	Infrastructure	15	4	Water	10
2	Energy and Climate Change	21	5	Transportation	18
No	Main Parameter	%	No	Main Parameter	%
3	Waste	18	6	Education and Research	18
Total	100				

The system operates on an online self-reporting mechanism, where institutions enter data and receive weighted scores for each category. One of GreenMetric's strongest aspects is its ability

to evaluate universities of different scales under a single framework. However, the self-reporting nature of data collection has been criticized for issues of data reliability and comparability (Yusof & Bakar, 2012). Although many Turkish universities participate in this system, the lack of full alignment between the indicators and local climate, infrastructure, and regulatory conditions limits the interpretability of the evaluation results.

2.2. Sustainability Tracking, Assessment & Rating System (STARS)

STARS, developed by the Association for the Advancement of Sustainability in Higher Education (AASHE) in the United States, is a comprehensive framework widely used by universities and colleges around the world. It comprises three main categories—environmental, social, and economic performance—further divided into 17 subcategories and 67 indicators (Table 2) (STARS, 2025).

Table 2. STARS parameter

No	Parameter	Sub-Parameter	Points
1	Academics	Curriculum	45
		Research	23
2	Engagement	Campus Engagement	25
		Public Engagement	25
3	Operations	Buildings & Grounds	20
		Energy & Climate	26
		Dining	10
		Purchasing & Waste	20
		Transportation	10
4	Planning & Administration	Coordination & Planning	11
		Investment	10
		Diversity & Equity	14
		Well-being & Work	11
5	Innovation & Leadership	Innovation & Leadership	10

STARS employs a scoring and rating system, assigning institutions a Bronze, Silver, Gold, or Platinum level. The framework supports transparent reporting and self-assessment, allowing institutions to track their progress over time (AASHE, 2024). However, its comprehensive set of indicators requires professional sustainability offices and specialized personnel, making implementation challenging for developing countries. In Türkiye, only a few universities have adopted STARS, mainly due to limited institutional capacity and financial constraints.

2.3. Auditing Instrument for Sustainability in Higher Education (AISHE)

AISHE, developed in the Netherlands, is an assessment tool that analyzes the sustainability maturity level of higher education institutions through five key parameters (AISHE, 2024):

1.vision and policy

2.expertise

3.educational goals and methods

4.educational content

5.evaluation of results

The most distinctive feature of AISHE is its participatory self-assessment model, in which diverse internal stakeholders academic staff, students, and administrative personnel contribute to determining the institution's sustainability maturity (Caeiro et al., 2020). This participatory approach promotes institutional learning and internal transformation (Roorda, 2010). However, the qualitative nature of the indicators limits comparability across different countries. In the Turkish context, AISHE holds strong potential for enhancing managerial awareness and strengthening stakeholder participation in sustainability practices.

2.4. International Sustainable Campus Network (ISCN)

Founded in 2007, the ISCN is a global network that promotes knowledge exchange and dissemination of best practices in sustainable campus management. Rather than serving as a certification system, ISCN operates as a voluntary membership-based framework built on commitment and reporting principles. Member institutions pledge to uphold three core principles: Development of sustainable campus infrastructure, resource efficiency and reduction of environmental impacts, integration of education, research, and societal impact.

Although ISCN does not provide formal scoring or ranking, it functions as a valuable platform for communication and collaboration among universities (ISCN, 2023). Membership from Türkiye remains limited, yet participation in the network enhances the international visibility of universities and allows them to share sustainability strategies on a global scale.

2.5. Global University Leaders Forum (GULF)

The Global University Leaders Forum (GULF) operates under the World Economic Forum, bringing together the leaders of the world's top universities. It aims to promote collaboration in global education and research, develop innovative solutions, and shape the future of higher education. Through this platform, university presidents and rectors address common challenges and share best practices.

GULF members focus on key global issues influencing education and research policy, including digital transformation, sustainability, social responsibility, and innovation (GULF, 2024). The forum leverages members' experiences and expertise to develop strategic guidance and policies in these domains (Wiseman et al., 2016; Al-Ahdal et al., 2021; Raettig & Muth, 2021). Furthermore, by sharing their visions for the future of higher education, GULF members aim to foster more flexible, inclusive, and innovative educational and research ecosystems.

Sustainable campus certification systems are holistic evaluation tools designed to measure the environmental, social, and managerial performance of universities. Although these systems are implemented across diverse geographical and institutional contexts, they share a common monitoring framework based on the three fundamental pillars of sustainability. Each system differs in its scope, methodological approach, and indicator weighting.

In this regard, international systems such as GreenMetric, STARS, AISHE, ISCN, and GULF address the social, managerial, and environmental dimensions of sustainability at varying levels (Bullock & Wilder, 2016; Puertas, &Marti, 2019; Düzgüneş et al., 2024). Provides a

comparative summary of these systems, outlining their approaches, strengths, and limitations across each sustainability dimension (Table 3).

Table 3. Social, managerial, and environmental dimensions

SOCIAL DIMENSION	**STARS**	One of the most comprehensive systems addressing social sustainability. It evaluates the integration of sustainability awareness into the curriculum through education and research indicators, and assesses social responsibility activities via criteria on community impact, student engagement, and stakeholder participation (Puertas, &Marti, 2019).	Social sustainability indicators are largely qualitative. The influence of cultural and local values is reflected to a limited extent.
	AISHE	Defines social sustainability through internal stakeholder participation. The evaluation process is carried out with the active involvement of academic staff, students, and administrative personnel (Berzosa et al., 2017).	Contributes to increased institutional awareness and the internalization of a sustainability culture.
	ISCN	Addresses the social dimension through experience sharing, networking, and dissemination of best practices (Aregarot et al., 2024).	Strengthens inter-university interaction and supports social learning.
	GreenMetric	Includes limited social indicators; community engagement is indirectly evaluated under the "Education and Research" category (Caeiro, et al., 2020; Aregarot et al., 2024).	Addresses social sustainability indirectly; the overall scope is limited.
	GULF	Associates community engagement with the dissemination of sustainability awareness and community service activities.	Promotes a regionally grounded approach to social responsibility.

MANAGERIAL DIMENSION	**STARS**	Evaluates managerial capacity through indicators such as institutional planning, management policies, and the presence of sustainability offices. The inclusion of a sustainability vision in strategic plans is emphasized(Bullock & Wilder, 2016).	Supports the institutionalization of management policies, though implementation levels vary across institutions.
	AISHE	Approaches the managerial dimension from an "institutional learning" perspective, emphasizing the institution's capacity to monitor its own sustainability progress and continuously improve (Caeiro, et al., 2020).	Encourages a culture of continuous development.
	GreenMetric	Assesses managerial sustainability based on the presence of policies and institutional declarations. Implementation processes are only partially measured (Caeiro, et al., 2020).	Transparency and monitoring are weak; focuses primarily on policy statements.
	ISCN	Operates on a "commitment-based" model in which members pledge to adhere to sustainability principles and submit progress reports.	Strengthens institutional accountability and a culture of monitoring.
	GULF	Evaluates managerial structure through a performance-based, recognition-oriented model that provides feedback based on achievement(Düzgüneş et al., 2024).	Enhances institutional motivation but may weaken continuous monitoring mechanisms.
ENVIRONMENTAL DIMENSION	**STARS**	Places the strongest emphasis on environmental criteria, including energy efficiency, water use, waste management, carbon emissions, and green space planning.	A quantitative system directly scoring environmental performance based on measurable indicators.
	AISHE	Links environmental performance with operational processes, emphasizing energy consumption, greenhouse gas emissions, and green building indicators (Doocy et al., 2021).	Provides detailed operational analysis and monitors environmental sustainability through concrete data.
	GreenMetric	Evaluates environmental sustainability not through direct measurement but through the level of integration into institutional policies and strategies.	Determines the institution's level of environmental maturity through a policy-based approach.
	ISCN	Monitors environmental indicators within a framework of commitment and reporting, emphasizing experience sharing among stakeholders.	Encourages the exchange of best practices and the dissemination of successful implementation examples.
	GULF	Prioritizes water and energy efficiency as key indicators, adapted to regional climatic conditions (Düzgüneş et al., 2024).	Offers an adaptive model tailored to local environmental contexts.

3. Implementation Challenges of Evaluation Systems in the Turkish Context

In the process of implementing international sustainable campus evaluation systems (such as GreenMetric, STARS, AISHE, and ISCN) in Türkiye, various environmental, administrative,

economic, and social challenges emerge (Özcan, 2023). These challenges are closely related to the existing institutional capacities, governance structures, financial resources, and legal frameworks of universities. Furthermore, the fact that the concept of sustainability has not yet evolved into a comprehensive institutional culture within Turkish higher education institutions limits the effectiveness of implementation efforts. Within this framework, implementation challenges can be analyzed under four main dimensions: administrative, economic, social, and environmental.

3.1. Administrative Challenges

Sustainability offices or environmental coordination units at Turkish universities have generally been established within the last decade and are still in the process of institutional development (Aksoy et al., 2024). Most of these units remain limited to symbolic or project-based activities, rather than functioning as strategic bodies directly linked to top management. To make sustainability an integral part of institutional identity, these units must work in an integrated manner—not only on environmental issues but also across education, research, and community engagement dimensions (Filho et al., 2020; 2023).

Although sustainability goals are included in the strategic plans of many universities, implementation, monitoring, and performance evaluation mechanisms are not yet systematic. This poses a significant barrier to the adoption of complex certification models such as STARS or AISHE, which require detailed reporting and institutional coordination (Son-Turan & Lambrechts, 2019). Moreover, knowledge sharing and institutional learning processes among universities remain weak (Mohammadi et al., 2023). Thus, clarifying the authority and responsibilities of sustainability units, defining data management roles institution-wide, and ensuring that sustainability objectives are endorsed at the rectorate level are of critical importance.

3.2. Economic Challenges

Most international evaluation systems require membership fees, reporting costs, and specialized personnel for monitoring and data management. Since public universities in Türkiye are largely dependent on central government budgets, the financial resources allocated to sustainability projects are limited (Son Turan & Lambrechts, 2019; Fındık & Erçetin, 2023; Eskinat &Teker, 2024)). In detailed systems such as STARS, the costs extend beyond participation fees to include data collection, consultancy, training, energy efficiency investments, and carbon footprint assessments, all of which demand substantial funding.

Although GreenMetric, being free of charge, offers a more accessible alternative, it also requires long-term investment in infrastructure improvement, renewable energy projects, and water management to yield tangible results. However, sustainability budgets often remain secondary to other institutional priorities, with short-term economic constraints outweighing long-term environmental benefits (Haessler, 2020; Tao et al., 2021). Therefore, sustainability financing should be transformed from project-based funding into a permanent budgetary component within institutional structures.

3.2.1. Data Collection and Monitoring Challenges

International assessment systems are fundamentally based on data-driven decision-making mechanisms. Continuous data production and reporting on energy consumption, water use, waste management, carbon emissions, transportation modes, and social indicators are critical

for the credibility of such systems. However, in Turkish universities, the systematic collection, storage, and analysis of such data are not yet institutionalized (Dawodu et al., 2022).

In most institutions, data collection is carried out fragmentedly across different departments, lacking a standardized monitoring system. This makes the implementation of data-intensive systems such as STARS or AISHE difficult. Additionally, the absence of data verification processes reduces the reliability of indicators (Dizdaroğlu, 2017; Uçar & Özdemir, 2022; Gudmundsdottir & Sigurjonsson 2024). Limited personnel responsible for environmental data management, technological infrastructure deficiencies, and the lack of measurement equipment further exacerbate these challenges. Therefore, it is essential to strengthen data management infrastructure, establish digital monitoring platforms, and develop standardized reporting protocols for effective sustainable campus practices (Boiral & Heras-Saizarbitoria, 2020).

3.2.2. Stakeholder Participation and Institutional Culture

The sustainable campus approach derives its meaning not only from physical environmental improvements but also from the transformation of behaviors and values within the university community (Özcan, 2023). In Türkiye, however, sustainability is often viewed primarily as a technical or environmental issue, while dimensions such as social justice, participation, and governance remain secondary (Son Turan & Lambrechts, 2019; Bulut, 2021; Agboola , 2025). Participation in sustainability initiatives by student organizations, academic staff, and administrative personnel is typically limited.

This poses a challenge for implementing stakeholder-based systems like AISHE and STARS, which emphasize participatory governance, democratization of decision-making, and awareness-building. The weak participatory culture in Türkiye can be attributed to strong institutional hierarchies, centralized decision-making, and the limited presence of sustainability education in curricula (Çalışkan & Zhu, 2019; 2020). Therefore, sustainability offices should evolve beyond purely technical roles to become engagement-oriented units that organize awareness programs, support student-led projects, and foster campus-wide involvement (Sulkun & Bengü, 2024).

3.2.3. Local Legislation and Compliance Issues

International evaluation systems are typically designed based on the legal, technical, and managerial standards of European or North American contexts. Consequently, they do not fully align with Turkish environmental regulations, energy policies, zoning codes, and campus planning standards. For instance, criteria for energy efficiency or methods for calculating carbon footprints often differ from Türkiye's national reporting standards.

Moreover, universities in Türkiye generally have limited autonomy regarding land ownership, building management, and budgeting, which can create legal barriers to sustainability investments (Abo-Khalil, 2024). The absence of national sustainable campus standards further limits institutional comparability (Katayama et al., 2018). Therefore, it is essential to develop a national evaluation model that reflects Türkiye's unique conditions while maintaining compatibility with international systems. Such a model would both preserve global recognition and make local sustainability performance measurable within national constraints.

3.3. Social Challenges

The concept of a sustainable campus extends beyond environmental and economic indicators to include social dimensions such as awareness, participation, equity, and quality of life (De

Aguiar & Paterson, 2018; Noaime et al., 2025; Tafese & Kopp, 2025). However, the social aspect of sustainability in Turkish universities often remains underdeveloped, hindering the evolution of a holistic sustainability approach. Among students, academics, and administrative staff, sustainability awareness is generally low and frequently perceived narrowly as environmental consciousness (Demir & Kaya, 2021). This limits behavioral changes related to energy conservation, waste management, mobility choices, and social responsibility initiatives on campuses.

Furthermore, key components of social Sustainability such as inclusivity and accessibility are not always prioritized in campus planning. Although indicators like accessibility for individuals with disabilities, gender equality, and student participation in decision-making are central to international systems, Turkish universities have not yet achieved standardized practices in these areas. To institutionalize a sustainable campus culture, universities must adopt a vision that reinforces social justice, volunteerism, ethical values, and community responsibility, alongside environmental investments (Wolff & Ehrström, 2020).

The limited number of student-led sustainability clubs, the lack of continuity in awareness campaigns, and restricted student representation in governance processes also highlight social sustainability deficiencies. Therefore, it is crucial to develop social sustainability indicators, provide funding for student-based initiatives, and encourage participatory governance models within universities. Through such efforts, sustainability can be embraced not merely as an environmental goal but as a comprehensive human-centered transformation process.

3.4. Environmental Challenges

Environmental sustainability is directly related to natural resource use, ecological balance, and carbon footprint within campus settings (Son Turan & Lambrechts, 2019; Amaral et al., 2020). Although many Turkish universities have undertaken initiatives to enhance their environmental performance, these efforts often remain project-based, short-term, and limited in scale (Özcan, 2023). The lack of integrated strategic approaches in key areas such as energy efficiency, renewable energy adoption, water recovery, waste management, and biodiversity conservation is a major concern (Yılmaz & Ersöz, 2023).

Many campuses lack monitoring systems for energy consumption, water use, and waste generation, and data collection is not conducted regularly. Aging building stocks often exhibit low energy efficiency, and the integration of renewable energy infrastructure remains limited. Furthermore, ecological sensitivity is not consistently considered in campus planning practices, leading to habitat fragmentation, increased surface runoff, and loss of green space functions especially on large campuses.

Due to Türkiye's diverse climatic regions, environmental priorities and challenges vary significantly among universities, complicating the development of standardized sustainability criteria (Özdemir et al., 2020; Aksoy et al., 2024).

For instance, water management is a critical issue in arid regions, while drainage and erosion pose challenges in the Black Sea region. This diversity makes it difficult to adapt fixed indicators of international systems to local realities. Therefore, achieving effective environmental sustainability requires the development of regionally adaptive strategies based on nature-based solutions and long-term resource management plans sensitive to local climate conditions.

4. Conclusion and Recommendations

Today, universities are regarded not only as institutions of education and research but also as key actors in the local implementation of sustainable development goals. In this context, sustainable campus evaluation systems serve as crucial tools for objectively measuring institutional environmental performance, assessing social responsibility, and fostering a culture of sustainability-oriented decision-making within governance structures.

The systems examined in this stud GreenMetric, STARS, AISHE, ISCN, and GUL differ in terms of scope, evaluation methodology, and indicator weighting. However, all share a common goal: to promote a holistic approach to sustainability in higher education institutions. The comparative analysis revealed that:

GreenMetric prioritizes environmental performance, STARS emphasizes social and administrative processes, AISHE focuses on stakeholder participation and institutional learning, ISCN highlights international collaboration and knowledge exchange, and GULF centers on regional conditions and resource efficiency.

These diverse perspectives across social, environmental, and managerial dimensions reflect the multi-layered nature of sustainability. However, within the Turkish context, the effectiveness of implementation is constrained by factors such as limited administrative capacity, insufficient data infrastructure, financial constraints, and regulatory incompatibilities.

In Turkish universities, sustainability policies are predominantly formulated at the strategic planning level, yet systematic mechanisms for implementation and monitoring remain underdeveloped. Although strategic documents often include goals and vision statements related to sustainability, their translation into concrete action plans, measurable performance indicators, and regular reporting processes is limited. Consequently, sustainability policies often remain symbolic rather than institutionalized.

Moreover, both internationally and in Türkiye, social and administrative indicators tend to receive less emphasis compared to environmental indicators. While areas such as energy efficiency, waste management, and carbon footprint dominate assessment frameworks, indicators of social justice, stakeholder participation, and governance transparency are frequently undervalued. This imbalance narrows the understanding of sustainability to an environmentally centered paradigm, thereby underrepresenting its holistic essence.

Since international sustainable campus systems are largely designed based on the economic structures, data infrastructures, and regulatory frameworks of developed countries, their direct application in Türkiye is not always feasible. In cases where energy and carbon data are not regularly collected, financial resources are limited, or legislative frameworks differ, the evaluation criteria of these systems cannot be fully met. Therefore, adapting indicators to local conditions and redefining them with contextual flexibility is essential.

Stakeholder engagement and sustainability awareness are critical for embedding a sustainability culture within campuses. However, in many Turkish universities, the participation of students, academic staff, and administrative personnel in sustainability initiatives remains limited. For sustainability to become permanent, efforts must extend beyond physical infrastructure investments to include the development of community awareness. In this regard, awareness programs, student clubs, collaborative projects, and volunteer-based activities play a vital role in transforming campus life through a sustainability lens.

Development of a National Sustainable Campus Evaluation Model; A nationally adaptable sustainable campus evaluation model should be developed by considering the diverse socio-economic, geographical, and climatic characteristics of Turkish universities. While the strengths and criteria of international systems should be taken as references, indicators must be redefined in alignment with local data sources, legal frameworks, and cultural dynamics. This model should aim to measure sustainability performance equitably and comparatively across universities, providing flexibility for different climatic regions and institutional scales within Türkiye.

Strengthening Institutional Capacity and Governance Mechanisms; To effectively implement sustainability initiatives, universities must enhance their institutional capacity. In this context, sustainability units should be legally recognized, supported with adequate budgets and qualified personnel, and integrated directly into strategic planning, budgeting, and decision-making mechanisms. Such integration will ensure that sustainability becomes a permanent component of institutional governance structures.

Digitalization of Data Management and Monitoring Systems; For sustainability performance to be measurable and traceable, data on key indicators such as energy, water, waste, and carbon—must be collected regularly in digital environments. Accordingly, centralized digital monitoring infrastructures that enable data sharing among universities should be established. Aligning these systems with international reporting standards will enhance transparency and facilitate comparative evaluation of institutional sustainability performance.

Expanding Education and Awareness Programs; The establishment of a sustainable campus culture depends not only on physical and technical investments but also on education-based awareness enhancement. Therefore, sustainability education should be integrated as a mandatory course or module across all faculties. Moreover, workshops, seminars, and field practices should be organized for students, academics, and administrative staff to promote participatory learning environments. In this way, sustainability awareness can be disseminated throughout all levels of the university community.

Enhancing Stakeholder Participation; The success of university sustainability policies depends not only on internal institutional efforts but also on collaborations with external stakeholders. Therefore, university administrations should establish multi-stakeholder governance structures involving local governments, non-governmental organizations, and private sector representatives. Through joint projects, grant-supported initiatives, and social responsibility programs, sustainability practices can be strengthened locally while enhancing public awareness and community engagement.

Promoting Localized Applications of Certification Systems; International certification systems such as GreenMetric, STARS, and AISHE should be implemented comparatively in Turkish universities, and the results should be evaluated at the national level. Such implementations would allow institutions to monitor their performance, share best practices, and foster continuous learning and improvement through a national reporting and evaluation network.

In this context, the TÜBİTAK 1002 project (Project No: 123Y075) titled “A New Certification System Proposal for Sustainable Campus Planning: The Campus Sustainability Scorecard (KASK)” was developed to address these challenges and to design a national certification system tailored to Turkish universities.

Unlike existing systems, KASK introduces a distinct administrative dimension alongside environmental, economic, and social components. The model includes:

8 main and 58 sub-indicators under the environmental dimension, 4 main and 14 sub-indicators under the economic dimension, 7 main and 41 sub-indicators under the social dimension, and 6 main and 34 sub-indicators under the administrative dimension.

The selection of indicators was carried out through consultation with a panel of 15 experts representing various professional fields including environment, natural resource management, ecology, sociology, economics, public administration, environmental law, sustainability, and planning as well as personnel from university sustainability units involved in prior system evaluations. The indicators were then weighted using the Analytic Hierarchy Process (AHP) technique.

A pilot implementation of the KASK model was conducted at Karadeniz Technical University (Kanuni Campus) to assess its applicability. The results confirmed the model's operational validity. Both the KASK framework and the outcomes of this pilot study will be presented in a forthcoming academic publication.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. Or Ethics Committee approval in the study.

In this section, project support and acknowledgment statements, conflict statements, studies that require an Ethics Committee Decision, etc. should be specified. All authors contributed equally to the article.

References

AASHE. (2024). *STARS Technical Manual: Version 3.0.* Association for the Advancement of Sustainability in Higher Education.

Abo-Khalil, A. (2024). Integrating sustainability into higher education challenges and opportunities worldwide. *Heliyon, 10.* https://doi.org/10.1016/j.heliyon.2024.e29946

Agboola, O., Nia, H., Alsharif, A., & Arapoğlu, M. (2025). Strengthening urban sustainability through higher education: A strategic framework for student-centered initiatives at Istanbul Gelisim University. *Proceedings of the International Contemporary Architecture and Urbanism Conference (ICCAUA).* https://doi.org/10.38027/iccaua2025en0408

Aksoy, O., Demir, S., Ersoz, N., & Gokkaya, M. (2024). Evaluation of an effective quantitative model using a multi-criteria decision-making method for sustainable campuses. *Environmental Science and Pollution Research International, 31,* 13230–13245. https://doi.org/10.1007/s11356-024-32040-7

Al-Naimi, S. (2021). Regional frameworks for sustainable university assessment in the Gulf. *Journal of Environmental Sustainability*, *14*(3), 112–124.

Alshuwaikhat, H., Abubakar, I., Aina, Y., Adenle, Y., & Umair, M. (2017). Development of a GIS-based model for campus environmental sustainability assessment. *Sustainability, 9*(3), 439. https://doi.org/10.3390/su9030439

Amaral, A., Rodrigues, E., Gaspar, A., & Gomes, Á. (2020). An empirical analysis of sustainability initiatives in university campus operations. *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2019.119558

Aregarot, P., Kubaha, K., & Chiarakorn, S. (2024). A study on sustainability concepts for developing green universities in Thailand. *Sustainability.* https://doi.org/10.3390/su16072892

Berzosa, Á., Bernaldo, M., & Fernández-Sánchez, G. (2017). Sustainability assessment tools for higher education: Empirical comparative analysis. *Journal of Cleaner Production, 161,* 812–820. https://doi.org/10.1016/j.jclepro.2017.05.194

Boiral, O., & Heras-Saizarbitoria, I. (2020). Sustainability assurance: Creating stakeholder accountability through hyperreality? *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2019.118596

Boiocchi, R., Ragazzi, M., Torretta, V., & Rada, E. (2023). Critical analysis of the GreenMetric world university ranking system: The issue of comparability. *Sustainability.* https://doi.org/10.3390/su15021343

Bullock, G., & Wilder, N. (2016). The comprehensiveness of competitive higher education sustainability assessments. *International Journal of Sustainability in Higher Education, 17,* 282–304. https://doi.org/10.1108/ijshe-05-2014-0078

Bulut, M. (2021). Building a sustainable university campus in Türkiye: The case of Istanbul Sabahattin Zaim University. *Journal of Sustainability Perspectives.* https://doi.org/10.14710/jsp.2021.12013

Caeiro, S., Hamón, L., Martins, R., & Aldaz, C. (2020). Sustainability assessment and comparison in higher education institutions: A critical reflection. *Sustainability, 12,* 543. https://doi.org/10.3390/su12020543

Çalışkan, A., & Zhu, C. (2019). Organizational culture type in Turkish universities using OCAI: Students' perceptions. *Journal of Education Culture and Society.* https://doi.org/10.15503/jecs20192.270.292

Çalışkan, A., & Zhu, C. (2020). Organizational culture and educational innovation in Turkish higher education: Students' perceptions and responses. *Educational Sciences: Theory & Practice.* https://doi.org/10.12738/jestp.2020.1.003

Dawodu, A., Dai, H., Zou, T., Zhou, H., Lian, W., Oladejo, J., & Osebor, F. (2022). Campus sustainability research: Indicators and dimensions to consider for the design and assessment of a sustainable campus. *Heliyon, 8.* https://doi.org/10.1016/j.heliyon.2022.e11864

Dawodu, A., Guo, C., Zou, T., Osebor, F., Tang, J., Liu, C., Wu, C., & Oladejo, J. (2023). Developing an integrated participatory methodological framework for campus sustainability assessment tools (CSAT): A case study of a Sino-foreign university in China. *Progress in Planning.* https://doi.org/10.1016/j.progress.2023.100827

De Aguiar, T., & Paterson, A. (2018). Sustainability on campus: Knowledge production through social and environmental reporting. *Studies in Higher Education, 43,* 1882–1894. https://doi.org/10.1080/03075079.2017.1289506

Dizdaroglu, D. (2017). The role of indicator-based sustainability assessment in policy and decision-making: A review and outlook. *Sustainability, 9,* 1018. https://doi.org/10.3390/su9061018

Doocy, L., Zarmehr, A., & Kider, J. (2021). A critical review of the STARS framework for campus sustainability evaluation. *Proceedings of the Building Simulation Conference.* https://doi.org/10.26868/25222708.2021.31030

Düzgüneş, E., Akkuş, B., & Kurt Konakoğlu, S. S. (2024). Qualitative comparison of sustainable campus evaluation criteria. In *Architectural Sciences and Sustainable Approaches: University Campuses* (pp. 171–211). İKSAD Publishing. ISBN: 978-625-367-861-6.

Efe, O., Özdemir, R., Işık, S., Durmuş, İ., & Ünver, Ü. (2022). Evaluation of Yalova University Faculty of Engineering building using the BEST green building certification system. *International Journal of Sustainable Energy, 41,* 1759–1777. https://doi.org/10.1080/14786451.2022.2109027

Eskinat, A., & Teker, S. (2024). Financial sustainability of the higher education system. *Pressacademia.* https://doi.org/10.17261/pressacademia.2023.1854

Filho, L. W., Abubakar, I., Mifsud, M., Eustachio, J., Albrecht, C., Dinis, M., Borsari, B., Sharifi, A., Levesque, V., Ribeiro, P., LeVasseur, T., Pace, P., Trevisan, L., & Dibbern, T. (2023). Governance in the implementation of the UN sustainable development goals in higher education: Global trends. *Environment, Development and Sustainability,* 1–24. https://doi.org/10.1007/s10668-023-03278-x

Filho, L. W., Eustachio, J., Caldana, A., Will, M., Salvia, A., Rampasso, I., Anholon, R., Platje, J., & Kovaleva, M. (2020). Sustainability leadership in higher education institutions: An overview of challenges. *Sustainability.* https://doi.org/10.3390/su12093761

Filho, L. W., Sálvia, A., Frankenberger, F., Akib, N., Sen, S., Sivapalan, S., Novo-Corti, I., Venkatesan, M., & Emblen-Perry, K. (2020). Governance and sustainable development in higher education institutions. *Environment, Development and Sustainability, 23,* 6002–6020. https://doi.org/10.1007/s10668-020-00859-y

Fındık, L., & Erçetin, Ş. (2023). How do universities in Türkiye integrate the Sustainable Development Goals into their strategies? *Sustainability.* https://doi.org/10.3390/su152416799

Gholami, H., Bachok, M., Saman, M., Štreimikienė, D., Sharif, S., & Zakuan, N. (2020). An ISM approach for barrier analysis in the implementation of green campus operations. *Sustainability.* https://doi.org/10.3390/su12010363

Gudmundsdottir, S., & Sigurjonsson, T. (2024). The need for standardized approaches to manage sustainability strategically. *Sustainability.* https://doi.org/10.3390/su16062319

Haessler, P. (2020). Strategic decisions between short-term profit and sustainability. *Administrative Sciences.* https://doi.org/10.3390/admsci10030063

ISCN. (2023). *ISCN Charter and Annual Report.* International Sustainable Campus Network.

Katayama, J., Örnektekin, S., & Demir, S. (2018). Implementation of policies related to education for sustainable development in Turkish higher education. *Environmental Education Research, 24,* 1017–1030. https://doi.org/10.1080/13504622.2017.1360843

Kömürlü, R., Arditi, D., & Gurgun, A. (2014). Applicability of LEED energy and atmosphere category in three developing countries. *Energy and Buildings, 84,* 690–697. https://doi.org/10.1016/j.enbuild.2014.07.095

Mohammadi, Y., Monavvarifard, F., Salehi, L., Movahedi, R., Karimi, S., & Liobikienė, G. (2023). Explaining universities' sustainability through students' pro-environmental behaviors and management system contributions. *Sustainability.* https://doi.org/10.3390/su15021562

Noaime, E., Alshenaifi, M., Albaqawy, G., Abuhussain, M., Abdelhafez, M., & Alnaim, M. (2025). Beyond buildings: How sustainable campus design shapes student lives? *Buildings.* https://doi.org/10.3390/buildings15091468

Özcan, K. (2023). Ranking Turkish universities in sustainability using different weighting approaches and the TOPSIS method. *Sustainability.* https://doi.org/10.3390/su151612234

Özdemir, Y., Kaya, S., & Turhan, E. (2020). Measuring sustainable campus services in higher education: "Sustainable Service Quality." *Journal of Cleaner Production, 245,* 118839. https://doi.org/10.1016/j.jclepro.2019.118839

Puertas, R., & Marti, L. (2019). Sustainability in universities: DEA-GreenMetric. *Sustainability.* https://doi.org/10.3390/su11143766

Roorda, N. (2010). Sustainability assessment tools for higher education institutions: AISHE 2.0. *Journal of Education for Sustainable Development, 4*(2), 231–244.

Silva-Da-Nóbrega, P., Chim-Miki, A., & Castillo-Palacio, M. (2022). Smart campus framework: Challenges and opportunities for education based on sustainable development goals. *Sustainability.* https://doi.org/10.3390/su14159640

Son-Turan, S., & Lambrechts, W. (2019). Sustainability disclosure in higher education. *International Journal of Sustainability in Higher Education.* https://doi.org/10.1108/ijshe-02-2019-0070

Suklun, H., & Bengü, E. (2024). Raising awareness about sustainable development goals in higher education institutions. *Research in Educational Administration and Leadership.* https://doi.org/10.30828/real.1357661

Tafese, M., & Kopp, E. (2025). Embedding social sustainability in education: A thematic review of practices and trends across educational pathways from a global perspective. *Sustainability.* https://doi.org/10.3390/su17104342

Tao, L., Chen, L., & Li, K. (2021). Corporate financialization, financing constraints, and environmental investment. *Sustainability.* https://doi.org/10.3390/su132414040

Uçar, O., & Özdemir, O. (2022). Sustainability activities and reporting examples in universities. *Ida Academia Journal of Accounting and Finance.* https://doi.org/10.52059/idaacmmd.1029118

Wolff, L., & Ehrström, P. (2020). Social sustainability and transformation in higher education environments: Utopia or possibility? *Sustainability, 12*, 4176. https://doi.org/10.3390/su12104176

Yılmaz, E., & Balyemez, S. (2020). Green building certification systems in Türkiye. *Anadolu Bil Vocational School Journal, 15*, 1–18.

Yusof, Z. M., & Bakar, S. H. (2012). Evaluating university sustainability using the UI GreenMetric ranking: Challenges and opportunities. *Sustainability*, *4*(12), 233–248.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Marine Protected Areas and Protection Strategies

Ertan DÜZGÜNEŞ [1]

ORCID 1: 0000-0002-1523-9722
[1]Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
ertan.duzgunes@ktu.edu.tr

Duygu KARABIÇAK GÜNAYDIN [2]

ORCID 2: 0000-0002-8227-8377
[2]Research Assistant, Nevşehir Hacı Bektaş Veli University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Nevşehir-Türkiye
duygukarabicak@nevsehir.edu.tr **(**Responsible Author)

Abstract

Oceans are of global significance for sustaining life, regulating climate, conserving biodiversity, and preserving cultural heritage. Beyond their ecological functions, they underpin strategic economic sectors such as fisheries, tourism, and maritime trade by providing essential food, energy, and mineral resources. Yet, growing anthropogenic pressures—including overfishing, pollution, bottom trawling, unplanned coastal development, and climate change—have exceeded the resilience of marine ecosystems, leading to biodiversity decline and the degradation of ecosystem services. Within this framework, Marine Protected Areas (MPAs) have gained prominence as effective instruments for safeguarding marine and coastal ecosystems, ensuring the sustainable use of natural resources, and strengthening local economies. MPAs deliver multifaceted benefits, including the conservation of fragile habitats, recovery of fish stocks, carbon sequestration, and enhanced resilience to climate change. Achieving such outcomes requires the adoption of ecosystem-based management approaches, participatory decision-making, scientific monitoring, and adaptive management strategies. Türkiye, surrounded on three sides by the Black Sea, Marmara, Aegean, and Mediterranean, possesses considerable potential for MPA implementation due to its diverse ecological features. Existing protection mechanisms, such as Special Environmental Protection Areas and marine national parks, represent important steps. However, the effectiveness of these initiatives depends on strengthening science-based planning, ensuring local stakeholder engagement, and fostering international cooperation. This study critically examines the importance, objectives, designation criteria, and management strategies of MPAs as a category of protected areas aimed specifically at marine ecosystems. It also evaluates Türkiye's current approach to marine conservation and highlights the urgent need to expand and enhance protection measures to safeguard the ecological integrity and socio-economic value of its seas.

Keywords: Protected areas, marine protected areas, Türkiye

1. Introduction

Today, rapid technological advances, intensive natural resource use, population growth, and urbanization are creating profound and irreversible impacts on our planet's natural balance. These factors are straining the carrying capacity of ecosystems, leading to the gradual decline of natural areas and the threat to biodiversity. At the root of this degradation lies the misguided human perception that nature can renew itself indefinitely, coupled with environmentally harmful production and consumption behaviors that prioritize short-term economic gain. The pressures of human activities on ecological systems have become direct threats to natural resources critical to the sustenance of life, such as air, water, and soil.

In response to these multifaceted environmental crises, the nature conservation movement has gained momentum since the 1950s, and various "protected area" systems aimed at preserving biodiversity have been established (Yalınkılıç & Yenilmez Arpa, 2005; Düzgüneş & Demirel, 2018). Developed with the active participation of local communities, non-governmental organizations (NGOs), and the private sector, these systems aim to maintain ecological integrity

and ensure the sustainable management of natural resources. In this context, in addition to protected areas for terrestrial ecosystems, Marine Protected Areas (MPAs) have emerged as one of the most important strategic tools for protecting marine and coastal ecosystems.

MPAs are special protected areas whose boundaries, management objectives, and permitted activities are defined by legal and policy frameworks and planned based on scientific research and stakeholder engagement. These areas protect critical habitats such as coral reefs, seagrass meadows, mangrove forests, and coastal lagoons, contributing to the breeding, feeding, and migration processes of numerous marine species (Jones, 2021). By limiting destructive activities such as overfishing, pollution, and unplanned coastal development, MPAs support the restoration of fish stocks, the resilience of marine ecosystems to environmental change, and the mitigation of climate change by protecting habitats with high carbon sequestration capacity.

Beyond their environmental benefits, MPAs contribute to the economic development of coastal communities by promoting sustainable fishing, tourism, and recreation. They also serve as living laboratories for scientific research, fostering knowledge of marine ecology and shaping large-scale conservation policies. Therefore, MPAs are considered a critical global tool not only for protecting marine biodiversity but also for maintaining ocean productivity, supporting the blue economy, and ensuring healthy marine ecosystems for future generations.

2. Concept of Protected Area

Accelerating technological advancements, population growth, and the resulting intensive concreting and misuse of land brought about by urbanization have led to societies' excessive and reckless consumption of natural resources, placing significant pressure on ecosystems. These pressures are triggering critical ecological problems such as soil erosion, desiccation of wetlands, deforestation, loss of biodiversity, and the decline or extinction of numerous plant and animal species. Increasing human impact has not only degraded the natural environment but has also reached a level that threatens ecosystem services and, consequently, the sustainability of human life.

To mitigate these negative impacts on the natural environment and resources and to ensure the conservation of biodiversity, various scientifically based conservation structures and management strategies have been developed over time. In this context, in light of the knowledge and experience accumulated over many years, "Protected Area" systems have become one of the most effective and widespread practices within global conservation strategies. The International Union for Conservation of Nature (IUCN) defines protected areas as "strictly geographically demarcated areas managed by legal or other effective means to ensure the long-term conservation of ecosystems and cultural values contained in nature" (IUCN, 2025). Similarly, the Convention on Biological Diversity (CBD) defines protected areas as "geographically defined areas managed by legal or other effective regulations to achieve specific objectives" (Juffe-Bignoli et al., 2017). In Türkiye, the Law on the Protection of Cultural and Natural Heritage No. 2863 defines protected areas as "areas whose protection is mandatory in order to ensure the preservation of immovable cultural and natural assets and their protection within the historical environment" (T. R. Official Gazette,1983).

The spread of protected areas globally has shown remarkable growth over the last half century. According to the World Database on Protected Areas (WDPA), in 2010, 147,000 protected areas covering approximately 17 million km² were declared worldwide, representing more than 13% of the Earth's surface (IUCN-UNEP-WCMC, 2012). By 2014, this proportion had

increased to 15.4% in terrestrial areas and 8.4% in marine areas, bringing the total protected area size to approximately 33 million km², approaching the size of the African continent (IUCN-WCPA, 2014). The diversification of protected areas and the adoption by governments of new protection categories such as Other Effective Area-Based Conservation Measures (OECMs) have been decisive in the increase in both the number and the surface area covered by declared areas.

This development trend continued in the following years. In 2018, the number of protected areas registered under the WDPA reached 238,563; approximately 20 million km² of terrestrial protected areas, covering 14.9% of the world's surface, and approximately 6 million km² of marine protected areas, an increase of 16.8%, were recorded (IUCN-WCPA-WCMC, 2018). According to the Protected Planet report, in 2021, the number of terrestrial protected areas increased to 248,113, and the ratio of the area they cover increased to 15.67%; the number of marine protected areas was determined to be 17,787, reaching 7.65% of the global ocean surface. By 2024 (May 2024 data), the number of terrestrial protected areas reached 275,492, and the ratio of the area they cover increased to 16.1%; Marine protected areas have increased to 18,200, representing 8.01% of the global ocean surface (Protected Planet, 2024). Including areas assessed within the scope of the OECM, these rates reach 17.28% for terrestrial areas and 8.12% for marine areas.

These data demonstrate that protected areas have become a strategic tool not only for their ecological functions but also for global environmental policies and sustainable development goals. The continuous increase in the number and extent of protected areas clearly reflects the success and future importance of international efforts to conserve biodiversity, adapt to climate change, and sustain ecosystem services.

The distribution and locations of declared marine and terrestrial protected areas worldwide are shown in Figure 1 (Protected Planet, 2025).

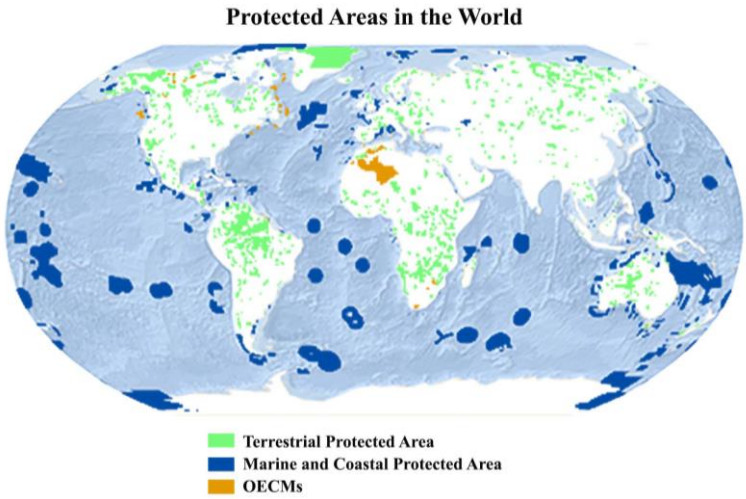


Figure 1. Map of protected areas worldwide, January 1, 2025.

Other Effective Area-Based Conservation Measures (OECMs) are an important conservation status defined for areas that do not have formal protected area status but provide effective on-site biodiversity conservation. OECMs offer a complementary mechanism to traditional protected areas, particularly in maintaining ecosystem integrity, protecting critical habitats, and supporting sustainable management practices by local communities. This approach ensures that

conservation objectives are not limited to areas with legal status but also encourages diverse land uses (e.g., sustainable forestry, traditional fisheries, local management practices) to generate ecological benefits.

According to data from the Protected Planet Database, the Aichi Biodiversity Target, set for 2020 and targeting 17% of land and inland waters to be protected, was achieved by 17.08% as of March 2023. By May 2024, this figure had risen to 17.28%, officially confirming the progress made in protecting terrestrial and inland water ecosystems on a global scale (Protected Planet, 2025). This progress demonstrates that not only traditional protected areas but also areas under OECM status contribute significantly to the achievement of global conservation goals.

These data demonstrate the increasing importance of OECMs in protecting ecologically critical areas, maintaining biodiversity, and implementing climate change adaptation strategies. In particular, recognizing OECMs in international conservation policies accelerates the qualitative and quantitative development of protected area networks, contributing to the implementation of a broader range of global environmental goals.

3. Marine Protected Areas

The International Union for Conservation of Nature (IUCN) defines marine protected areas (MPAs) as "any or all of the tidal or intertidal land designated by law or other effective means for the protection of the surrounding waters, associated flora, fauna, and historical and cultural features" (IUCN-WCPA, 2021). This definition represents a holistic approach that protects not only the sea surface but also the seabed, biomes, and cultural elements.

According to assessments by the IUCN World Commission on Protected Areas (WCPA, 1999; IUCN-WCPA, 2021), the fundamental characteristics and principles of MPAs can be summarized as follows:

- **Nature Conservation Priority:** The primary objective of MPAs is to protect marine ecosystems and biodiversity.
- **Flexibility of Within-Area Protection:** The degree of protection does not have to be uniform across the entire area; large MPAs often implement a multi-layered management plan, dividing the area into different use and impact zones.
- **Extent of Coverage:** Each MPA necessarily includes the marine environment, but it may also encompass land masses, islands, or coastal areas within its boundaries. If the marine area is larger than the land area, or if the marine portion of a large protected area is of sufficient size on its own, this portion can be classified as an independent MPA.
- **Holistic Conservation:** MPAs must cover not only the seabed but also the associated flora and fauna. If biodiversity conservation is not a primary objective and meets the criteria of the Convention on Biological Diversity (CBD), the area in question may be considered an Other Effective Area-Based Conservation Measure (OECM).
- **Coexistence of Natural and Cultural Elements:** MPAs encompass not only natural habitats; Cultural heritage elements such as shipwrecks, historic lighthouses, and piers may also be protected.
- **Various Management Models:** MPAs can be areas directly managed by government agencies or fall under a wide range of protection categories, such as biosphere reserves, Ramsar sites, or World Heritage sites.

These are shown in Table 1.

Table 1. Types of MPA

Types of MPAs	Examples
Declared under customary tenure	MPAs in the Pacific region
Managed on a voluntary basis	Some MPAs in the UK
Developed and managed by the private sector	Chumbe, Zanzibar, Tanzania
Established and managed by a local community	Philippine fishing villages

In this context, MPAs play a critical role in global marine conservation strategies as multidimensional areas that require a holistic management and protection approach in terms of protecting both ecological and cultural values.

a. Purpose of Marine Protected Areas

The International Union for Conservation of Nature (IUCN) defines the primary purpose of Marine Protected Areas (MPAs) as protecting the biodiversity and productivity of the oceans (including ecological life-support systems). Both aspects of this goal are equally critical for improving the health and long-term sustainability of marine ecosystems. For example, protecting seagrass beds with relatively low species diversity but high biological productivity can be vital for maintaining viable populations of threatened species such as dugongs. In this context, maintaining biological productivity is essential not only for maintaining ecological stability but also for contributing to human well-being.

The success of MPAs depends largely on the support of local communities. To ensure this support, the MPA must contribute to tangible community benefits such as food security, economic income, and cultural benefits by maintaining biological productivity. While marine conservation and the sustainable use of marine resources are often viewed as distinct goals, in reality, the two objectives are strongly interconnected. However, past experience has shown that MPAs can fail when external stakeholders prioritize biodiversity conservation while local communities prioritize resource use. Therefore, it is crucial to clearly and balancedly define the relationship between conservation and sustainable use at the planning stage.

Different spatial planning strategies can be applied in MPA management, depending on the primary objective. If the primary objective is to protect a specific species or ecosystem, establishing a large, completely no-take area may be the most appropriate method. Conversely, if the primary objective is sustainable resource management, a network of smaller, interconnected protected areas can yield higher fish stocks for surrounding fisheries, as studies conducted in the Caribbean have shown.

Experience suggests that two basic approaches to protecting the entire ecosystem stand out (WCPA, 1999):

1. Establishing a series of relatively small but complementary marine protected areas within a broader integrated ecosystem management framework.
2. Declaring a large-scale, multi-regional MPA covering all or a large portion of the marine ecosystem.

Both methods are valid, but a significant advantage of the latter approach is that management responsibility for the entire area is generally assigned to a single institution. This reduces jurisdictional conflicts that might arise if management were shared among different institutions, facilitating the implementation of an integrated and holistic conservation strategy.

These assessments demonstrate that MPAs are multidimensional strategic areas that simultaneously protect not only biodiversity but also ecosystem productivity and human well-being.

4. Criteria for Declarıng Marine Protected Areas

The designation of Marine Protected Areas (MPAs) requires a multidimensional assessment process to effectively protect marine biodiversity, ecosystems, and cultural resources. This process necessitates meticulous consideration of interconnected elements such as ecological value, socio-economic contribution, governance capacity, and legal compliance (WCPA, 1999; IUCN-WCPA, 2021). The primary criteria are grouped under the following main headings:

1. Biodiversity and Ecosystem Value
- Species Richness: Areas of high biological diversity, including rare, endemic, or endangered species.
- Habitat Importance: Areas containing critical breeding and feeding habitats, such as coral reefs, mangroves, seagrass beds, and kelp forests.
- Ecosystem Services: Areas that provide essential ecosystem services, such as carbon sequestration, coastal protection, water filtration, and climate regulation.
- Integrity: The degree to which an area encompasses an entire ecosystem, either alone or in conjunction with other protected areas.

2. Ecological Importance
- Ecological Connectivity: Areas that enhance connectivity between habitats for species migration and genetic flow.
- Representativeness: Areas that reflect the typical marine ecosystems and habitat diversity of specific biogeographic regions.
- Naturalness: Reference ecosystems where natural processes can be observed and where human impact is minimal.

3. Threat Level and Conservation Urgency
- Threatened Areas: Areas subjected to human-induced pressures such as overfishing, pollution, habitat destruction, or climate change.
- Urgent Response Requirement: Areas requiring immediate protection to prevent the rapid degradation of critical species or habitats.

4. Socio-Economic and Cultural Value
- Cultural Heritage: Areas of cultural or archaeological significance, such as traditional fishing grounds, sacred sites, and historical shipwrecks.
- Economic Contribution: Areas that support local economies through sustainable fishing, tourism, and recreation.
- Community Support: Areas where local people, civil society organizations, and fishing cooperatives actively participate in conservation efforts.

5. Scientific and Educational Potential
- Research Opportunities: Areas that offer unique opportunities for scientific research on marine ecology, climate change, and biodiversity.

- Educational Value: Areas suitable for promoting environmental education, public awareness, and marine conservation awareness.

6. Feasibility and Management Capacity

- Feasibility: The availability of the necessary infrastructure and resources for monitoring, control, and implementation of conservation measures.
- Management Competence: Areas with effective management capacity through stakeholder engagement, financing mechanisms, and governance structures.
- Stakeholder Engagement: Active involvement of local communities, governments, and NGOs in planning and management processes.

7. Legal and Policy Framework

- Legal Protection: Areas that can be protected under national legislation or granted legal status through new regulations.
- Alignment with International Goals: Alignment with national and global conservation priorities, such as the Convention on Biological Diversity (CBD) and the United Nations Sustainable Development Goals (SDGs).

These criteria enable MPAs to provide effective, feasible, and sustainable long-term conservation by balancing ecological priorities, societal benefits, and management opportunities. By considering this multidimensional framework, decision-makers can prioritize areas that safeguard marine biodiversity, sustain ecosystem services, and provide economic and cultural benefits to local communities.

4.1. Establishment and Declaration of Marine Protected Areas

Establishing a Marine Protected Area (MPA) involves a comprehensive process, encompassing ecological, social, and administrative aspects, and often requires a time-consuming, multi-stakeholder approach. This process involves the collaborative efforts of all relevant management bodies, local rights holders, and stakeholders, the preparation of legal regulations, and the careful conduct of scientific assessments. Initially defining the characteristics of the designated area is critical to clarifying the expected ecological and socio-economic benefits of the MPA. This allows the potential biodiversity contributions of the area to be identified in line with management objectives (Figure 2).

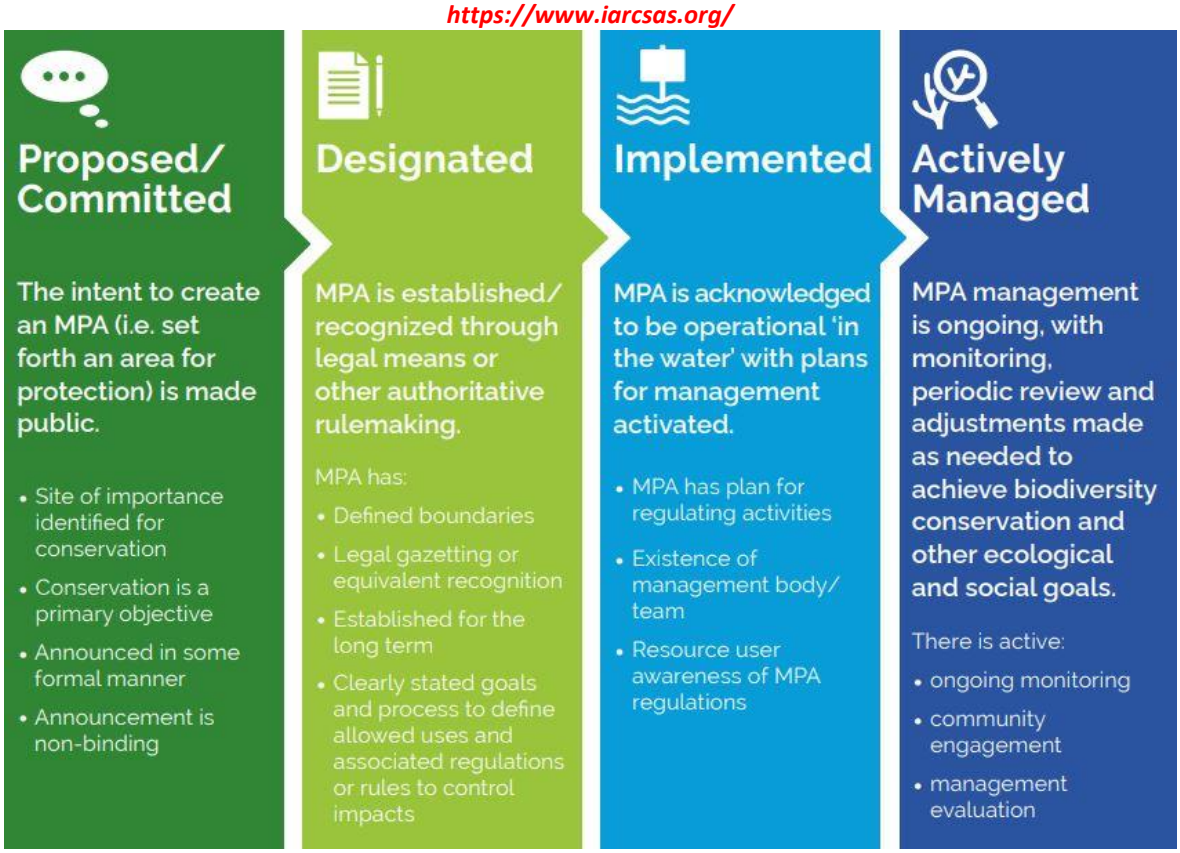


Figure 2. Establishment stages of MPAs

According to the MPA Guidelines prepared by the IUCN World Commission on Protected Areas (WCPA, 1999; IUCN-WCPA, 2021), the establishment process consists of four main stages:

1. Proposal/Commitment Stage: A formal proposal or commitment to protect a specific area as an MPA is made by a relevant management authority, public institution, or authorized organization.
2. Legal Designation: Clarification of the area's boundaries and formal recognition of its conservation status through national legislation or other effective legal instruments.
3. Regulation and Implementation: Entry into force of conservation decisions and management plans; active implementation of activity restrictions, monitoring programs, and conservation measures.
4. Active Management and Monitoring: Implementation of a dynamic management process supported by ongoing monitoring, adaptive management, and scientific assessments to ensure the long-term protection of the area.

These stages ensure not only the declaration of an MPA but also its sustainable and effective management. This makes it possible to conserve biodiversity, maintain ecosystem services, and contribute to the well-being of local communities.

The process of establishing a Marine Protected Area (MPA) is a gradual process encompassing not only the selection of the area but also legal recognition, implementation, and effective management. These stages clarify the degree of protection, management capacity, and ecological objectives of the designated area, ensuring long-term conservation success (WCPA, 1999; IUCN-WCPA, 2021). The process consists of the following four key stages:

1. Proposed/Committed

This first phase begins with the public announcement of the intention to protect an area as an MPA.

- It is formally stated that an important area has been selected for protection and that protection is the primary objective.
- The announcement is usually made through official channels but does not carry a binding legal status.
- This phase provides public disclosure of the area's potential ecological and socio-economic values and initiates initial stakeholder consultations.

2. Designated

In the second phase, the proposed area is formally recognized through legal or other authorized regulatory means, gaining MPA status.

- The area's boundaries are clearly defined and published in the official gazette or equivalent.
- The conservation objectives and management processes to be implemented are clearly defined.
- It is established for long-term protection, and permitted activities and restrictions are clarified within the legal framework.

3. Implemented

This stage refers to the period when the MPA becomes operational and management plans are actively implemented.

- A management plan governing activities is enacted, and relevant regulations begin to be implemented.
- A formal management body or team responsible for the protection of the area is established.
- Resource users (fishermen, tourism businesses, etc.) are informed about MPA regulations, and awareness is raised.

4. Actively Managed

The final stage is when the MPA is operated in accordance with the principles of continuous monitoring, evaluation, and adaptive management.

- Regular monitoring and reporting are conducted to protect biodiversity, maintain ecosystem health, and achieve social objectives.
- Management plans are updated through periodic evaluations, and necessary management adjustments are made.
- Community participation is actively maintained in decision-making and implementation processes.

These stages ensure that MPAs are not only declared but also maintain their long-term ecological integrity and sustainable use. Adaptive management, particularly in the final stage, allows for the continuous development of conservation strategies in response to changing environmental conditions and societal needs.

5. Marine Protected Areas Protectıon Strategies

Marine Protected Areas (MPAs) are designated areas managed through multilayered strategies to ensure the conservation of marine ecosystems, biodiversity, and cultural resources. These areas are protected not only by legal regulations but also through complementary mechanisms such as active management, community participation, scientific research, and sustainable financing (WCPA, 1999; IUCN-WCPA, 2021).

1. Regulatory Measures

MPAs are founded on legal frameworks and spatial arrangements. These areas, whose boundaries and management objectives are defined by national or regional legislation, include:

- No-take zones
- Multi-use areas (areas where sustainable activities are permitted)
- Restrictions on harmful activities such as fishing, mining, drilling, and tourism.

2. Active Management

Management plans, habitat restoration, and breeding and reintroduction programs for endangered species are implemented to achieve conservation goals. These include projects such as coral reef restoration, mangrove planting, or seagrass beds rehabilitation.

3. Monitoring and Surveillance

Water quality, species populations, and habitat conditions are regularly assessed to monitor the health of marine ecosystems. Drone technology, satellite imaging, and marine patrols are used to prevent poaching.

4. Enforcement

Coast guards, rangers, and law enforcement officers play an active role in ensuring the effectiveness of legal regulations. Violations are subject to legal sanctions such as fines, sanctions, and license revocation.

5. Community Participation

The success of MPAs depends on the support of local communities and stakeholders. Therefore,

- Stakeholder participation,
- Educational programs, and
- Economic alternatives to fishing, such as ecotourism or handicrafts, are critical.

6. Scientific Research

MPAs serve as living laboratories for scientific research and education. Continuous research on biodiversity, ecosystem health, and human impacts contributes to the updating of management strategies.

7. Sustainable Financing

Funding for long-term conservation is secured through government budgets, international grants, ecotourism revenues, and public-private partnerships. Incentives such as eco-certification for fishing and tourism businesses support sustainable activities.

8. Adaptive Management

Regularly reviewing management plans and adapting strategies in response to environmental changes and scientific findings ensures long-term conservation success.

MPAs are divided into four main categories based on the degree of protection they provide (Figure 3):

1. Fully Protected Areas: These are areas where all extractive or destructive activities are prohibited, and only low-impact activities such as swimming, diving, education, and scientific research are permitted.

2. Highly Protected Areas: These are areas where activities such as low-impact fishing or limited mining are permitted to a limited extent, but where biodiversity is prioritized.

3. Lightly Protected Areas: These are areas where biodiversity is partially protected, and moderate fishing or tourism activities are carried out under controlled conditions.

4. Minimally Protected Areas: These are areas where extensive mining or high-impact activities are permitted, but are still considered MPAs under the IUCN definition, providing essential conservation benefits.



Figure 3. MPA protection levels

Ultimately, effective MPAs require a multifaceted approach that integrates legal regulations, scientifically informed management, local participation, and financial sustainability. When implemented together, these strategies protect the health of marine ecosystems, support biodiversity, and generate long-term socioeconomic benefits for coastal communities.

6. Discussion and Conclusion

While terrestrial and marine protected areas in Türkiye are critical for protecting biodiversity and ecosystem integrity, the current system faces several structural and administrative challenges. One of the most significant problems in terrestrial protected areas is weak implementation and oversight, resulting from insufficient funding and human resources. The late integration of the concept of protection into development projects, combined with

economic and political pressures, makes it difficult to prioritize conservation objectives. This situation, combined with habitat fragmentation and the lack of ecological corridors, negatively impacts species migration and the continuity of ecological processes. Furthermore, a lack of scientific data limits the development of effective monitoring and adaptive management mechanisms, while low levels of public awareness and local participation lead to weak compliance with conservation regulations.

In addition to these structural challenges, climate change is placing increasing pressure on Türkiye's protected areas. Sea level rise, increased frequency of extreme weather events, and habitat displacement create new risk areas requiring additional protection measures, particularly in coastal and marine ecosystems.

Despite being surrounded by sea on three sides, Türkiye faces a significant gap in the number of Marine Protected Areas (MPAs). The economic interests of the fishing and tourism sectors, access restrictions to marine areas, and concerns about potential revenue loss are among the primary obstacles to declaring MPAs. This deficiency jeopardizes the conservation of marine biodiversity and leads to the degradation of critical ecosystems such as coral reefs, seagrass beds, and fish breeding and feeding grounds due to overfishing, pollution, and unregulated coastal development.

However, the establishment of MPAs offers multifaceted benefits, including:

- Protecting marine biodiversity,
- Supporting sustainable fisheries,
- Combating climate change by protecting carbon-sequestering habitats such as mangroves and seagrass meadows,
- Promoting ecotourism and contributing to local economies,
- Raising public awareness of marine ecosystems.

Given Türkiye's rich biodiversity and extensive coastline, the rapid establishment and effective management of marine protected areas is a strategic necessity from ecological, economic, and cultural perspectives. In this regard, a holistic conservation policy supported by stronger political will, adequate financial resources, science-based management plans and active participation of local communities is a fundamental condition for the long-term sustainability of both terrestrial and marine ecosystems.

References

Düzgüneş, E. (2018). *Visitor Management in National Park Planning*, First Edition, s: 31-32. Mauritius: LAP LAMBERT Academic Publishing

IUCN-UNEP-WCMC, (2012). Protected Planet Report 2012: Tracking Progress Towards Global Targets for Protected Areas, Cambridge, UK.

IUCN-WCPA, (2014). United Nations List of Protected Areas, Cambridge, UK.

IUCN-WCPA-WCMC, (2018). Protected Planet Report 2018, Cambridge UK; Gland, Switzerland; and Washington, D.C., USA.

IUCN-WCPA, (2021). The MPA Guide User Manual, Cambridge, UK.

Jones, J. S. (2021). Analysis and Discussion of 28 Recent Marine Protected Area Governance (MPAG) Case Studies: Challenges of Decentralisation in The Shadow of Hierarchy, Marine Policy, 127, 104362.

Juffe-Bignoli D., Bingham, H., MacSharry, B., Deguignet, M., Lewis, E., Milam, A., ve Kingston, N. (2017). World Database on Protected Areas User Manual 1.5, UNEP-WCMC, http://wcmc.io/WDPA_Manual, Cambridge, UK.

Law on the Protection of Cultural and Natural Heritage. (1983). T. R. Official Gazette (No: 18113), Prime Ministry Printing House, Ankara. Access Address (30.09.2025): https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=2863&MevzuatTur=1&MevzuatTertip=5

IUCN (International Union for Conservation of Nature). (2025). Effective Protected Areas. Access Address (10.09.2025): https://iucn.org/our-work/topic/effective-protected-areas

Protected Planet. (2025). Discover the World's Protected and Conserved Areas. Access Address (01.09.2025): https://www.protectedplanet.net/en

Protected Planet. (2025). January 2025 Update of the WDPA, WD-OECM and GD-PAME. Access Address (09.11.2025): https://www.protectedplanet.net/en/monthly-release-news/january-2025-update-of-the-wdpa

Protected Planet (2025). Achievement of 17% Target for Protected and Conserved Areas Now Reflected in Official Data. Access Address (09.11.2025): https://www.protectedplanet.net/news-and-stories/achievement-of-17-target-for-protected-and-conserved-areas-now-reflected-in-official-data

World Commission on Protected Areas (WCPA). (1999). Guidelines for Marine Protected Areas. Access Address: https://portals.iucn.org/library/efiles/documents/pag-003.pdf

Yalınkılıç, M. K. ve Yenilmez Arpa, N., (2005). *Protected Natural Areas Symposium*. Protected Areas and Ecotourism in Türkiye (s. 33-36). SDÜ, Isparta. Access Address: https://ormanweb.isparta.edu.tr/kdas/index.php?page=cagrilibildiriler

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Media Representation of Non-Structural Elements Following the February 6 Kahramanmaraş Earthquakes in Türkiye

Ayşan Ilgın POLAT [1]*

ORCID 1: 0000-0001-7856-9473
[1]Research Assistant, Antalya Bilim University, Faculty of Design and Architecture, Department of Interior Architecture and Environmental, Antalya-Türkiye
ilgin.polat@antalya.edu.tr (Responsible Author)

Şebnem ERTAŞ BEŞİR [2]

ORCID 2: 0000-0002-0568-6529
[2]Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya-Türkiye
sertasbesir@akdeniz.edu.tr

Abstract

The earthquakes in Kahramanmaraş, which took place on 6 February 2023, demonstrated not only the failures and collapses of the load -bearing structures of buildings, but also the destruction, which happened to the non-structural objects in the interior areas. The resulting damage has had some important implications on life safety, economic losses and the psychology of the user and has been defining in post-disaster respons. Technical research in the seismic performance of non-structural elements has grown in recent years, but little has been done in studying how this is being conveyed to the media i.e. how they are communicated to the masses. The aim of this study is to examine how non-structural elements were addressed in online news platforms in Türkiye following the 6 February earthquakes. The research will analyze news texts, visuals, and hashtagged social media content published during the first three months after the earthquakes. These materials will be examined to identify the themes associated with non-structural elements in media outlets, the actors that were emphasized, and the differences between technical knowledge and public discourse. The expected contributions of the study include systematically revealing the visibility and representational forms of non-structural elements in media narratives, identifying how technical findings from engineering and damage-assessment literature are reflected in the media, and offering recommendations for enhancing post-disaster communication policies and risk awareness.

Keywords: Non-structural elements, media, news, earthquake

1. Introduction

The damaging effects of an earthquake on the natural and built environment are many. In the short term in this initial stage, estimates of fatalities, physical damage to buildings and other structures, loss of building function, loss of human activity, and secondary effects such as fires and gas leaks that may lead to further fatalities and damage may be required. Injuries might be caused by both structural and non-structural elements. Thus it is essential that those responsible for the design of buildings, and their internal layout and contents, are earthquake aware (Ahmed, 2023). The Kahramanmaraş earthquakes of 6 February 2023 were one of the most catastrophic natural disasters in modern Türkiye. They exposed the inadequacy of not only the load-bearing systems of the buildings but also the potentially fatal risks resulting from NSEs in the interior of buildings. Non-Structural Elements (NSE) include cabinets, suspended ceilings, glass partitions and mechanical equipment. NSEs are subject to the same earthquake dynamic forces as the load-bearing systems, are often overlooked and not considered for design or anchorage, or are incomplete in terms of material specification (Wang et al., 2021).

As a result, even in buildings that remain structurally intact, NSE failures can cause severe injuries, fatalities, economic losses, and psychological trauma.

An examination of public discussions and media coverage after disasters shows that the main focus was mostly on “collapsed buildings” and “structural system failures.” Both traditional and digital media mainly shared images of rubble and destruction to highlight the scale of the tragedy. However, from the very first moments of the disaster, thousands of posts circulated on social media and news platforms. These posts showed interior furnishings knocked over, building services systems broken, and dangerous conditions caused by these failures. Yet, these visuals and stories about NSEs were often used just as dramatic backdrops. The root causes of risk, the preventability of these failures, and the design responsibilities linked to them were rarely discussed in a technical or professional context .(Underwood et al., 2020).

Despite the fact that recent years have seen a dramatic rise in the engineering and architectural research on the seismic behavior of NSEs, a systematic study of the way this technical knowledge is presented to the general population via the media, the framing mechanisms applied, and the effects on social risk perception, has not been established. This is a serious deficiency in relation to the phenomenon of risk communication and design awareness which is also crucial to the development of disaster-resistant communities.

Even though the damages in the aftermath of the earthquakes are permanent and severe, the structural elements are often associated with the damage, whereas injuries and loss of the functionality of a building are closely connected with non-structural ones. In 1999, 50 percent of injuries and 3 percent of deaths in the İzmit earthquake were as a result of non-structural elements, according to Demir et al., 2024 all the building components and contents that do not comprise the load-bearing system are referred to as non-structural elements. They do not support any vertical or horizontal loads, but they are subjected to the identical seismic forces as structural elements and can collapse during the shaking of the ground (İpek, 2015). Such elements include architectural systems, mechanical systems, electrical systems, and plumbing systems, furniture, fixtures, equipment, and other contents (FEMA, 2017). A very broadest list of non-structural elements is offered by FEMA (2012), which includes three categories of them:

- Architectural Components: doors and windows, suspended ceilings, service floors, interior partitions, parapets, façade elements and glazing systems, cladding materials, stairways, architectural ornaments, shopfronts, railings, and similar components.
- Mechanical, Electrical, and Plumbing Components: pumps, chillers, heaters, HVAC units, pipes, generators, and related systems.
- Furniture, Fixtures, and Equipment (FFE): shelving units, cabinets, desks, chairs, ceiling-mounted televisions or monitors, hazardous materials, workshop equipment, museum artifacts, and collection items.

In the TÜBİTAK 1001 (2023) project numbered 121K927, non-structural elements were classified into three main categories: architectural elements, furniture and accessories, and electromechanical equipment. A total of 11 modules were identified, including 6 in architectural elements, 2 in furniture and accessories, and 3 in electromechanical equipment.

Like structural failures, the malfunction or displacement of non-structural elements can be life-threatening. Moving systems, equipment, and furniture may pose serious risks to occupants during an earthquake. However, when both structural and non-structural components are properly designed and installed by qualified professionals, the built environment can provide significantly safer conditions—particularly for vulnerable populations. For instance, furniture can create protective spaces during earthquakes, increasing the survival chances of older adults, individuals with disabilities, and children (Polat & Gül, 2023).

This study aims to address precisely this gap. Its central focus is to examine how NSEs were represented in Turkish news portals) during the first three months following the 6 February earthquakes—a critical period for public communication and meaning-making.

- The study seeks to answer the following research questions:Through which thematic frames (safety, responsibility, resilience, drama, etc.) were non-structural elements in interior spaces represented in post-earthquake digital media? (Nkrumah et al., 2025).
- Which actors (contractors, the state, users, experts) were foregrounded in NSE-related representations, and what roles were attributed to these actors? (Blum, 2024).
- How do these media representations influence the perceived role and societal relevance of the interior architecture discipline in reducing disaster risk? (Soriano et al., 2025)

Responding to these questions, the study will present an interdisciplinary contribution that will be found at the point of contact between the post-disaster communication and the media studies and interior architecture. The final objective will be to learn the effects of media narratives on the overall risk perception and protection behavior in the population, and to come up with recommendations on communication in the designing of disaster-resilient interior environments.

This paper explains the theoretical framework of a media discussion of the depictions of NSEs following an earthquake. In this regard, the notions of disaster studies, interior architecture and media studies were used. In the present work, the concept of NSEs, its purpose in disaster risk reduction (through the prism of interior architecture), media framing theory, and the influence of social media on disaster communications will be discussed (Bonati et al., 2023).

The media are an important participant in public opinion and policy processes and have a strong role in disasters. A framework that helps us understand how media create reality is Entman (1993). He defines framing as a process in which communication texts "select, emphasize, exclude, and organize" aspects of the perceived reality to promote a particular interpretation of an issue or object. This process serves four main functions

- Problem Definition: Defining and clarifying a problem.
- Causal Interpretation: We can explain the problem.
- Moral Evaluation: Making value judgments about the issue.
- Treatment Recommendation: Proposing solutions or interventions (Ercan et. al., 2022).

Frames used in disaster journalism are often "drama", "heroism", "helplessness", and "blame attribution" (Devès et al., 2019). Issues of the technical nature, such as with a non-structural issue, are often used for illustrative purposes within these dramatic frames without mentioning the technical nature and the cause of the problem. This narrows the public's understanding of risk, and hampers efforts at preparedness.

Unlike the one-directional structures of customary media, media platforms allow for a multilayered and participative approach to disaster communication (Bruns & Burgess, 2012).

- Rapid Information Flow: Real-time updates during crisis moments.
- Emotional Solidarity: A space for sharing trauma and expressing collective grief.
- Alternative Discourses: Dissemination of information that challenges or complements official narratives.

- Social Accountability: Opportunities for citizens to provide direct critical input with the goal to hold contractors or authorities accountable.

Existing scholarship has explored the technical performance of non-structural elements (FEMA, 2012), the role of interior environments in disaster management (Lizarralde et al., 2015), and media representations of disasters (Entman, 1993; Hasan et. al, 2017). Yet, there is no study that integrates these three strands to systematically examine how NSEs are represented in digital media following an earthquake—particularly within the context of Türkiye.

This research seeks to address this interdisciplinary gap and to initiate a discussion on how media representations shape public perceptions of the interior architecture discipline.

2. Materials and Methods

The study examines the media discourses of the NSEs in Türkiye using qualitative research techniques that analyze the media discourses created after the Kahramanmaraş earthquakes of 6 February 2023 (Aktuna & Bahar-Özvarış, 2023; Özbilgin et al., 2023). The article uses a descriptive content analysis research design as suggested by Krippendorff (2018), to determine the content, context, and themes of the media discourses.



Figure 1. Data Analysis Process

News Portals: All three news portals with the highest traffic and the most reports posted immediately after the earthquake such as NTV, BBC Türkçe, and Sözcü, were chosen due to their different media positions: mainstream commercial media, public broadcasting, and popular press.

This study seeks to examine, through qualitative content analysis, how non-structural elements (NSEs) were represented and discussed on digital platforms that include news websites following the earthquakes that struck on February 6, 2023. Analyzes were conducted through Excel spreadsheets specialized software was not used.

Content was retrieved using keywords such as *earthquake*, *furniture*, *interior*, *suspended ceiling*, *#deprem*, and *#mobilyasabitleme*. A total of 50 items were included in the dataset, consisting of 50 media posts. The analysis followed main steps:

All the gathered texts of news, and other related visuals were systematized in one folder. A unique identifier was given to each item, e.g., the news items were labeled with H1.

Table 1. Each content item was examined and coded under five categories in an Excel spreadsheet

Coding Category	Description	Example Codes
Theme	The overall subject of the content	"Safety Threat", "Accountability" "Resilience" "Drama"
Actor	Prominent individual or organization	"Contractor", "Government", "Disaster Survivor", "Expert"
Space	Depicted location	"Residence", "Office", "Hospital"
Emotion	Dominant emotion conveyed	"Anger", "Sadness", "Solidarity", "Neutral"
Visual Focus	Most salient NSE in images	"Overturned Cabinet", "Collapsed Ceiling", "Broken Glass"

Excel's filtering and pivot table functions were used to identify:

- The most frequently occurring themes
- Dominant emotions on each platform
- NSEs most commonly highlighted (e.g., overturned cabinets)

These analyses allowed the construction of thematic frameworks supported by quantitative summaries.

3. Findings and Discussion

As analyses of digital contents created during three months after the earthquakes that happened in February 6, 2023 show, there were specific patterns of how non-structure elements worked to reproduce them, with the differences between the traditional news portals.The results are discussed below.In news portals, NSEs were mostly deemphasized by structural collapse and placed in a small number of thematic lenses.

analyses of 50 digital contents created within the 3 months after the earthquakes on February 6, 2023 will demonstrate significant trends in the way non-structural elements (NSEs) were committed to each media platform.

There is a strong inbalance in the activity on the platform, with social media taking over the conversation after the earthquake (80% of the content). This implies that the role of the traditional media in disaster communication is somewhat reduced in comparison to its social media. The few content production of the news portals can be explained by the resource constraints and more time-consuming editorial process, as the communications at social media can create content that is instant and has mass production, making it a more efficient medium in emergency cases.

Table 2. Thematic Distribution Across All Contents

Theme	Frequency (n)	Percentage (%)
Drama/Helplessness	22	44%
Responsibility/Accountability	15	30%
Safety Threat	8	16%
Design Awareness	3	6%
Resilience/Survival	2	4%

The thematic analysis shows that close to 44% of the content is focused on drama and helplessness which is a classical tendency in disaster coverage. The high ranking of responsibility/accountability theme (30%) can be explained by the desire of the population to find justice and blame someone. On the contrary, the fact that design awareness is represented with the bare minimum (6%), shows that very little attention is paid to the technical and design components of NSEs and this is a sign of a discourse that places more emphasis on results than prevention.

Table 3. Thematic Comparison by Platform

Theme	News Portals (n=10)
Drama/Helplessness	6
Responsibility/Accountability	2
Safety Threat	1
Design Awareness	0
Resilience/Survival	1

Comparison of platforms reveals that they have varied differences in the themes covered. Newsportals underline the drama, which is in line with the traditional journalistic behaviors. Remarkably, every example of design consciousness can be found on media, indicating that these sources not only criticize but also encourage solutions and raise awareness of people, traditional media do not accommodate such content, which could be explained either by editorial decisions or simply by the lack of such viewpoints expressed by experts.

Table 4. Emotional Tone Distribution

Emotional Tone	Frequency (n)	Percentage (%)
Anger/Blame	20	40%
Sadness/Helplessness	18	36%
Neutral/Informative	8	16%
Solidarity/Hope	4	8%

The analysis of emotional tones shows that 76 percent of the content contains negative emotions (anger and sadness), which were the traumatic experience of the population after the earthquake. The prevalence of anger and blame is very high indicating that the society wants to hear its accountability. Information is neutral and objective (16%), which implies that rational and solution-oriented texts are less eminent. The very low ratings of solidarity and hope (8%) demonstrate that media reporting is mostly problem-oriented.

Table 5. Most Prominent Non-Structural Elements in Visual Content

NSE Category	Frequency (n)	Percentage (%)
Furniture (cabinets, shelves, beds)	25	50%
Architectural Elements (suspended ceilings, partition walls)	12	24%
Mechanical/Plumbing (AC, water systems)	8	16%
Other (chandeliers, windows, mirrors)	5	10%

Visual content analysis demonstrates that the most represented NSE is furniture (50%), probably because of its daily appearance and visual effects. Shelves and cabinets that have collapsed visually appeal and are directly connected to living spaces, which is why they feature in the media features. Suspended ceiling and partition walls have an architectural contribution of 24, which means that they are relevant as visual materials. Mechanical systems are underrepresented (16%) because of its hidden form and less impressive visual appearance. By and large, such distribution means that media focuses on NSEs that have great visual and dramatic potential.



Figure 3. Summary of Main Findings

These results propose that NSEs are mostly discussed in references of emotional and blame-related narratives instead of technical or design-oriented approaches.

4. Conclusion and Recommendations

This research shows that the design and safety of the non-structural aspects of design are not brought out clearly in the post disaster media coverage. The fact that dramatic and blame-oriented stories take the center stage of media coverage undermines the process of changing the topic of discussion to constructive and solution-driven discussions by the people. This low profile of the possible contributions of the interior design field in this respect can be seen as the lack of visibility, which, in addition to a professional gap, is also a serious weakness in the context of safety and resilience of the society.

To further studies, it would be of interest to carry out comparative studies of media representations of various disasters and in different cultural settings. Moreover, the experimental research investigating the effect of media content on the perception and behavior of the population may have a practical contribution towards establishing more effective disaster communication strategies.

Finally, it is necessary to have a combined effort that cuts across the media, design disciplines, and policymakers to develop disaster-resilient communities. The safety of non-structural elements should be the primary focus of this strategy because these elements are vital in minimizing damages, saving lives, and enhancing the general resilience of the constructed environment.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Ahmed, I. (2023). Key Building Design and Construction Lessons from the 2023 Türkiye–Syria Earthquakes. *Architecture*, *3*(1), 104-106. https://doi.org/10.3390/architecture3010007

Aktuna, G., & Bahar-Özvarış, Ş. (2023). Investigating the aftermath of the Türkiye 2023 earthquake: exploring post-disaster uncertainty among Syrian migrants using social network analysis with public health approach. *Frontiers in public health*, *11*, 1204589.

Blum, I. (2024). "Facebook is a bit like a lost cause": Social Movement Actors' Perspectives on Social Media Affordances. In *ECREA 2024: Electronic Book of Abstracts* (pp. 133-134). Czech Technical University in Prague.

Bonati, S., Nardini, O., Boersma, K., & Clark, N. (2023). Unravelling dynamics of vulnerability and social media use on displaced minors in the aftermath of Italian earthquakes. *International journal of disaster risk reduction*, *89*, 103632.

Demir, A., Günay, S., Marinković, M., Dilsiz, A., Bektaş, N., Khalil, Z., ... & Sezen, H. (2024). 2022 Düzce, Türkiye earthquake: advances in the past 2 decades, lessons learned, and future projections. *Bulletin of Earthquake Engineering*, *22*(11), 5835-5862.

Devès, M. H., Le Texier, M., Pécout, H., & Grasland, C. (2019). Seismic risk: the biases of earthquake media coverage. *Geoscience Communication*, *2*(2), 125-141.

Entman, R. M. (1993). Framing: Towards clarification of a fractured paradigm. *McQuail's reader in mass communication theory*, *390*, 397.

Ercan, S. A., Asenbaum, H., Curato, N., & Mendonça, R. F. (2022). *Research methods in deliberative democracy* (p. 529). Oxford University Press.

FEMA. 2012. Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide. Federal Emergency Management Agency. Washington, DC, 885 p.

FEMA. 2017. FEMA P-1000, safer, stronger, smarter: A guide to improving school natural hazard safety. Washington, DC: Federal Emergency Management Agency.

Hasan, H., Smith, S., & Finnegan, P. (2017). An activity theoretic analysis of the mediating role of information systems in tackling climate change adaptation. *Information Systems Journal*, *27*(3), 271-308.

Lizarralde, G., Chmutina, K., Bosher, L., & Dainty, A. (2015). Sustainability and resilience in the built environment: The challenges of establishing a turquoise agenda in the UK. *Sustainable Cities and Society*, *15*, 96-104.

Nkrumah, S. A. M., Filippova, O., Levy, D., & Ying, F. (2025). Bridging the Gap: A Literature Review of Post-Earthquake Building Functional Recovery through a User-Informed Lens. *Journal of Real Estate Literature*, 1-30.

Ozbilgin, M., Erbil, C., Demirbağ, K. Ş., Demirbağ, O., & Tanriverdi, V. (2023). Afet yönetiminde sorumluluğun yeniden inşası: Deprem, sosyal dramalar, sosyal politikalar. *Sosyal Mucit Academic Review*, 4(1), 71-112.

Polat, A.I. and Gül, M. 2023. An Analysis of Mitigation Measures for Furniture in Education Buildings to Prevent Earthquake Hazards. *Journal of Interior Design and Academy*, 3(1), 77–95. https://doi.org/10.53463/inda.20230186

Soriano Jr, M. A., Jaojoco, P., Carroll, B., Maxwell, R., & Carruth, A. (2025). Public discourses and personal narratives of learning from disaster. *npj Climate Action*, *4*(1), 20.

TÜBİTAK. (2023). Research project report of TÜBİTAK 1001, "Deprem Sürecinde Yapısal Olmayan Elemanların Neden Olduğu Risk ve Tehlikeler İçin Ölçülebilir Bir Yöntem ve Eğitim Programı İle İç Mimarlık Öğrencilerinin Bilgi ve Farkındalıklarının Geliştirilmesi" Project Number 121K927. The Scientific and Technological Research Council of Türkiye.

Underwood, B. S., Mascaro, G., Chester, M. V., Fraser, A., Lopez-Cantu, T., & Samaras, C. (2020). Past and present design practices and uncertainty in climate projections are challenges for designing infrastructure to future conditions. *Journal of Infrastructure Systems*, *26*(3), 04020026.

Wang, T., Shang, Q., & Li, J. (2021). Seismic force demands on acceleration-sensitive nonstructural components: a state-of-the-art review. *Earthquake engineering and engineering vibration*, *20*(1), 39-62.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Spatial Hybridization and the Transformation of Identity: A Study on Rural Settlements and Secondary Houses in the Edremit Gulf

Aysu ÇAKIR [1]*

ORCID 1: 0000-0002-6922-9896
[1]Research Assistant, İzmir Democracy University, Faculty of Architecture, Department of Architecture, İzmir-Türkiye
aysucakir1994@gmail.com **(**Responsible Author)

Gaye BİROL [2]

ORCID 2: 0000-0001-8230-3547
[2] Prof. Dr., İzmir Democracy University, Faculty of Architecture, Department of Architecture, İzmir-Türkiye
gaye.birol@idu.edu.tr

Abstract

"Sayfiye" areas emerged in 19th-century Europe to escape urban pressures and seek renewal. In Türkiye, this culture gained popularity after the 1950s, initiating a new spatial transformation through widespread second-home developments in coastal areas. Unlike large-scale tourism practices on the Marmara and Aegean coasts, development in the Edremit Gulf is dominated by individual second homes, fundamentally changing the region's olive-based rural character. This area has recently undergone a deeper transformation driven by luxury housing demand, particularly from Istanbul. This study examines the spatial hybridization of Edremit Gulf settlements, interpreted through the regional urbanization literature. The methodology includes mapping and spatial analyses to reveal growth and change, while zoning plans and demographic data assess the transformation. Consequently, the emergence of hybrid spatialities can be observed where rural landscapes intersect with second-home developments. This process involves the conversion of olive groves into residential areas, leading to transformations in traditional production patterns and the blurring of the urban–rural boundary, reflecting an ongoing process of regional urbanization.

Keywords: Second homes, rural settlements, spatial hybridization, Edremit Gulf, seasonal urbanism

1.Introduction

Places located outside the city but connected to it, which are visited for recreational purposes at certain times of the year, are defined today as secondary residences, while historically this phenomenon was known as "sayfiye." Derived from the Arabic words "sayf" (summer season) and "sayfi" (belonging to or related to summer), 'sayfiye' is defined by the Turkish Language Association as "a place or house where one spends the summer season" or "a rural area close to the city" (Türk Dil Kurumu, 2025). This concept has a conceptual depth that encompasses not only the structure used solely for spending the summer season, but also the region where this structure is located.

In Türkiye, the modern understanding of "sayfiye" seasonal leisure retreats used by urban residents began to take shape in the everyday practices of the urban elite in Istanbul from the 18th century onward. Throughout the 19th century, with the development of transportation, the transformation of leisure culture, and increasing class differentiation, areas such as Bosphorus waterfront mansions (*yalı*), garden pavilions, Adalar, and Kadıköy emerged as spatial manifestations of the seasonal movement from the city toward the countryside (Alkan, 2014). From the mid-century onward, improved transportation networks facilitated the emergence of "sayfiye" zones in regions beyond the Marmara area as well (Yağan, 2015, p. 115).

This state-supported process accelerated the discovery of Anatolia's coastal and rural areas, enabling a broader segment of society across different income groups to acquire second homes along the coast or in rural settings. Although initially perceived as a positive development, this trend turned into uncontrolled growth toward the end of the century, generating serious challenges. These dwellings, used only during certain periods of the year, remained vacant for the rest of the time, effectively transforming into "ghost settlements" a condition that continues to pose significant issues today (Çoban, 2012).

Today, second home mobility has evolved from a seasonal vacation practice into a multi-layered phenomenon that permanently alters regional economies, land use, and demographic structures. Unlike the rapid urbanization and tourism-focused large-scale projects observed along the Aegean and Mediterranean coasts, especially over the past twenty years, regions such as the Edremit Gulf, which have preserved their unique rural production structures, are being transformed primarily by individual second homes and, more recently, by increasing demand for luxury housing (Birol, 2017). This process is fragmenting the traditional fabric of coastal and rural areas, increasing real estate values, and accelerating regional urbanization processes that blur the distinction between urban and rural areas.

The primary objective of this study is to analyze the spatial hybridization experienced by rural settlements in the Edremit Gulf through second home development and the effects of this process on local identity. The study aims to evaluate the findings in light of the regional urbanization literature, demonstrating how rural areas integrate with new urban extensions.

2.Materials and Methods

2.1. Area of the Case Study

The Northern Aegean Region, as a significant part of the Mediterranean basin, encompasses the coastal strip extending from the Dardanelles Strait to the Foça district of İzmir on the map of Türkiye. This broad geography includes the provinces of Balıkesir and Çanakkale, as well as part of İzmir, offering a distinctive landscape where rural, coastal, and urban dynamics intertwine (Figure 1).



Figure 1. Edremit Gulf Area (Prepared by Authors)

The Edremit Gulf within this region has been designated as the main area of study due to its unique spatial development characteristics. Unlike other popular coastal areas in Türkiye, the

transformation in the Gulf is almost entirely focused on individual secondary residences rather than large tourism facilities. This situation provides a suitable ground for examining the direct impact of second homes on the rural character. The Edremit Gulf has been a holiday destination for the middle class from Istanbul and the Marmara Region, especially since the 1980s, and today it has established a deepening relationship with the demand for luxury housing from large cities.Within this unique context, the study covers the Edremit district of Balıkesir province and its coastal and rural neighborhoods in detail. The district of Edremit offers the opportunity to observe the process of spatial hybridization at different scales and layers, as it has both inner neighborhoods that maintain a strong rural production structure based on olive cultivation and coastal neighborhoods with a high concentration of second homes. The intersection of these two distinct fabrics forms a critical section where concrete problems such as the destruction of olive groves and the transformation of traditional structures are most clearly visible.

2.2. Methods

In this study, mapping, demographic analysis, and archival research were employed as the main methodological tools to examine the spatial transformation of the Edremit district through a multi-layered approach. In the first section, the historical evolution of summer resort areas and their transformation into second-home zones is explained. The subsequent section discusses the pressures on coastal areas and the Integrated Coastal Zone Plan developed to mitigate these pressures.

In the following part of the study, the spatial dimension of transformation in the Edremit district is analyzed by identifying the growth boundaries of coastal and rural settlements through satellite imagery from different periods. This mapping process concretely reveals the land-use changes, particularly in areas where olive groves have been destroyed and opened to residential development. To evaluate the legal framework of spatial change, the Balıkesir–Çanakkale Integrated Coastal Zone Plan was examined.

Additionally, by using periodic demographic data obtained from TÜİK, the long-term changes in rural and urban populations were analyzed. Ultimately, all findings derived from the mapping, legal review, and demographic analyses were interpreted in light of the regional urbanization literature, and the resulting spatial hybridization and the transformation of local identity were assessed.

3.Historical Development of “Sayfiye Houses’’

Structures located outside urban settlements and used for temporary dwelling can be traced back to Ancient Rome (Alkan, 2014, p. 16). The Roman aristocracy developed a seasonal lifestyle in which they could simultaneously maintain agricultural production and leisure, particularly through the construction of rural residences such as *villa rustica* and *villa urbana*, built to escape the heat and the intensity of the city during the summer months (Alkan, 2014, p. 16). In terms of both their functions and spatial configurations, these building typologies can be considered the earliest precursors of what is today conceptualized as sayfiye houses.

From the 15th century onwards, this concept has been maintained in various forms across Europe. For example, wealthy Florentine families in the Tuscany region had summer residences built outside the city, surrounded by nature; while in the 16th century, Venetians in the Veneto region built summer villas in rural areas, turning towards nature while also reproducing their urban identity in the countryside. These structures were not merely summer residences; they also functioned as representative spaces where art, landscape, and architecture converged.

"Sayfiye" areas that emerged in the 17th and 18th centuries began to proliferate rapidly after World War II, as the middle class discovered these places as recreational destinations (Özgüç, 1977, p. 13). Factors such as rapid economic growth in economically strong countries, urban expansion and increasing building density, the growing difficulties of urban life, advances in transportation technologies, the widespread ownership of automobiles, increased individual mobility, reduced working hours, and lower retirement ages all encouraged people to acquire a second home (Gündüz, 2003, p. 1).,

The formation of "sayfiye" culture in Türkiye has developed in parallel with the historical continuity of settlement traditions in Anatolia. The recreational practices observed during the Roman period through coastal palaces, bathhouses, and thermal springs continued in various forms throughout the Seljuk and Ottoman periods (Kuru & Yazıcıoğlu Halu, 2020).

In Türkiye, the modern notion of "sayfiye" began to take shape in the everyday practices of the urban elite in Istanbul from the 18th century onward. Although the "sayfiye" culture in Istanbul is known to have existed since the Byzantine period, it became more widespread among the general population in the 19th century under Ottoman rule (Yağan, 2015, p. 92). Throughout the 19th century, improved transportation opportunities, transformations in leisure culture, and increasing class differentiation led areas such as Bosphorus waterfront mansions (*yalı*), garden pavilions, Adalar, and Kadıköy to emerge as spatial expressions of the seasonal movement from the city toward the countryside (Alkan, 2014, p. 22).

The establishment of Şirket-i Hayriye, the city ferry company, in 1851 marked a turning point in accessing "sayfiye" areas (Yağan, 2015, p. 93). During this period, the Bosphorus and the Adalar developed as prominent "sayfiye" settlements. As "sayfiye" life became more common among the public in the 19th century, new spaces such as hotels, sea baths, beaches, summer cinemas, and waterfront entertainment venues also began to appear in addition to summer houses (Figure 2) (Özkahraman Şen, 2024, p. 47).



Figure 2. Sea Baths in İstanbul (Url-1)

During the Republican Period, with the dissolution of the Ottoman Empire and the establishment of the new state, Türkiye underwent extensive transformation processes across many domains. These changes also influenced *sayfiye* houses; particularly the innovations in

social and cultural life, along with the opportunities brought by technological developments, redefined both the architectural typology and the spatial distribution of *sayfiye* dwellings (Yağan Köylü, 2024, p. 1840). During this period, owners of traditional wooden summer pavilions began to demolish their houses and replace them with new modern villas (Özkahraman Şen, 2024, p. 48).

In Istanbul, Florya became an important *sayfiye* settlement especially for the general public. During the Republican Period, a decision was made to transform Florya into a coastal recreational facility. In this context, the Florya Public Beach was constructed in 1935, along with the Florya Sea Pavilion (*Florya Deniz Köşkü*), designed as Atatürk's summer residence (Figure 3) (Özkahraman Şen, 2024, p. 48).



Figure 3. Florya Atatürk Marine Mansion (URL-2)

From the mid-20th century onward, as intercity transportation opportunities improved, *sayfiye* areas began to emerge in various regions beyond the Marmara Region. Many of the *sayfiye* areas within Istanbul lost their recreational character as they became engulfed by rapid urbanization and were absorbed into the expanding city center. This transformation of *sayfiye* settlements also led to profound changes in the meanings attributed to these spaces by society. Traditionally, *sayfiye* areas were defined as places that allowed individuals to escape the pressures of urban life, rest, and reconnect with nature (Bora, 2014). Accordingly, these areas were expected to maintain limited construction, preserve the natural environment, and offer a lifestyle far from urban density.

As people sought to move away from the increasing pressures of the city, they began to turn toward coastal zones in different regions (Yıldız, 2011). In the 1960s, various holiday destinations in Türkiye started to be promoted through newspapers and brochures, and the first planned second-home settlements in the country began to be developed in Çeşme (Şuta, 2020).

The planning flexibilities and investment incentives provided by the 1969 Cooperatives Law and the Tourism Encouragement Law enacted in 1982 enabled state policies to be shaped in a way that supported the use of coastal areas for tourism purposes (Yıldız, 2011).

In 1969, the coastal strip between the provinces of Çanakkale and Balıkesir was designated as a Tourism Region, and tourism-oriented planning was envisaged for this area. From the 1980s onward, second-home practices began to spread across much of Türkiye's coastal zone.

An examination of the development of *sayfiye* areas in Türkiye reveals that the 1950s marked a significant turning point, after which these areas increasingly transformed into second-home zones. This shift profoundly altered the spatial organization, user profiles, and functional character of coastal settlements. As a result, the traditional *sayfiye* culture historically rooted in seasonal leisure and rest was gradually replaced by denser construction patterns, tourism-oriented developments, and a new coastal settlement model that supports continuous population mobility (Figure 4).

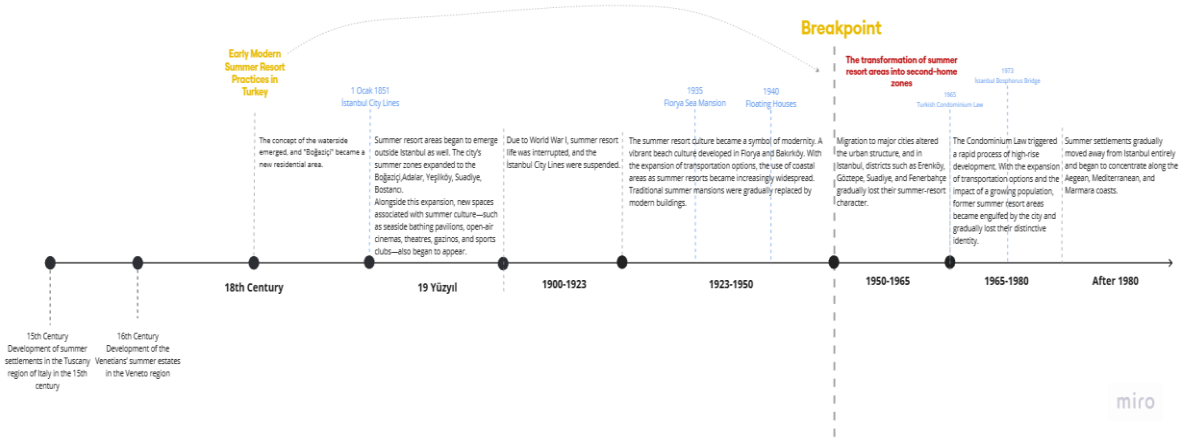


Figure 4. Historical development of summer resort areas (Prepared by the authors)

4. Threats to Coastal Areas and Integrated Coastal Management

The coast is defined as a transition zone between land and sea and has historically been an attractive area of settlement due to its natural characteristics and ecological opportunities. Coastal areas have become significant spatial focal points throughout different periods, preferred for settlement, production, and recreation owing to their transportation and trade advantages as well as their climatic and environmental benefits.

Coastal areas in Türkiye are confronted with a range of challenges. The primary sources of these issues can be identified as urbanization, tourism activities, specialized industrial uses, and the search for identity within coastal zones (Figure 5). The intense rural-to-urban migration of the 1960s brought about unplanned urbanization and informal construction, and coastal regions became some of the most affected areas in this process. The rapid expansion of cities, insufficient environmental control mechanisms, and infrastructural deficiencies weakened the fragile structure of coastal ecosystems in a short period of time. In addition, recent transformations in the energy, transportation, and housing sectors have further increased the pressure on coastal areas (Gülbitti & Özüduru, 2020).

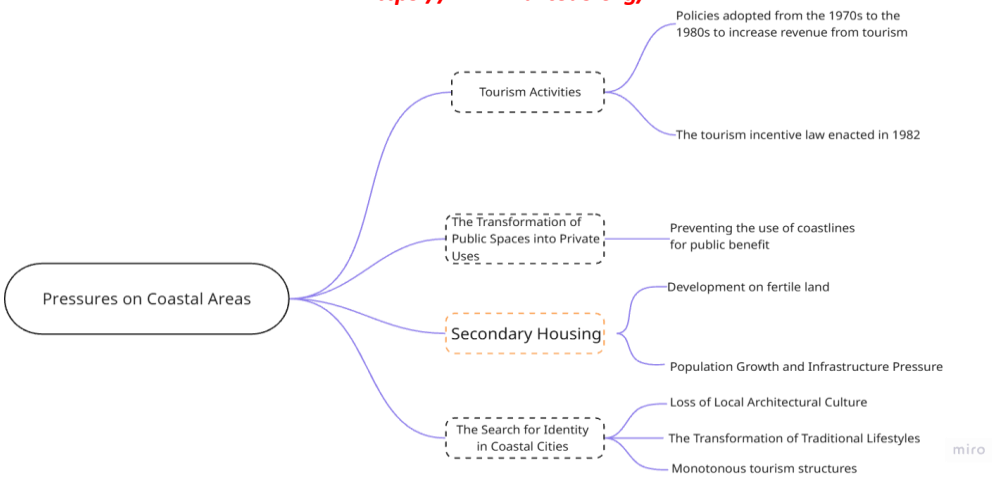


Figure 5. Pressures on Coastal Areas (Prepared by the authors)

Since the 1980s, state-led tourism policies have stimulated mass tourism along coastal zones and opened extensive areas to construction (Alkay, 1995). During this period, tourism centers expanded rapidly with the development of hotels and holiday complexes, while the growing number of second homes further intensified urban pressures on coastal regions. Consequently, coastal areas have increasingly lost their natural and cultural qualities and have become zones whose sustainability is seriously threatened by the combined impacts of tourism facilities and second-home development.

Ensuring the sustainability of coastal areas is closely tied to planning practices and coastal management. To support the sustainable use and controlled governance of these zones, the concept of Integrated Coastal Zone Management has emerged. According to the Spatial Plans Construction Regulation (2014), Integrated Coastal Zone Plans are defined as strategic plans prepared specifically for coastal and interaction zones, operating outside the formal spatial planning hierarchy and guiding lower-level zoning plans.

In Türkiye, Integrated Coastal Zone Plans have been prepared for various regions since 2007. The distribution of the 1/100,000-scale planning studies developed for different parts of the country is presented in Figure 6.

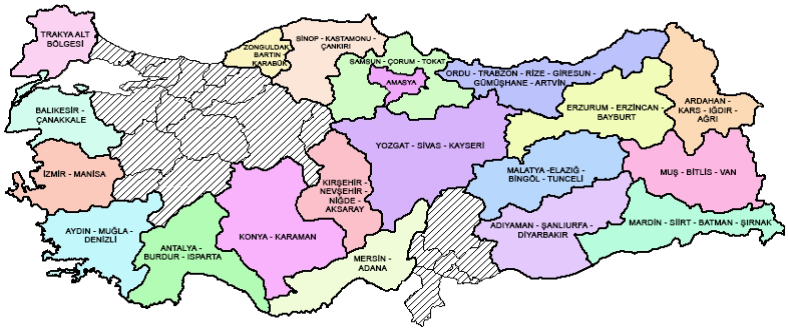


Figure 6. 1/100,000-scale Environmental Plan and the Integrated Coastal Zone Plans covering the coastal provinces (MPGM, 2023).

According to the seven main coastal regions defined in the Integrated Coastal Zone Plan for the Çanakkale–Balıkesir provinces, the area examined in this study the Edremit Gulf falls within Regions 5 and 6 (MPGM, 2023). Planning studies have been conducted for regions 5 and 6,

which are divided into sub-regions. Region 5 consists of an area rich in natural values. The most important value in the region is Kaz Mountains National Park (Uzun Aydın, 2024). While residential areas constitute the settled use of Region 5, the predominant non-settlement use areas consist of agricultural areas and forests. Among the settlements in the Fifth Region, the two districts with the highest population density are Edremit and Burhaniye. These districts are subdivided into sub-regions, with sub-region 5.1 covering Edremit and sub-region 5.2 covering Burhaniye district.

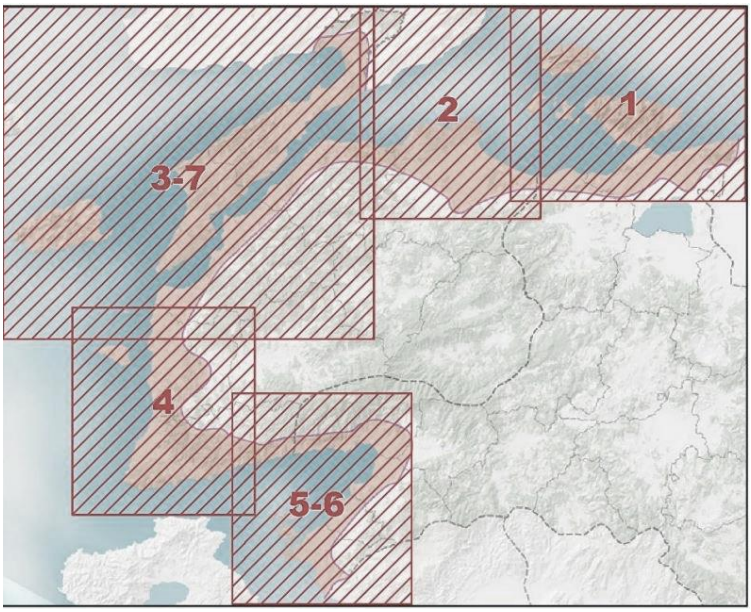


Figure 7. Seven main coastal regions defined in the Integrated Coastal Zone Plan for the Çanakkale–Balıkesir provinces (MPGM, 2023).

5. Spatial Hybridization and the Transformation of Identity in the Edremit Region

Within the scope of this study, the Edremit Region located in the fifth zone of the Integrated Coastal Zone Plans prepared for the Çanakkale–Balıkesir provinces was examined, with a particular focus on the spatial transformation and identity change occurring between rural and urban areas as a result of second-home development.

Located in the northwest of the Aegean Region, Edremit District is a settlement with 5 towns, 15 neighborhoods, and 20 villages belonging to the province of Balıkesir. However, with the law enacted in 2012, all settlements in the district have been granted neighborhood status as part of Balıkesir's process of becoming a metropolitan municipality. Currently, there are 47 neighborhoods. The district is located 10 km inland from the Edremit Gulf, which shares the same name. The neighborhoods of the district are lined up from the slopes of the Kaz Mountains overlooking the gulf to the Ayvacık district of Çanakkale (Şimşir, 2020).

The region is characterized by a Mediterranean climate, with hot and dry summers and mild, rainy winters. Most of Edremit’s vegetation consists of forested areas and olive groves (Kocadağlı, 2009). Olive groves account for 85% of the total agricultural land (Edremit Chamber of Commerce, 2021). According to data from the Edremit District Directorate of Agriculture, since 1990 a large portion of these olive-producing areas has been degraded due to second-home developments and tourism activities. Tourism in the region is known to have begun in 1969, when the Turban Holiday Village was leased by a French company (Uzun

Aydın, 2024). Following this period, the construction of second homes increased, accompanied by the development of boutique hotels, campgrounds, and summer housing complexes.

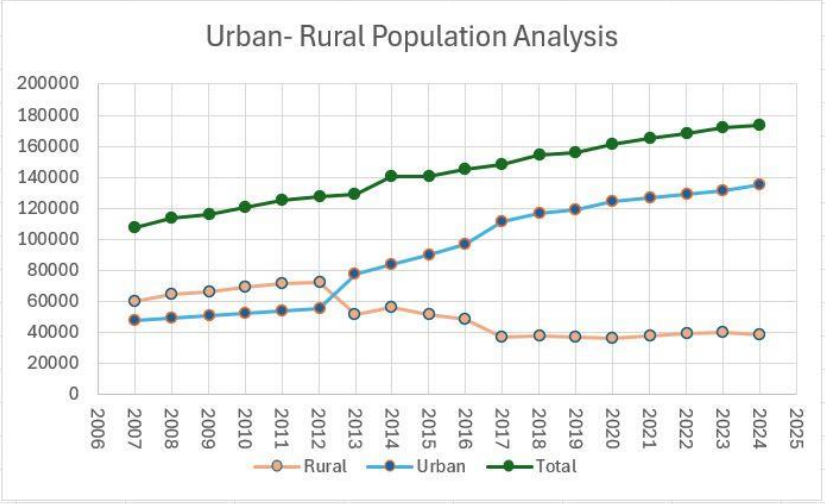
According to data obtained from TÜİK, the population of Edremit in 2024 is 173,689. Of this total, 15 neighborhoods are classified as urban, while 32 neighborhoods have a rural character (Table 1).

Table 1. Edremit Urban/Rural Population

EDREMİT URBAN/RURAL POPULATION		
NEIGHBORHOOD NAME	URBAN / RURAL	TOTAL POPULATION (2024)
CENNETAYAĞI	URBAN	15424
ALTINKUM	URBAN	13685
TUZCUMURAT	URBAN	12121
İKİZÇAY	URBAN	11977
CUMHURİYET	URBAN	9533
SARIKIZ	URBAN	9029
ŞAHİNDERE	URBAN	8986
KADIKÖY	URBAN	8558
HAMİDİYE	URBAN	8371
ALTINOLUK	URBAN	7140
EROĞLAN	URBAN	6370
GAZİCELAL	URBAN	5963
AKÇAY	URBAN	5597
CAMİVASAT	URBAN	4632
İSKELE	URBAN	4037
DARSOFA	URBAN	3921
ZEYTİNLİ	RURAL	3640
AVCILAR	RURAL	3061
İBRAHİMCE	RURAL	3034
GÜRE	RURAL	2793
ATATÜRK	RURAL	2541
SOĞANYEMEZ	RURAL	2196
GAZİİLYAS	RURAL	2046
ÇAMLIBEL	RURAL	1882
GÜRE	RURAL	1741
ORTAOBA	RURAL	1721
HEKİMZADE	RURAL	1710
NARLI	RURAL	1686
KIZILKEÇİLİ	RURAL	1331
TAHTAKUŞLAR	RURAL	1255
YOLÖREN	RURAL	1187
TURHANBEY	RURAL	1136
BOSTANCI	RURAL	968
KAPICIBAŞI	RURAL	585
ÇAMCI	RURAL	559
YAŞYER	RURAL	465
MEHMETALAN	RURAL	405
ÇIKRIKÇI	RURAL	371
DERELİ	RURAL	335
HACIARSLANLAR	RURAL	328
DOYRAN	RURAL	285
YAYLAÖNÜ	RURAL	275
KAVLAKLAR	RURAL	203
ARITAŞI	RURAL	194
PINARBAŞI	RURAL	145
HACITUĞRUL	RURAL	141
BEYOBA	RURAL	126
		173689

While the overall population of the settlement has continued to increase, an examination of the changes in urban and rural populations over the years shows that the population in urban neighborhoods has grown, whereas the population residing in rural neighborhoods has declined (Table 2).

Table 2. Edremit Urban/Rural Population



This situation is directly linked to the concentration of second-home oriented development along the coastal zones, the shift of the population withdrawing from agricultural production toward the service and tourism sectors, and the increasing development pressure on rural areas (Birol, 2017). The decline in the rural population leads to the weakening of traditional production practices and the transformation of rural identity, while the growth of the urban population—particularly in coastal neighborhoods—introduces new dynamics such as seasonal density, infrastructure pressure, and spatial hybridization. Among the urban neighborhoods of Edremit, Altınoluk and Akçay are located along the coastline and rank among the most populated districts in the region. As one moves inland from the coast, rural neighborhoods become more prominent; among these, Güre and Zeytinli maintain a rural character yet exhibit intensive second-home development (Figure 8).



Figure 8. Edremit Region Rural and Urban Neighbors (prepared by the authors based on Google Earth image)

An examination of the 2017 Çanakkale–Balıkesir Integrated Coastal Area Design reveals that land use in coastal zones has been largely allocated for development purposes. Residential and tourism-oriented development areas located immediately behind the shoreline constitute the uses that exert the greatest pressure on the coastal ecosystem. In contrast, moving inland from

the coast, forested areas and extensive olive groves dominate the landscape, indicating a stronger preservation of natural and agricultural environments. This spatial differentiation highlights the pronounced tension between the intense development pressure along the coastline and the agricultural production zones that remain protected in the inland areas.

According to the planning data, the Güre and Zeytinli neighborhoods examined within the scope of this study are marked in yellow and designated as "areas open to development" (MPGM, 2023). This indicates that these neighborhoods lie within potential development corridors where both current construction trends and second-home demand are expected to increase further in the future (Figure 9). The fact that olive groves in these areas are exposed to such development pressures presents a critical risk in terms of the weakening of rural character, the fragmentation of the natural landscape, and the acceleration of urban sprawl. Accordingly, the land-use pattern outlined in the plan provides important insights into the coastal–rural interaction across the Edremit Gulf and illustrates the deepening imbalance between dense coastal development and the preservation of agricultural and natural areas further inland.

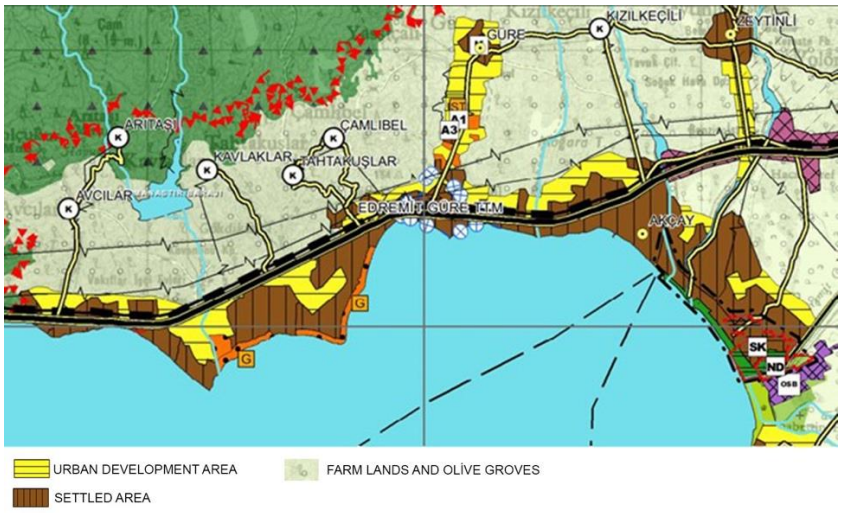


Figure 9. I17 Sub-Region of the 1/100,000-Scale Environmental Plan for the Balıkesir–Çanakkale Planning Area (MPGM, 2025).

An examination of the change in built-up areas over the years shows that, as indicated in the Çanakkale–Balıkesir Integrated Coastal Area Plan, the neighborhoods of Güre and Zeytinli have increasingly been opened to development. Coastal settlement areas, which were already subject to intensive use, have grown even denser over time, and the expansion of the building stock has produced a continuous urban fabric along the shoreline. This increase in density has reinforced second-home–oriented development trends spreading inland from the coast; consequently, agricultural landscapes particularly olive groves have begun to fragment, disrupting the continuity of the natural environment (Figure 10).

Moreover, the shift of development toward rural areas contributes to the blurring of spatial boundaries between the coast and the countryside, the erosion of traditional settlement character, and the increasing visibility of the region's vulnerability associated with seasonal population growth. This rise in building density intensifies pressure on infrastructure services, strains carrying capacity, and threatens the long-term sustainability of coastal ecosystems (Birol, 2017).

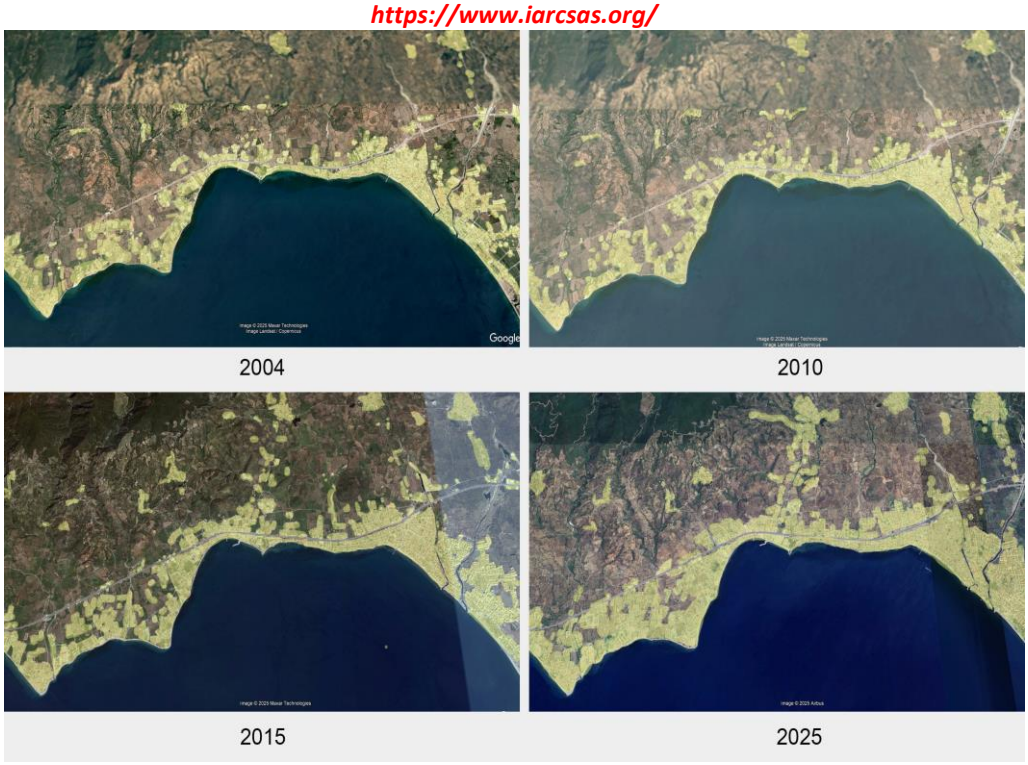


Figure 10. Temporal Transformation of the Built Environment in the Edremit Region (prepared by the authors based on Google Earth image)

The expansion of second-home oriented development into inland areas increasingly undermines the region's distinctive rural character. Güre Neighborhood possesses a unique settlement structure, shaped by its historical fabric that includes houses inherited from the Greek communities who once lived in the area, as well as traces of an olive-based production culture (Kahyaoğlu, 2021). However, the recent intensification of development pressure has made it difficult to perceive this distinctive character in a coherent and holistic manner (Figure 11).

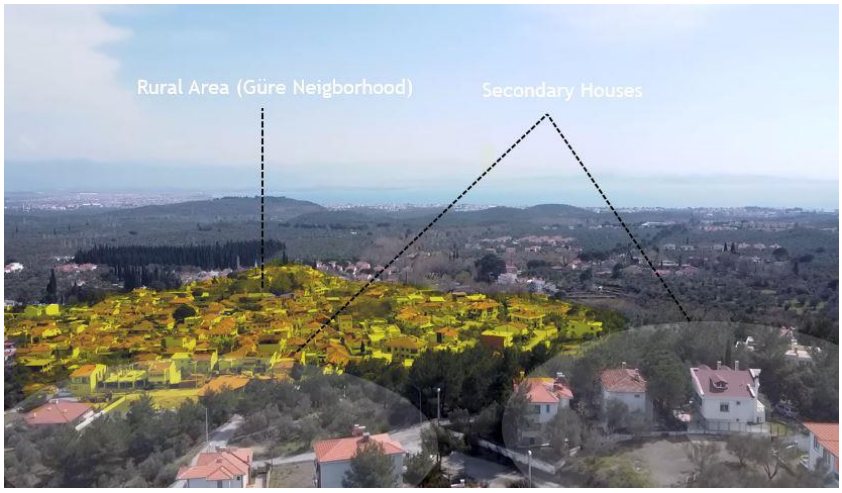


Figure 11. Temporal Transformation of the Built Environment in the Edremit Region (prepared by the authors)

The traditional houses built with stone or adobe construction techniques, which constitute the unique spatial character of the settlement, have gradually been replaced by new buildings of

low architectural quality, standardized forms, and weak connections to the local context. This transformation not only results in a loss of physical and architectural quality in the environment but also visibly erodes the historical identity and cultural memory of the settlement.



Figure 12. Example of traditional housing (left) and new building typology (right) (Aysu Çakır personal archive, 2024).

Identity-defining elements such as the traditional street layout, the use of courtyards, the material vocabulary, and the scale of buildings are increasingly fading under the pressure of new development; the unique rural spatial character is fractured and replaced by a homogeneous, repetitive, and often "everywhere-like" anonymous housing typology. This process generates both morphological and socio-cultural ruptures within the settlement: while the olive-based production culture weakens, seasonal second-home use introduces a new population profile and lifestyle into the neighborhood. Consequently, the historical and local identity is gradually pushed into the background, and the settlement assumes an intermediate character that can be described as spatial hybridization.

6. Conclusion and Recommendations

This study comprehensively reveals how the second-home development that accelerated particularly after the 1980s in the Edremit Region has transformed the spatial organization between the coastal and inland areas and how it has affected rural identity. The findings indicate that second-home–oriented growth is not merely a dynamic of physical expansion; rather, it represents a multilayered transformation process that redefines the interaction between coastal and rural zones.

Urry's (1995) approach, which argues that space is continually reproduced through consumption practices, provides an important framework for understanding this transformation in Edremit. According to Urry, modern individuals are drawn to certain places in their desire to escape the pressures of everyday life; however, this very act of consumption eventually triggers a transformation that erodes the unique qualities of those places (Urry, 1995). The rapid proliferation of second homes in the Edremit Gulf has evolved in a similar manner: coastal settlements initially chosen for their appeal as places "away from the city" have, under the pressure of rising demand, been reshaped into areas that reproduce urban lifestyles, housing typologies, and expectations. Consequently, these coastal settlements have gradually lost their inherent *sayfiye* character and, in line with Urry's conceptualization, have become spatial commodities that are consumed and continually reproduced (Urry, 1995).

The spatial analyses of the study show that second-home developments concentrated along the coastline have gradually expanded inland, leading to significant fragmentation of the agricultural landscape, particularly the olive groves. Urbanization advancing toward the Kazdağları National Park has also begun to pose a threat to protected sites over time (Uzun Aydın, 2024).

In rural neighborhoods characterized by traditional stone and adobe housing patterns, the local architectural identity has weakened, giving way to standardized, low-quality, and contextually detached building typologies. This shift can be regarded as a significant rupture that undermines the historical continuity of the settlement and accelerates the erosion of rural identity. Population analyses based on TÜİK data reveal a steady population decline in inland neighborhoods, in contrast to the increasing urban population in coastal areas. This pattern creates a fragmented settlement structure shaped by seasonality and second-home use, leading to marked changes in the region's socio-economic fabric. The sharp rise in population during the summer months places considerable pressure on infrastructure and challenges the carrying capacity of these settlements, while the dramatic population decline in winter prevents the maintenance of a coherent year-round settlement cycle.

Planning documents indicate that the neighborhoods of Güre and Zeytinli are designated as "areas open to development," signaling that current pressures are likely to intensify in the future. In this context, the protection of olive groves, the ecological management of the coast–rural transition zone, and capacity-based planning for second-home development are of critical importance for the sustainability of the region.

To mitigate the adverse effects of second-home driven spatial hybridization in the Edremit Region, there is a need for planning strategies grounded in carrying-capacity–based coastal–rural management. Protecting olive groves and agricultural landscapes through clear regulatory measures, limiting building density, height, and parcel-based development in "areas open to development" such as Güre and Zeytinli, and concentrating new second-home growth in designated zones while strictly restricting construction in ecologically sensitive areas would help preserve both the coastal ecosystem and the continuity of the rural landscape.

Furthermore, managing the ongoing transformation of local identity requires tools not only at the planning scale but also at the level of architectural character and participatory governance. Design guidelines that reference the traditional stone and adobe housing patterns, street layouts, material use, and building scales, along with mechanisms supporting the registration and maintenance of culturally significant structures, can strengthen the visibility of rural architectural heritage. Ensuring that these processes involve local governments, professional chambers, civil society actors, long-term residents, and second-home users will allow seasonality, infrastructure pressures, and identity-related challenges to be addressed more holistically. Such an approach also creates a foundation for comparative research on spatial hybridization dynamics across other coastal regions in Türkiye.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Alkan, M. (2014). Osmanlı'da Sayfiye'nin İcadı. *Sayfiye Hafiflik Hayali.* İstanbul: İletişim Yayınları.

Alkay, E. (1995). *Kentsel Peyzaj Öğesi Olarak Kıyı Mekanı ve Bandırma Üzerine Bir Inceleme.* (Yüksek Lisans Tezi). İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.

Arkon, C. (1997). Kıyılarımızın günümüzdeki görüntüsü. *Ege Mimarlık*. 7-24, 39-43.

Birol, G. (2017). Türkiye'de Yazlık İkinci Konutların Yarattığı Sorunlar Bağlamında Balıkesir İli Ege Kıyılarındaki Yazlık İkinci Konutlara Genel Bir Bakış. Access Address (10.11.2025)https://www.arkitera.com/gorus/turkiyede-yazlik-ikinci-konutlarin yarattigi-sorunlar-baglaminda-balikesir-ili-ege-kiyilarindaki-yazlik-ikinci-konutlara-genel-bir-bakis/

Bora, T. (2014). *Sayfiye Hafiflik Hayali.* İstanbul: İletişim Yayınları.

Çoban, A. N. (2012). Cumhuriyetin ilanından günümüze konut politikası. *Ankara Üniversitesi SBF Dergisi*. 67-3. 75-108.

Edremit Ticaret Odası. (2021). *2022-2025 Stratejik Plan Raporu.*

Emekli, G. (2014). İkinci konut kavramı açısından turizm coğrafyasının önemi ve Türkiye'de İkinci konutların gelişimi. *Ege Coğrafya Dergisi*. İzmir.

Gülbitti, M., & Özüduru, B. H. (2020). Türkiye'deki bütünleşik kıyı alanları yönetimi süreçlerinin stratejik mekânsal planlama süreçleri ile ilişkili olarak değerlendirilmesi. *Planlama, 30*(1), 36–53. https://doi.org/10.14744/planlama.2019.09815

Gündüz, E. (2003). *Tatil Amaçlı İkincil Konutların Fiziksel ve Sosyal Yapıya Etkileri Mahmutlar Örneği* (Master's Thesis). Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Konya.

Çevre, Şehircilik ve İklim Değişikliği Bakanlığı. (2023). *Balıkesir-Çanakkale İlleri Bütünleşik Kıyı Alanları Plan Açıklama Raporu.* Ankara: Mekansal Planlama Genel Müdürlüğü.

Kahyaoğlu, S. (2021). Edremit Tarihi - Uygarlıkların Körfezinde 3500 Yıl. Kafe Kültür Yayıncılık.

Kocadağlı, A. Y. (2009). Türkiye'de zeytincilik faaliyetlerinde Edremit Körfezi kıyılarının önemi. *Coğrafya Dergisi, 19*, 28-58. Online ISSN: 1305-2128.

Kuru, Z., & Yazıcıoğlu Halu, Z. (2020). Sayfiye Yerleşimlerinin tarihsel süreç içerisindeki değişimine yönelik bir araştırma: Dragos, Orhantepe Mahallesi örneği. *Akdeniz İnsani Bilimler Dergisi*, 10, 339-361. https://doi.org/10.13114/MJH.2020.535

Özgüç, N. (1977). Sayfiye yerleşmeleri: Gelişme ve başlıca özellikleri. *İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi*, 22: 144-162.

Özkahraman Şen, M. (2024). İstanbul'da yazlık kültürünün değişimi. *Arredamento Mimarlık*, 365, p. 45-50.

Şimşir, N. (2020). Balıkesir Tarihi Araştırmaları II- Edremit Tarihi Araştırmaları.

Türk Dil Kurumu (2025). Güncel Türkçe Sözlük. Access Address (10.11.2025) https://sozluk.gov.tr/

Uzun Aydın, B. (2024). *Kuzey Ege Kıyı Bandının Peyzaj Mimarlığı Bağlamındaki Zamansal-Mekânsal Değişimi* (Yüksek lisans tezi). İstanbul Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, İstanbul. https://polen.itu.edu.tr/items/b975b230-5f46-44c6-bb7d-61b00e8acb50

Urry, J. (1995). Consuming Places, London and New York: Routledge.

Yağan, N. B. (2015). *Transition Process of Urban Resort Areas in Istanbul Before 1980* (PhD thesis). Yıldız Technical University, Graduate School of Science and Engineering, Department of Architecture. Accessed Address (08.11.2025).

Yıldız, M. (2011). *Turizmin Gelişmesine Bağlı Olarak İkincil Konutlarda Mekân Analizi: Manavgat Örneği*. (Yayınlanmamış Yüksek Lisans Tezi). Selçuk Üniversitesi/Fen Bilimleri Enstütisü, Konya.

Url-1, https://www.istdergi.com/index.php/tarih-belge/deniz-hamaminda-bir-saat, 10.11.2025

Url-2, https://www.kulturportali.gov.tr/turkiye/istanbul/gezilecekyer/florya-ataturk-denz-kosku, 10.11.2025

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

A Comparative Analysis of Similar Traditional Wall Construction Techniques in Different Regions

Ayça AKKAN ÇAVDAR [1]

ORCID 1: 0000-0002-3333-8943
[1] Research Assistant, Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
ayca.akkan@erdogan.edu.tr

Esra LAKOT ALEMDAĞ [2*]

ORCID 2: 0000-0003-0959-2068
[2] Assoc. Dr., Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
esra.lakotalemdag@erdogan.edu.tr **(**Responsible Author)

Abstract

Traditional wall construction techniques have produced solutions of high value in terms of functionality, aesthetics, and culture across different geographical regions by adapting to local materials and climatic conditions. Methods known as "Bağdadi" and "Çörten" in Turkiye, "Wattle and Daub" in Europe, and "Oeyeokki" in Korea have resulted in structures that are both durable and visually striking through the creative combination of natural materials such as wood and earth. A review of the literature reveals that traditional wall techniques not only address local needs but also play an important role in social memory, craftsmanship knowledge, and cultural continuity. These systems directly reflect sustainable design approaches through their contributions to moisture management, thermal insulation, and material efficiency. The study compares the historical origins, structural characteristics, and environmental contexts of these techniques to explain why similar methods developed in different regions. It also discusses how these traditional techniques can inspire modern architectural practices in terms of sustainability, material efficiency, and the preservation of cultural heritage. The results indicate that these construction methods are not only a reflection of the past but also an important resource for environmentally friendly and innovative designs. Consequently, the preservation of traditional wall construction methods and their adaptation to contemporary architectural practices are considered important approaches that can contribute both to the preservation of regional identities and to the development of sustainable building practices.

Keywords: Bağdadi, wattle and daub, oeyeokki, traditional wall construction, cultural heritage.

1. Introduction

Traditional timber construction methods can look quite different from one region to another, but they almost always reflect the everyday life and values of the people who built them. The wooden buildings in the Dong community, for example, have very unique shapes and meanings. They clearly show how their cultural traditions affected how they built (Huang & Qin, 2023). In Korea, the method is a little different. Builders often used gently curved wood pieces to make the building stronger and because it looked more elegant (Ryoo & Youn, 2019). These kinds of examples suggest that traditional builders had a strong understanding of their environment and materials, and they tried to design in a way that felt natural and appropriate for where they lived.

Environmental factors also shaped timber systems in many places. In Aceh, Indonesia, people used hardwood species that could stand against pests and decay (Novita et al., 2020). Most traditional wooden buildings make use of local materials, which bring advantages like insulation and even better acoustics (Shabani et al., 2020). Still, they are not perfect; wooden structures can be affected by biological problems. For instance, climate change has made

termites more active in Korea, which puts many old wooden sites in danger and shows that better ways to protect them are needed (Kim & Kim, 2023).

In different regions, wooden buildings also carry cultural and symbolic meaning. The old wooden houses in Istanbul are a prime example. They reflect centuries of local life, but many are now under pressure because of rapid urban development (Ergün & Mazlum, 2015). Understanding these structures enables us to appreciate their significance. The traditional craftsmanship, small details and decorative features also show how important it is to protect regional architectural identity, especially today when cities are becoming more uniform.

Traditional wooden buildings can even support the local economy. Some regions use their timber heritage as part of ecotourism, drawing visitors who are interested in culture and sustainability. This can help local businesses and, at the same time, support the preservation of these buildings (Okan et al., 2016). When traditional architecture is understood as both a cultural and an economic resource, communities are more encouraged to protect it and promote sustainable tourism.

Traditional timber construction still has a strong influence on modern architecture. Using local materials and older carpentry techniques can help cut down on transportation-related carbon emissions and support more sustainable building practices overall (Bartha & Olarescu, 2020). These approaches also keep traditional skills in use and allow local communities to stay involved in the construction process.

The design of wooden buildings is also influenced by environmental factors. In places with plenty of forests, people usually take advantage of the wood species they can find nearby. A clear example of this is the “serender” barns in Türkiye’s Eastern Black Sea region, which are built from local timber and carefully adapted to the climate there (Erarslan, 2020). These barns show how the availability of local materials affects not only the form but also the function of a building.

Cultural and social elements are just as important. Local traditions, beliefs, and aesthetic preferences influence how wooden structures take shape. For instance, Korea’s traditional bracket systems are not only useful as structural components but also carry symbolic cultural meanings and often catch the interest of visitors (Ryoo & Youn, 2019). Many traditional timber systems around the world also share similar construction practices. Mortise and tenon joints seen in ancient Chinese temples are a good example of carpentry techniques that have been passed down for many generations (Zhang et al., 2024).

Environmental factors like climate, terrain and the materials people have around them all play a big part in shaping wooden architecture. Even if the cultures are completely different, they can develop strikingly similar building styles when they are subjected to similar conditions (Huang & Xue, 2024). At the same time, architectural styles help build a sense of cultural identity and history for a place (Xie et al., 2023). A single building can follow global design trends while still showing its local character and maintaining its connection to the region (Aly & Lotfi, 2023).

In this study, traditional wall-building methods that developed in different regions under similar cultural and environmental situations were examined. The main goal is to compare buildings that use the wattle and daub technique and to point out the shared principles that make this method environmentally sustainable. Within this scope, systems known as Bağdadi and Çöten in Türkiye, Wattle and Daub in Europe, and Oeyeokki in Korea were analysed. In order to

support sustainable architectural design in the modern era, recommendations were made regarding how traditional construction knowledge could be modified to accommodate their material use, structural behavior, and environmental compatibility.

2. The Historical Development of Traditional Wall Construction Techniques

One of the oldest and most common techniques in timber construction is the mortise and tenon joint (MTJ), where two wooden elements interlock without the need for metal fasteners. This method has been used in major historical buildings such as the Daxiong Hall in China and provides a strong and durable connection between wooden parts (Zhang et al., 2024). Timber construction methods vary by region. For example, in northern Europe and the Alpine areas, people built log walls using solid timber to withstand cold and harsh climates (Steiger, 2020). These structures show how communities adapted their building traditions to their environment. In southern China, where humidity is high, timber panel walls became common because their moisture and thermal performance better suits the local climate (Zhao & Künzel, 2023). These examples illustrate how timber construction responds to both cultural needs and environmental conditions.

Recently, interest in timber buildings has grown due to the development of engineered wood products such as cross-laminated timber (CLT) (Tonyalı et al., 2024). In the past, stone and brick were often preferred because of their fire resistance and durability (Leszczyszyn et al., 2022). However, improvements in wood preservation and construction technologies have made wood an important sustainable option for modern architecture. Studies also show that timber has a low carbon footprint and is suitable for mid-rise buildings (Chen et al., 2020; Akkan Çavdar & Vural, 2024). This indicates that traditional timber knowledge can be successfully applied in contemporary sustainable design.

Wooden wall systems have been around for thousands of years. This long use shows that wood is a flexible and dependable material. In very early periods, wood was used for many parts of a building, including walls, foundations, and load-bearing elements. Some early cultures even used timber to build wells (Kovács & Hanke, 2015; Tegel et al., 2012). Over time, each region created its own wall types based on local traditions and practical needs.

In medieval Europe, one of the most recognisable techniques was the half-timbered system. Builders framed the structure with timber and filled the spaces with brick or plaster, giving the buildings both strength and a unique look.This method became especially widespread between the 14th and 16th centuries (Escobar et al., 2020; Staveley, 2000). In Northeast Asia, timber framing stayed influential in housing design. Korean wooden homes followed local traditions but slowly adopted certain ideas from North American and European construction (Lee et al., 2020). All of these examples remind us that architecture is always in motion, shaped and reshaped as cultures interact and learn from one another.

Existing research further demonstrates the strong seismic behaviour of wooden walls. Findings suggest that timber systems offer greater resistance than unreinforced masonry, particularly in earthquake-prone regions (Hariyanto et al., 2022). In several countries, builders added wooden components to stone or brick structures to make them more resistant to earthquakes. Historical buildings in Italy are a good example: timber supports hidden within the walls helped increase their durability during seismic events (Touliatos, 2015). Such examples demonstrate how adaptable timber systems are to various climates and soil types.

As climate conditions change, traditional timber structures need to be reinterpreted with modern knowledge while still protecting their historical value (Erarslan, 2019; Zhao et al., 2023). Restoring traditional wooden walls with local materials and contemporary construction approaches can contribute to safeguarding cultural heritage while also improving structural behaviour (Brimblecombe et al., 2011).

3. Primary Wall Construction Techniques Used in Different Regions

Traditional woodworking techniques can primarily be classified according to the type of work being done. One such technique involves joining wooden pieces without the use of nails or screws. Methods such as mortise and tenon, tail and finger joints reflect a deep understanding of the characteristics and structural strength of wood (Aguilera & Martin, 2001; Sandak & Sandak, 2021). These techniques go beyond their functional role; they also reflect the craftsmanship that influences how the final product looks. Equally important are finishing methods that enhance the wood's appearance and extend its lifespan. Traditional methods include varnishing, oiling, and coating with natural dyes or stains (Baysal et al., 2013). For example, the yaki-sugi (Shou Sugi Ban) technique used in Japan blackens the wood by burning it; this method both gives the wood a unique visual texture and protects it from the weather (Fahrussiam et al., 2023; Kerdiati, 2021).

Traditional timber wall construction techniques can generally be categorised as log structures, solid timber structures, frame structures, and infilled frame structures. Güneş (2014), who provides a broader classification, initially divided traditional timber wall systems into timber block and timber frame. Timber block walls are further divided into timber log walls and block timber infill walls, while frame walls are divided into Timber Frame Walls with cross elements (Çatkı) and Timber Frame Walls without cross elements (Çatkısız), depending on whether or not they contain supporting cross-timber elements. The walls created using the wattle and daub technique and concept examined in this study fall under the Timber Frame Walls with cross elements (Çatkı) wall system. The *Bağdadi* (Lath and plaster wall) wall system is a non-filled (containing compressed air) system, while *Çöten, Wattle and Daub*, and *Oeyeokki* are included in this classification as filled frame wall systems. This broad classification is shown in Figure 1.

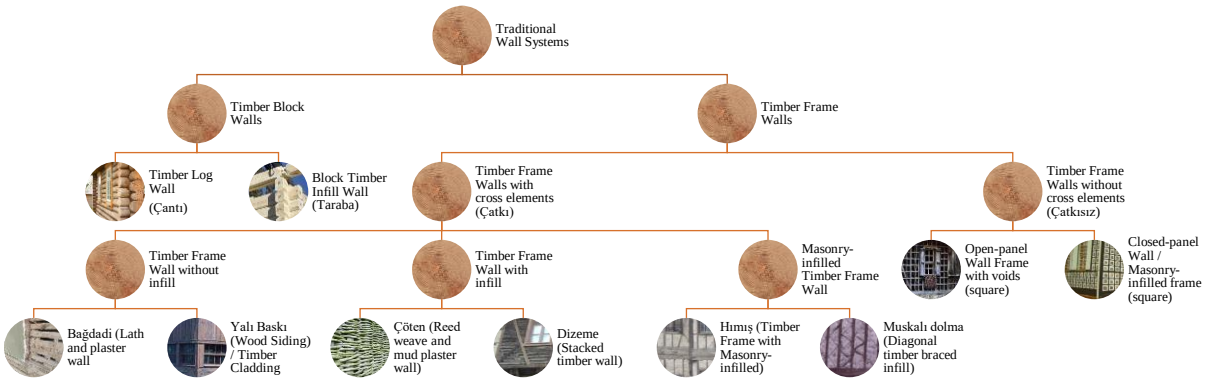


Figure 1. Classification of wall systems in traditional timber constructions (Güneş, 2014; *recreated*).

In log house construction, which is common in Finland and other Scandinavian countries, the logs are stacked horizontally to form the walls. Thanks to wood's natural insulating qualities,

these buildings are well suited to cold climates. Log structures are a sustainable traditional method that requires minimal processing using local materials (Ilgın & Karjalainen, 2023). Solid timber systems incorporate engineered timber materials to create thick, load-bearing walls. They combine traditional methods with modern materials science and offer a lower carbon footprint compared to concrete or steel (Ilgın & Karjalainen, 2023; Buchanan & Honey, 1994).

Timber frame structures utilise a framing system composed of timber posts and beams. The frame bears the load of the structure, while infill materials such as stone, adobe, or wattle and daub are placed between the frames. These systems have been favoured, particularly for their earthquake resistance, in regions such as northern China, Portugal, Türkiye, and Mediterranean countries (Vasconcelos & Poletti, 2015; Shen et al., 2022). Historic timber-framed structures not only offer a traditional aesthetic appearance but also demonstrate long-lasting resistance to earthquakes. In infilled timber frame systems, the timber frame is combined with infill materials. For example, adding stone and adobe to walls increases the energy efficiency and thermal performance of the structure (Shen et al., 2021; Shen et al., 2022; Poletti & Vasconcelos, 2014). These systems provide both structural and thermal advantages and adapt to local climate and material conditions.

In Türkiye, timber wall construction systems are similarly classified into three types: masonry, frame (skeleton), and timber-framed (Sümerkan, 1990). In masonry wall systems, timber is used as the main element of the wall, while in frame systems, timber only serves as a frame, and the voids within the frame can be filled with different materials to provide some insulation. In Türkiye, particularly in the Black Sea and Central Anatolia regions, the ‘hımış’ technique is widely used as a method of placing infill material into a wooden frame. In this technique, timber frame walls are first constructed, then materials such as stone and adobe found in the surrounding area are filled into the voids. This both completes the structure of the walls and reduces heat loss (Aşanlı, 2021).

An example of a skeleton system similar to the hımış wall technique is the ‘bağdadi’ system. In this system, the inner and outer surfaces of the walls are covered in an airtight manner and plastered with a special plaster, thus trapping air inside the wall. In addition, infill materials such as adobe, wood or stone can be used to provide additional insulation (Şenol & Akan, 2011). Similar to the plastered *Bağdadi* system in Türkiye, in Korea, wooden panels are plastered with mud to provide insulation in walls (Cho, 2010). In traditional techniques, organic materials such as straw bales or infill materials such as adobe, stone and wood are used for insulation (Kafesçioğlu, 1955). It can be said that these methods, known as ‘Bağdadi’ and ‘çöten’ in Türkiye, “Oeyeokki” in Korea, ‘Wattle and Daub’ in England, and ‘Zhúbiān Tǔ Qiáng’ in China, are both widespread and locally applied in different geographical areas (Güneş, 2014; Akkan Çavdar & Lakot Alemdağ, 2024).

3.1. An examination of the wall techniques ‘Bağdadi’, ‘Çörten’, “Oeyeokki” and ‘Wattle and Daub’

The names of these wall techniques directly reflect not only the construction systems themselves, but also the cultural thinking and material logic behind these systems. Each one, with its root meaning in the local language, defines the fundamental action of the construction process: the *Bağdadi (lath and plaster)* system refers to the structure formed by binding wooden slats together; the *Çöten* system (*reed tissue + mud plaster*) refers to the weave formed by thin branches; *Oeyeokki (woven on the outside)* technique, in its literal sense, the ‘weaving on the

outside' method; *Wattle and Daub (woven and mud plaster)*, the process of 'plastering the woven branch skeleton with mud'. These names emerge as a linguistic reflection of craftsmanship knowledge in each culture; despite the formal differences between the systems, they show that they are united around a common action of 'weaving, binding and covering'.

Bağdadi and Çöten system:

The *Bağdadi* system is created by covering both sides of the wooden frame with battens approximately 3 cm thick, placed at intervals of 2–2.5 cm, and then covering the surface with lime-based plaster. The *Bağdadi plaster* (horasan mortar) applied to the gaps between the slats seeps back, ensuring the integrity of the wall, and the air layer remaining inside the frame acts as thermal insulation. In some examples, these gaps are filled with earthen mortar. The plaster, made with lime binder and brick aggregate Horasan mortar, prevents rain from seeping in while providing a breathable structure (İpekoğlu, Böke & Çizer, 2007; Erman, 2000). The system adapts well to the region's humid-temperate climate due to its lightness, moisture-resistant properties, and the possibility of large window openings (Aşanlı, 2021).

Historically concentrated in the Trabzon and Giresun areas, this technique is defined as a building system that provides thermal comfort by keeping buildings warm in winter and cool in summer (Tuna, 2008; Şahin, 2013). This system provides resistance in earthquakes thanks to flexible connections; in Anatolia, 'Bursa-type' (close spacing) (1.5-2 cm) and 'Antalya-type' (more sparse) (4-7 cm) applications are common. In the Black Sea region, a similar system called 'çöten' exists, where the wall is constructed in a lattice pattern (Erarslan, 2019; Erman, 2000). *Çöten* structures generally refer to barns in the region and are used without plastering to allow crops to dry and moisture to be removed. Figure 2 shows examples of *Bağdadi* and *Çöten* walls.



Figure 2. An example of a bağdadi building and a çöten building with crumbling plaster (Erarslan, 2019).

The *Çöten* timber-filled wall system (*reed tissue + mud plaster*) refers to a filling technique in which the gaps between timber framework elements are filled with thin branches woven horizontally to a thickness of 2–3 cm, and then covered with plaster on both the inside and outside to create a solid wall (Güneş, 2014). This construction technique is also known in the Balkans and has been observed in Anatolia since the early Neolithic period (Gündoğan, 2018). Figure 3 shows examples of *bağdadi* walls and *çöten* walls using the lattice technique and the different uses of wood in walls. *Bağdadi* battens are placed in front of and behind the wooden posts, creating an air gap in the interior, while the branches used for *çöten* walls are interwoven between the intermediate posts to fill the interior void.



Figure 3. Example of a *Bağdadi* wall and a *çöten* wall (Güçhan, 2017; Güneş, 2014; *Original: Arun, 2013*).

Wattle & daub system:

The *wattle and daub* system is defined as *"a framework of woven branches covered with a clay-based plaster"* and is considered the most characteristic wall type in rural English architecture due to its flexibility, moisture permeability and repairability (Graham, 2009). It is a traditional infill system created by placing vertical poles (staves) between wooden frames, weaving hazel or willow branches (withy) horizontally around them, and plastering the surface with a daub layer consisting of a mixture of clay, straw, dung, and lime. Studies of the Wiltshire region indicate that the staves are usually made of oak or hazel, with a diameter of approximately 20–30 mm; the weave spacing varies between 250–450 mm and the plaster thickness averages 30–50 mm (Graham, 2003). This technique, traces of which have been found in Europe since the Neolithic period, was widely used, particularly in rural dwellings and granaries (Shaffer, 1993). The woven part forming the inner part of the wall — the 'wattle' — is usually made of flexible willow, hazel or oak branches. This wattle serves as a filler that carries the daub rather than the load. The daub applied over it is a mortar consisting of clay, straw and sometimes lime, providing both insulation and surface protection. While wet, it is pressed onto the wall by hand or with a trowel, hardening as it dries, with cracks being filled with new layers. With these characteristics, the system offers a breathable and renewable building envelope (English Heritage, 2009) (Figure 4).

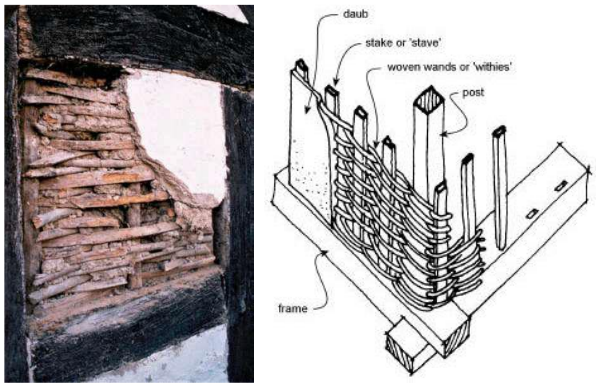


Figure 4. Wattle and daub system within a timber wall (Graham, 2009).

Archaeomagnetic studies, particularly investigations conducted on structures belonging to the Stentinello culture in the Calabria region of Italy, have revealed that such structures were occasionally deliberately burned to harden the walls. The sintered clay fragments resulting from

the burning were reused as filler in the mortar of new walls. This situation is interpreted as a prehistoric example of material recycling (Shaffer, 1993). In recent conservation practices, field studies in the Wiltshire region of England have documented in detail the maintenance requirements of wattle and daub walls against climatic conditions. The cracking of the plaster layer over time is remedied by the natural renewal of the material in response to moisture and frost cycles. This technique is considered an important historical reference for bio-based wall systems in contemporary sustainable architecture (Harrison, 2018).

Oeyeokki system:

Oeyeokki, literally meaning 'woven from the outside,' is a woven infill wall system in traditional Korean architecture, created by weaving horizontal and vertical branches, bamboo, or reeds between wooden frames. In construction, horizontal pieces called *nulhoi (*눌외*)* and vertical elements called *seolhoi (*설외*)* are tied together with string or reeds to form a net-like skeleton; this surface is plastered with a mixture of clay, straw, lime and funori (seaweed extract). This natural mixture increases both flexibility against cracks and vapour permeability (Cho, 2014).

Widespread during the Joseon Dynasty (1392–1897), this system was used particularly in temples and government buildings. Internal reinforcement posts called *joongkit (*중깃*)* and horizontal spiked elements called *sakmok (*槊木*)* support the woven layer. Studies reveal that examples of this system have been documented in the Huireung Jeongjagak, Heungneung Jeongjagak, Yulgok-sa and Yongmun-sa structures. These elements are placed approximately 500 mm apart in the walls, with 30×15 mm vertical 'spike' elements and 10–20 mm horizontal battens woven between them. The mud plaster layer applied over them strengthens both the load-bearing capacity and the heat-moisture balance of the wall (Lee & Jang, 2019) (Figure 5).



Figure 5. Elements and mesh appearance in the *Oeyeokki* system (Lee & Jang, 2019).

In some examples, it has been observed that the wall is constructed in a two-layered (front and back) manner with an air gap in between (Cho, 2014). This system adapts to Korea's humid climate conditions while also increasing seismic resistance due to its lightness and flexible structure. However, Lee & Jang (2019) emphasise that in cultural heritage restoration, bamboo weaving techniques sometimes replace the traditional *Oeyeokki* weave, and this change may undermine the original Joseon-era understanding of materials (Figure 6).



Figure 6. The *oeyeokki* walls of Yongmunsa and Jongmyo Shrine (Cho, 2014; Lee & Jang, 2019).

4. Comparison of Lath And Plaster Techniques and Common Points

The wall techniques examined in this study—*Bağdadi/Çöten* (Turkiye), *Wattle and Daub* (Europe), and *Oeyeokki* (Korea)—are based on similar principles, despite having developed in different regions. In all three methods, the basic structure consists of a lath and plaster system based on a wooden frame and earth-based plaster/filling. These similarities demonstrate that people in each region developed similar solutions, taking into account local materials, climatic conditions and daily needs. Table 1 provides a comparison of traditional lath and plaster wall construction techniques.

Table 1. Comparative table of traditional lath and plaster wall construction techniques

				
Feature	**Bağdadi (Turkiye)**	**Çörten (Turkiye)**	**Wattle & Daub (England / Europe)**	**Oeyeokki (Korea)**
Main Material	Wooden laths + lime plaster	Thin branches + mud plaster	Willow / hazel rods + clay–straw mix	Bamboo + clay–lime–seaweed mix
Structural System	Timber frame with double-sided lath covering	Timber frame with horizontal reed weaving	Timber framework with interwoven rods	Timber / bamboo frame with woven infill
Binder Material	Lime-based mortar (Horasan)	Mud + lime + straw	Clay, straw, dung, lime	Clay + lime + *funori* (seaweed extract)
Climatic Suitability	Humid–mild (Black Sea region)	Humid rural areas	Mild–temperate (Europe)	Humid–rainy (East Asia)
Thermal Performance	Medium–High (air cavity insulation)	High (natural ventilation)	Moderate (thick daub layer)	High (double-layer wall)
Flexibility / Earthquake Resistance	High	Medium	High	High
Material Availability	Local timber and lime easily accessible	Reed and clay widely available	Organic materials common	Bamboo and lime regionally available

Maintenance Requirement	Moderate	Low	High (requires re-plastering)	Moderate
Cultural / Craft Value	High – reflects local identity and craftsmanship	High – rooted in rural culture	Moderate – agricultural heritage	High – temple and palace tradition

In terms of materials, the fundamental aim in all three regions is to utilise locally available natural materials. In Turkiye, the *Bağdadi* and *çöten* walls are constructed using local tree species to form the framework, thanks to the abundant forests of the Eastern Black Sea region; the gaps are then filled with mortar, clay, or a mixture of straw and earth, or in some structures, they are left without plaster. In the European *wattle and daub* technique, a woven surface made from flexible willow branches is covered with straw-mixed earth mortar. In the Korean *oeyeokki* system, a wooden frame is used in combination with a mixture of earth and gravel. These examples show that the 'wood + earth' combination is interpreted in a similar way in different geographical areas.

From a climatic perspective, it can be seen that all three systems are shaped by the humidity, temperature and rainfall conditions of their respective regions. In the humid-temperate climate of the Eastern Black Sea, the air gap and lime-based plaster used in *Bağdadi* walls both protect against rain and help the wall release moisture. In the Çöten system, leaving the walls unplastered allows products to dry, especially in barns, and facilitates the renewal of indoor air. In the European wattle and daub technique, thick earth fill stores heat during the day and releases it at night, balancing temperature differences. *Oeyeokki* walls in Korea are designed to be breathable yet water-resistant, adapting to rainfall and seasonal humidity changes. Therefore, although these three techniques developed in different geographical regions, they represent a common approach to passive climate control.

Structurally, the seismic behaviour of wattle and daub walls is quite similar. In such structures, the timber frame provides the main support, and the earth or mud filling works mostly as a shell that controls heat and moisture. Thanks to the flexible structure of the wooden frame, the walls can move under horizontal loads, and any cracks that form are generally easy to repair. Studies in the literature also indicate that such timber frame-infill walls, when constructed with appropriate details, can perform well in earthquakes. Therefore, the *Bağdadi*, *wattle and daub*, and *oeyeokki* systems exhibit similar seismic behaviour based on the common principle of 'timber frame + flexible infill,' even though they use different materials.

From a social and cultural perspective, wattle and daub techniques are not merely a method of wall construction, but also part of traditional craftsmanship and anonymous architectural knowledge. The techniques used in these systems are based on manual labour passed down from master to apprentice and have been sustained across generations. In Turkiye, *Bağdadi* and *çöten* walls have become a cultural element of rural life, while *wattle and daub* structures in Europe reflect the historical identity of villages. In Korea, *oeyeokki* walls are an important part of cultural continuity in temples and traditional dwellings. Therefore, wattle techniques can be considered cultural elements that not only produce structures but also shape local memory and regional identity.

Despite these similarities, there are some important differences between the systems. In *Bağdadi* walls, the outer surface is usually plastered and smooth; in contrast, in *wattle and daub* examples, the wattle texture is partially visible on the façade, particularly in barns and agricultural structures. In Korea, *oeyeokki* walls are applied with more meticulous

craftsmanship and a regular modular system in special structures such as temples. Furthermore, binding materials, infill thicknesses, and the position of openings vary according to climate and cultural needs in each region. However, these differences do not compromise the common structure of the wattle and daub technique in terms of its fundamental characteristics of lightness, flexibility, use of local materials, and repairability; on the contrary, they allow these techniques to be adapted to their own conditions in each geography.

Consequently, the *Bağdadi/çöten*, *wattle and daub*, and *oeyeokki* systems can be considered examples of the wattle and daub technique in different geographical regions. These methods share common characteristics such as the use of local materials, adaptation to climate, structural flexibility, and cultural continuity. These similarities also explain why communities living in distant regions developed similar wall-building techniques.

5. Conclusions

This study looks at traditional wattle-and-daub wall systems—*Bağdadi* and *Çöten* in Türkiye, *Wattle and Daub* in Europe, and *Oeyeokki* in Korea. Its goal is to identify the shared features of these techniques, which arose in different regions but rely on similar principles. The results indicate that these wall systems are important both for understanding past building cultures and for the role they can play in today's sustainable architecture.

The first finding is that the wattle and daub technique provides locally sourced, low-energy and easily repairable wall solutions in all three regions. Using a wooden frame together with natural materials such as earth, clay, straw or stone reduces the carbon footprint during construction. It also allows for simple and low-cost maintenance throughout the life of the building. For this reason, these techniques offer useful ideas for creating building solutions with low embodied energy that can be adapted to modern architectural design.

The second finding is that these traditional walls already used passive ways of managing heat and moisture, shaped by the climate. Breathable plasters, air cavities, thick earth fillings, and sometimes leaving a surface unplastered all helped regulate heat and moisture. Many of the ideas we now label as sustainable design were already part of these traditional techniques long ago.

Another important outcome of the study is the emphasis on the value of wattle and daub techniques in terms of cultural heritage and place identity. *Bağdadi, wattle and daub* and *oeyeokki* systems are structures that embody craftsmanship knowledge, anonymous architecture and everyday life practices. Documenting, preserving and relating these techniques to contemporary designs will contribute to both strengthening local identity and maintaining diversity in architecture. In this context, the main contributions of the study can be summarised as follows:

- Examining wattle and daub techniques, which have developed according to similar principles in different geographical areas, within a comparative framework.
- Revealing the potential of traditional wall systems in terms of sustainable material use, passive climate control, and seismic resistance.
- Proposing these techniques as a reference and source of inspiration for contemporary architectural design and conservation practices.

Future studies should include quantitative performance analyses (such as heat transfer, moisture behaviour, life cycle assessment, and seismic behaviour) of the systems discussed here;

examining them in conjunction with different reinforcement methods; and producing hybrid solutions with contemporary material technologies. Thus, wickerwork techniques can be re-evaluated not only as a legacy of the past but also as a contemporary design tool for sustainable and resilient building production.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Aguilera, A., & Martin, P. (2001). Machining qualification of solid wood of Fagus silvatica L. and Piceaexcelsa L.: Cutting forces, power requirements and surface roughness. *Holz als roh-und Werkstoff*, *59*(6), 483-488.

Akkan Çavdar, A., & Vural, N. (2024). Analysis of the Embodied and Operational Energy of Wood-Based Prefabricated Panels Produced with Different Design Concepts According to Vernacular. *Journal of Polytechnic*, *27*(4). https://doi.org/10.2339/politeknik.1239942

Akkan Çavdar, A., & Lakot Alemdağ, E. (2024). Ahşap Yapılarda Enerji Verimli Yalıtım Uygulamalar, In *Ahşap Malzeme ve Yapı Tasarımı*, Lakot Alemdağ, E., Eds.; Duvar Yayınevi: İstanbul, Turkiye, pp. 176-205.

Aly, T. F. and Lotfi, Y. A. (2023). Sustainable architectural pluralism through contemporary architectural design. *MSA Engineering Journal*, 2(2), 193-217. https://doi.org/10.21608/msaeng.2023.291870

Arun, G. (2013). *Traditional Timber Construction in Türkiye*, Japonca çeviri: Kaori Fujita, Ki no Forumu 04.2013, s.38-41.

Aşanlı, M. (2021). *Geleneksel yapı teknikleri: doğal ve ekolojik yapı rehberi* (Vol. 33). Yeni İnsan Yayınevi.

Bartha, B. and Olarescu, A. (2020). Neo-vernacular concepts for value-adding in contemporary european architecture and design. *Series II - Forestry • Wood Industry • Agricultural Food Engineering*, 13(62)(2), 71-80. https://doi.org/10.31926/but.fwiafe.2020.13.62.2.6

Baysal, E., Tomak, E. D., Ozbey, M., & Altin, E. (2013). Surface properties of impregnated and varnished scots pine wood after accelerated weathering. *Coloration Technology*, 130(2), 140-146. https://doi.org/10.1111/cote.12070

Brimblecombe, P.; Grossi, C.M.; Harris, I. (2011). Climate change critical to cultural heritage. In *Survival and Sustainability: Environmental Concerns in the 21st Century*; Gökçekus, H., Türker, U., LaMoreaux, J.W., Eds.; Springer: Berlin/Heidelberg, Germany, pp. 195–205.

Buchanan, A. H., & Honey, B. G. (1994). Energy and carbon dioxide implications of building construction. *Energy and Buildings*, *20*(3), 205-217.

Chen, Z., Gu, H., Bergman, R., & Liang, S. (2020). Comparative life-cycle assessment of a high-rise mass timber building with an equivalent reinforced concrete alternative using the athena impact estimator for buildings. *Sustainability*, 12(11), 4708. https://doi.org/10.3390/su12114708

Cho, I. S. (2010). An Overview of Korean wooden architecture. In S. Sungwoo & S. Jang-Yeol (Eds.), *Proceedings of the International Conference on Sustainable Building Asia SB10 SEOUL* (pp. 141–150). South Korea: Big Apple Communications.

Erarslan, A. (2019). Timber construction systems in anatolian vernacular architecture. *Series II - Forestry • Wood Industry • Agricultural Food Engineering,* 12(61)(2), 37-52. https://doi.org/10.31926/but.fwiafe.2019.12.61.2.3

Erarslan, A. (2020). An example of traditional timber building techniques from Anatolia. granary structures in the region of the eastern black sea, Türkiye; Serender. *International Wood Products Journal*, 12(1), 58-70. https://doi.org/10.1080/20426445.2020.1805688

Ergün, S. and Mazlum, D. (2015). Traditional timber houses of Istanbul: heritage values and preservation problems. *Journal of Architectural Conservation*, 21(3), 160-177. https://doi.org/10.1080/13556207.2016.1139853

Fahrussiam, F., Chaerani, N., Lestari, D., Musdi, M., Shabrina, H., & Prasetyo, A. R. (2023). Introduction of eco-friendly finishing method (yakisugi) among the millennial generation in Perina village: innovation in unique furniture products with high aesthetic value. *Jurnal Malikussaleh Mengabdi*, 2(2), 369. https://doi.org/10.29103/jmm.v2i2.13605

Güneş, M. A. (2014). *Geleneksel ahşap yapilarda taşiyici sistem kurgusunun incelenmesi: Safranbolu örneği* (Master's thesis), Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul. Accessed from database Access Address (09.10.2025).

Hariyanto, A. D., Triyadi, S., & Widyowijatnoko, A. (2022). A simple stilt structure technique for earthquake resistance of wooden vernacular houses in Bima, Sumbawa Island, Indonesia. *International Journal on Advanced Science, Engineering and Information Technology*, 12(4), 1491. https://doi.org/10.18517/ijaseit.12.4.12848

Huang, Z. and Qin, L. (2023). The culture of residential buildings promotes the construction of beautiful countryside: taking Dong ethnic wooden structure buildings as an example. *Frontiers in Educational Research*, 6(22). https://doi.org/10.25236/fer.2023.062223

Huang, Y. and Xue, Q. (2024). Analysis of the spatial distribution characteristics and influencing factors of traditional mosque architecture in the Hehuang area (China). *Buildings*, 14(5), 1258. https://doi.org/10.3390/buildings14051258

Ilgın, H. E. and Karjalainen, M. (2023). Massive wood construction in Finland: past, present, and future. *Wood Industry - Past, Present and Future Outlook*. https://doi.org/10.5772/intechopen.104979

Kafesçioğlu, R. (1955). *Kuzeybatı Anadolu'da Ahşap Ev Yapıları*. İstanbul: İTÜ Mimarlık Fakültesi, Pulhan Matbaası.

Kerdiati, N. L. K. R. (2021). Understanding wood finishing using the Japanese wood burning technique (shou sugi ban) in architecture. *Journal of Aesthetics, Design, and Art Management*, 1(1), 15-23. https://doi.org/10.58982/jadam.v1i1.100

Kim, S. and Kim, J. (2023). Korean wooden architectural heritages at an increased risk of termite damage due to temperature change. *Journal of Conservation Science*, 39(5), 657-662. https://doi.org/10.12654/jcs.2023.39.5.01

Kovács, K. and Hanke, K. (2015). Recovering prehistoric woodworking skills using spatial analysis techniques. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, II-5/W3, 153-158. https://doi.org/10.5194/isprsannals-ii-5-w3-153-2015

Lee, S.-H., & Jang, H.-D. (2019). A Study on the Method of Oeyeokki and Joongkit in Earth Wall of Government Constructions in the period of Chosun Dynasty. *Journal of Architectural History, 28*(4), 27–36. https://doi.org/10.7738/JAH.2019.28.4.027

Lee, J., Wi, S., Chang, S. J., Choi, J., & Kim, S. (2020). Prediction evaluating of moisture problems in light-weight wood structure: Perspectives on regional climates and building materials. *Building and Environment, 168*, 106521. https://doi.org/10.1016/j.buildenv.2019.106521

Leszczyszyn, E., Heräjärvi, H., Verkasalo, E., García-Jaca, J., Araya-Letelier, G., Lanvin, J., … & Kouyoumji, J. (2022). The future of wood construction: opportunities and barriers based on surveys in Europe and Chile. *Sustainability*, 14(7), 4358. https://doi.org/10.3390/su14074358

Novita, N., Amiruddin, H., Ibrahim, H., Jamil, T., Syaukani, S., Oguri, E., … & Eguchi, K. (2020). Investigation of termite attack on cultural heritage buildings: a case study in aceh province, Indonesia. *Insects,* 11(6), 385. https://doi.org/10.3390/insects11060385

Okan, T., Köse, N., Arifoğlu, E., & Köse, C. (2016). Assessing ecotourism potential of traditional wooden architecture in rural areas: the case of Papart valley. *Sustainability,* 8(10), 974. https://doi.org/10.3390/su8100974

Ryoo, S. and Youn, H. (2019). The evolutionary use of curved wood in Korean traditional architecture. *Sustainability,* 11(23), 6557. https://doi.org/10.3390/su11236557

Poletti, E. and Vasconcelos, G. (2014). Seismic behaviour of traditional timber frame walls: experimental results on unreinforced walls. *Bulletin of Earthquake Engineering*, 13(3), 885-916. https://doi.org/10.1007/s10518-014-9650-9

Sandak, A. and Sandak, J. (2021). Special issue "Wood modification: characterization, modelling, and applications". *Coatings,* 11(7), 869. https://doi.org/10.3390/coatings11070869

Shabani, A., Kioumarsi, M., Plevris, V., & Stamatopoulos, H. (2020). Structural vulnerability assessment of heritage timber buildings: a methodological proposal. *Forests,* 11(8), 881. https://doi.org/10.3390/f11080881

Shen, Y., Yan, X., Yu, P., Liu, H., Wu, G., & He, W. (2021). Seismic resistance of timber frames with mud and stone infill walls in a Chinese traditional village dwelling. *Buildings,* 11(12), 580. https://doi.org/10.3390/buildings11120580

Shen, Y., Yan, X., Liu, H., Wu, G., & He, W. (2022). Enhancing the in-plane behavior of a hybrid timber frame–mud and stone infill wall using pp band mesh on one side. *Polymers*, 14(4), 773. https://doi.org/10.3390/polym14040773

Steiger, L. (2020). *Basics timber construction*. Birkhäuser.

Sümerkan, M. R. (1990). *Biçimlendiren Etkenler Açısından Doğu Karadeniz Kırsal Kesiminde Geleneksel Evlerin Yapı Özellikleri,* Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Trabzon.

Şenol, P., & Akan, A. E. (2011). Kırsal yaşam/kırsal konut: bir yaşam biçimi olarak geleneksel kırsal konut üretiminde Kızılcık Köyü örneği. *Süleyman Demirel Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi,* 2011(24), 143–160.

Tegel, W., Elburg, R., Hakelberg, D., Stäuble, H., & Büntgen, U. (2012). Early neolithic water wells reveal the world's oldest wood architecture. *PLoS ONE,* 7(12), e51374. https://doi.org/10.1371/journal.pone.0051374

Tonyalı, Z., Lakot Alemdağ, E., & Tandoğan Kibar, G. (2024). Evaluation of seismic response of the cross-laminated timber (CLT) multi-storey residential building under the February 6, 2023, Kahramanmaraş Earthquakes. *Journal of Architectural Sciences and Applications*, 9(Special Issue), 41-63. https://doi.org/10.30785/mbud.1338909

Touliatos, P. (2015). Coopereting Timber and Stone Antiseismic Frames in Historic Structures of Greece. In H. Cruz et al. (Eds.): *Historical Earthquake-Resistant Timber Framing in the Mediterranean Area*, Springer, pp. 3-15.

Vasconcelos, G. and Poletti, E. (2015). Traditional timber frame walls. *Handbook of Research on Seismic Assessment and Rehabilitation of Historic Structures*, 30-59. https://doi.org/10.4018/978-1-4666-8286-3.ch002

Zhao, M. and Künzel, H. M. (2023). Assessing different insulation strategies for historic wooden facades based on modeled mold growth risk. *16th International Conference on Durability of Building Materials and Components*. https://doi.org/10.23967/c.dbmc.2023.076

Zhao, M., Künzel, H. M., & Mehra, S. (2023). Design hygrothermally functional wooden insulation systems: A parametric study for mixed climate. *Journal of Building Physics*, 46(4), 474-509. https://doi.org/10.1177/17442591221142506

Zhang, H., Gao, W., & Wang, Y. (2024). A wooden pin reinforcement of ancient Chinese wooden temple: a case of Daxiong hall. *Advances in Civil Engineering*, 2024(1). https://doi.org/10.1155/2024/8824310

Xie, B., Wei, W., Li, Y., Liu, C., & Sheng-liang, J. (2023). Research on spatial distribution characteristics and correlation degree of the historical and cultural towns (villages) in China. *Sustainability*, 15(2), 1680. https://doi.org/10.3390/su15021680

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Analysis of Studies on Transparent Wood and Its Potential Use in the Construction Industry

Nilay AYKAN [1]

ORCID 1: 0000-0003-3039-3135
[1]Research Assistant, Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
nilay.aykan@erdogan.edu.tr

Esra LAKOT ALEMDAĞ[2*]

ORCID 2: 0000-0003-0959-2068
[2]Assoc. Prof. Dr., Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Architecture, Rize-Türkiye
esra.lakotalemdag@erdogan.edu.tr **(**Responsible Author)

Abstract

Building materials have significant negative impacts on the environment due to their intensive energy consumption, carbon emissions, and waste production during raw material extraction, processing, transportation, and use. The high energy consumption and greenhouse gas emissions associated with glass production also contribute to environmental burdens, accelerating the search for sustainable alternative materials in construction. In this context, wood, a renewable resource, is being revaluated and its use expanded thanks to technological developments that improve its physical, mechanical, and optical properties. Transparent wood, in particular, which has been developed to enhance its optical properties and provide light transmittance, is attracting attention as an environmentally friendly building material that can be used as a substitute for glass. In this study, 32 academic studies accessed using the keywords “transparent wood and construction” in the Web of Science database were examined. The literature review revealed that the studies primarily focused on the production methods of transparent wood, the development of its mechanical and optical properties, the degradation processes of the material, and its energy performance. These findings reveal that transparent wood is an important alternative that can contribute to the use of sustainable materials in architecture. The original contribution of this study is that it addresses existing research on transparent wood from a holistic perspective, evaluating both current developments and topics that stand out for future research. In this respect, transparent wood has the potential for wider use in the future as an environmentally friendly solution in architectural applications. Furthermore, increased research in this field will contribute to the widespread use of the material and innovative design applications.

Keywords: Transparent wood, sustainable building material, energy efficiency, renewable material, architectural applications

1. Introduction

Approximately 40% of global energy consumption is accounted for by the construction sector, a significant portion of which is generated by heating and cooling processes to ensure indoor thermal comfort (Kahlout, 2025). In line with increasing energy demand and sustainable development goals, efforts to promote the use of renewable biomass-based alternatives to traditional petroleum-based building materials are gaining increasing importance (Kahlout et al., 2025; Zhu et al., 2023).

The most common transparent material used to allow natural light into buildings is glass (Pandit et al., 2025). However, glass production requires the melting of raw materials such as silica, sodium carbonate, limestone, and magnesium carbonate at temperatures of approximately 1500–1600 °C. This increases energy consumption. Furthermore, glass has several disadvantages, such as glare, fragility, high weight, and high thermal conductivity (Pandit et al., 2025; Kahlout, 2025). Due to these drawbacks that arise during the production and use of

glass, the need for alternative transparent materials with lower environmental impact and higher energy performance has increased. In this context, transparent wood has become an important research topic in recent years.

Wood is widely used in the construction industry due to its renewable nature, low density, processability, and carbon sequestration capacity. It has a multicomponent structure composed of cellulose, hemicellulose, and lignin. Cellulose fibers also increase mechanical strength. Thus, wood provides a suitable basis for the development of new-generation composite materials. Furthermore, wood has a porous structure at the micro- and macro-scales and is highly susceptible to chemical and physical changes (Şanlı & Vural, 2024). Wood's characteristic color stems from lignin and other light-absorbing components. Approximately 80–95% of total light absorption is accounted for by lignin (Pandit et al., 2025).

The first study on transforming wood into a light-transmissive material was conducted by Fink in 1992 (Mariani, 2024). The production of transparent wood begins with chemical pretreatments that involve the complete or partial removal of lignin from its structure. By filling the resulting porous structure with a polymer, light scattering is reduced and optical transmittance is increased (Hai et al., 2025). This preserves the mechanical properties of natural wood. Furthermore, wood, which gains new optical properties, is transformed into a sustainable material that can replace glass.

1.1. Bleaching and Delignification

In the first stage of the transparent wood production process, components within the wood structure that cause light absorption are chemically removed. This process is called bleaching (delignification). Following this process, the wood's natural color is significantly lightened (Chutturi, 2023). Various chemicals such as $NaClO_2$, H_2O_2, NaOH, and acetic acid are used in delignification processes (Hai et al., 2025). The type of chemical applied and the processing time directly affect the optical and mechanical performance of transparent wood.

At this stage, it is crucial for sustainable environmental protection that the chemicals used are derived from renewable sources and are biodegradable. Choosing other agents instead of chlorinated compounds is more environmentally sound. The application of advanced technologies such as delignification shortens processing times, thus reducing energy consumption and environmental impact during delignification (Kahlout et al., 2025). Transparent wood produced this way becomes more environmentally friendly on an industrial scale.

1.2. Polymerization of Bleached Wood

After the delignification process, the lignin in the wood structure is removed, creating pores of various sizes. These pores must provide optical transparency. To achieve this, a polymer material with a refractive index compatible with the wood is used, a process called polymerization (Figure 1) (Chutturi, 2023; Pandit et al., 2025). The polymers penetrate the pores within the wood uniformly. Subsequently, light scattering is reduced. This is one of the key factors determining the optical performance of transparent wood.

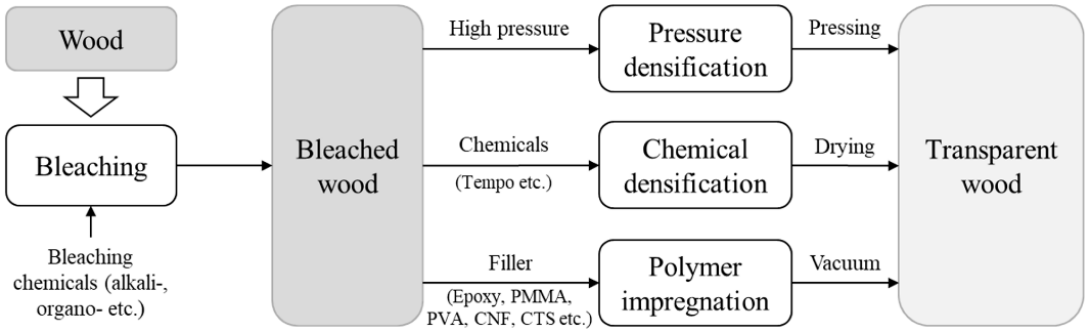


Figure 1. General fabrication methods of TW (Hai et al., 2025).

Chemical compatibility with wood is crucial in polymer selection. Various polymers, including polymethyl methacrylate (PMMA), epoxy resins, polyvinylpyrrolidone (PVP), n-butyl methacrylate, polystyrene, dibutyl phthalate, isobornyl methacrylate, and polyvinylcarbazole, are commonly used in the production of transparent wood (Li et al., 2017).

1.3. Optical Properties of Transparent Wood

The optical performance of transparent wood is primarily evaluated through light transmittance and haze (Zhu, 2023). Light transmittance depends on factors such as wood thickness, cellulose fiber orientation, cellulose volume fraction, degree of delignification, and the optical properties of the polymer used (Pandit et al., 2025). Literature reports that light transmittance values for transparent wood range from 10% to 90% (Hai et al., 2025). Haze, on the other hand, indicates how much of the light passing through the material is scattered. It provides information about image clarity. This value is calculated as the ratio between the intensity of the emitted light and the total intensity of the transmitted light (Zhu, 2023).

Transparent wood offers both high light transmittance and the desired level of haze. It can be considered a valuable material, particularly for energy efficiency, natural lighting, and translucent panel applications, compared to glass and polymer-based alternatives. Optical performance is directly related to delignification and polymerization processes, so careful control of the production stages is essential.

1.4. Mechanical Properties of Transparent Wood

The mechanical properties of transparent wood depend on the wood's density, the quantity and orientation of cellulose fibers, and the annual ring structure (Li et al., 2017). During the delignification process, lignin is removed, and the cellulose fibers that form the wood's structural framework become more pronounced.

The mechanical performance of transparent wood is evaluated using standard tests such as three-point bending tests, tensile strength, and ductility tests (Pandit et al., 2025). Studies have shown that when appropriate polymer selection and the correct production parameters are met, the mechanical properties of transparent wood are comparable to those of natural wood. In some cases, they can even be superior.

Transparent wood has a higher fracture toughness than glass, offering a significant advantage in applications requiring impact resistance. In this respect, transparent wood stands out not only for its optical properties but also for its safety, durability, and lightness, making it a potential material for structural applications.

2. Materials and Methods

In this study, a search was conducted using the keywords "transparent wood" and "construction" in the Web of Science database. 32 academic publications were retrieved and analyzed. To access up-to-date and reliable studies on the subject, searches were conducted within the WoS Core Collection.

The publications identified through the search were categorized by publication type (research article vs. review article), method used (experimental study, simulation, literature review), and content covered. Furthermore, each study was thematically analyzed within the context of transparent wood production methods, optical and mechanical performance properties, and application types.

The classification of the publications is presented in tables. The findings of the content analysis are described under the heading "Findings and Discussion."

3. Findings and Discussion

The methods used in the 32 articles reviewed were literature review, experimental research, simulation, and experimental research and simulation. Of the 32 articles reviewed, 11 were review articles (Table 1), and 21 were research articles (Table 2). When looking at the distribution of publications by year, the highest number of publications was published in 2025, representing 31.2%. The second most publications were published in 2023, representing 25%, and in 2024, representing 15.6%. The classification of the 32 studies examined in terms of journal, publication year and article type is presented in Table 1.

Table 1. Classification of the thirty-two articles reviewed

No	Name of the Journal	Year	Research	Review
1	International Review of Applied Sciences and Engineering IRASE,	2018		X
2	Molecules	2025		X
3	Progress in Materials Science	2023		X
4	Biomass Conversion and Biorefinery	2025		X
5	Cellulose	2023		X
6	Industrial Crops & Products	2023		X
7	Science of the Total Environment	2023		X
8	Progress in Materials Science	2023		X
9	Building and Environment	2025		X
10	Philosophical Transactions of The Royal Society A	2017		X
11	Industrial Crops & Products	2025		X

12	Forests	2025	X
13	International Journal of Biological Macromolecules	2025	X
14	Materials Today Communications	2024	X
15	International Journal of Biological Macromolecules	2024	X
16	Adv. Funct. Mater.	2025	X
17	ChemSusChem,	2018	X
18	Wood Material Science & Engineering,	2025	X
19	Wood Material Science & Engineering	2023	X
20	Cellulose	2024	X
21	European Journal of Wood and Wood Products	2025	X
22	Chemical Engineering Journal	2022	X
23	Advanced Materials Technologies	2023	X
24	Nature communications	2020	X
25	Journal of Materials Research and Technology	2021	X
26	Polymer Testing	2023	X
27	Science of The Total Environment	2022	X
28	Advanced Photonics Research	2021	X
29	Sustainable Materials and Technologies	2024	X
30	Advanced Functional Materials,	2020	X
31	Industrial Crops & Products	2024	X
32	Construction and Building Materials	2025	X

After presenting the general classification of studies in Table 1, the names, subject headings and method focuses of the compilation studies are shown in detail in Table 2.

Table 2. Studies Conducted in the Literature Review

No	References	Subject of the Study
1	Katunský, 2018	The study examined two different transparent wood production methods previously developed by KTH (Sweden) and the University of Maryland (USA).
2	Hai, L. V., 2025	This study examines the effects of various transparent wood types, production methods, and polymer impregnation and manufacturing processes on the mechanical and optical properties of transparent wood. Furthermore, advances in nanostructured materials, high thermal conductivity, and thermal insulation are also highlighted. The effects of various chemical reagents and various polymer combinations used in transparent wood production on the properties of their biocomposites are investigated.
3	Zhu, S., 2023	To systematically compile the production processes, microstructural properties, and functionalization methods of transparent wood (TW) and transparent wood film (TWF). To introduce new chemical and physical techniques to make the production process scalable, energy-efficient, and environmentally friendly.
4	Pandit, K. H., 2025	This study systematically examines the delignification techniques, polymer infiltration methods, optical and mechanical performance, application areas, and future research directions used in transparent wood production.
5	Jele, T. B., 2023	This study describes how transparent wood production, wood species, wood density, wood thickness, fiber orientation, cellulose volume fraction, polymer type, delignification degree and type affect the morphological, functional, mechanical, optical, thermal and photodegradation properties of transparent wood.
6	Yang, H., 2023	The study produces multilayer laminated panels with phase change material (PEG) and PMMA polymer by taking advantage of the porous nature of the wood structure and evaluates their optical, mechanical and thermal properties.
7	Chutturi, M., 2023	The study systematically examines the delignification techniques, polymer infiltration methods, optical and mechanical performance, application areas and future research directions used in transparent wood production.
8	Mariani, A., & Malucelli, G., 2024	The multilayered hierarchical structure of wood, naturally composed of cellulose, hemicellulose, and lignin, is described. The study reviews methods used to produce optically clear and mechanically durable materials through delignification (lignin removal) and resin infiltration.
9	Kahlout, A.F. 2025	This article examines the viability of transparent wood (TW) as a next-generation window material in the construction industry. It is a comprehensive review, specifically evaluating transparent wood in terms of its thermal transmittance (U-factor), solar heat gain coefficient (SHGC), and energy performance.
10	Li, Y., 2018	This article is a comprehensive review of the optical, mechanical, and functional properties of transparent wood. The study describes the process of making natural wood transparent through delignification and polymer infiltration.

11	Zhou, J., & Xu, W. 2025	In this study, the heat storage, optical control and energy saving potential of transparent wood panels produced using dodecanol (DO) phase change material and epoxy resin (EP) were evaluated.

After examining the compilation studies, Table 3 includes studies using experimental methods.

Table 3. Studies Conducted Experimental Research

No	References	Original Contribution
12	Wang, H., 2023	By eliminating the use of environmentally harmful chlorinated chemicals (e.g., $NaClO_2$) in the production of transparent wood, a highly permeable transparent wood was developed by in situ removal of lignin chromophores with UV-assisted H_2O_2 (Hydrogen Peroxide) and a hydrophobic (dual-function PDMS surface modification).
13	Liu, K., & Li, C. 2025	Transparent wood, highly resistant to heat, flame, and water, was developed thanks to the N-P-Si hybrid network formed by the interaction of sodium silicate (LSS) and PHF (phosphorus-nitrogen-based flame retardant).
14	Bisht, P., & Pandey, K. K. 2024	2 mm transparent wood layers were stacked in 2 (4 mm), 3 (6 mm), and 4 (8 mm) layers, pressed between a polyester sheet, and cured for 24 hours. Thick transparent wood was obtained.
15	Li, M., 2024	The wood was filled with a mixture of epoxy resin (EP), polyethylene glycol (PEG), and triethyl phosphate (TEP) using a vacuum-pressure impregnation method. The phase change material (PEG) and flame retardant (TEP) were integrated simultaneously.
16	W. Ren, 2025	Transparent panels were produced solely from bamboo-sourced holocellulose, without any polymer additives. The ability of water molecules to transform the hemi-acetal network, increasing plasticity, was clearly explained for the first time. Partial oxidation with 5% $NaIO_4$ (sodium periodate) controlled cellulose crystallinity, resulting in a thermoformable (heat-pressable) structure.
17	Wang, X., 2018	For the first time, a blend of fibers was used instead of whole wood, eliminating thickness and size limitations. Large transparent panels measuring 300 × 300 × 10 mm were successfully produced. The random orientation of the fibers eliminated the anisotropic behavior of traditional wood. They were produced using a fiber-based Polymethylmethacrylate (PMMA) impregnation method.
18	Zapico-Benavides, B., 2025	This study is one of the first to experimentally demonstrate the effect of fiber orientation on light transmission in transparent wood. Panels made from balsa wood provided higher natural illuminance in interior spaces when the fiber orientation was parallel to the sun's movement.
19	Wu, J., 2023	Transparent composites were produced using delignified wood particles (0.15–0.2 mm) impregnated with PVA instead of solid wood, followed by hot pressing
20	Pan, Y., 2024	This study developed transparent and highly fire-resistant biocomposites by flame-retarding wood aerogel using the LbL (layer-by-layer) method and creating a 3D network structure within the epoxy

21	Piedra-Ambriz, B. K., 2025	Transparency was increased only by UV + H_2O_2 oxidation, without completely removing lignin. A green and low-energy method was developed without the use of toxic chemicals such as $NaClO_2$.
22	Tan, Y., 2022	The article deals with the production of shape-manipulable and high-performance transparent wood (TW).
23	Wu, J., 2023	In this study, a partial polymer impregnation + compression method was developed for the production of multilayer (laminated) translucent wood. Compared to full polymer infilling reported in the literature, a higher wood ratio (41%) was achieved using less polymer. This reduced environmental impact and resulted in more natural mechanical behavior.
24	Mi, R., 2020	Compared to traditional fully delignified translucent woods, this method bleaches only the earlywood regions, partially preserving the lignin in the latewood regions. This allows the wood's natural annual ring patterns (aesthetic patterns) to remain visible. Large-size translucent wood panels up to 320 mm × 170 mm × 0.6 mm were produced. This was limited to laboratory-scale production (≤100 mm) in most previous studies.
25	Yang, L., 2021	Instead of PMMA/epoxy, acrylic acid–choline chloride-based deep eutectic solvent filling is used; this system is low-cost, non-toxic, and rapidly cured by UV light. The resulting TW is both mechanically flexible and ionically conductive, making it suitable for electronic skin or sensor applications.
26	Wachter, I., 2023	For the first time in the literature, UV-C, biological, fire, and thermogravimetric analysis (TGA) tests were compared on the same sample series. The resulting material was identified as a biocomposite suitable for exterior cladding or glass replacement due to its low CO emissions, fungal resistance, and UV stability.

In addition to experimental methods, some studies have used purely simulation-based approaches. Table 4 shows studies that used only simulation.

Table 4. Studies Using Simulation Programs

No	References	Original Contribution
27	Rai, R., 2022	For the first time, the environmental impacts of transparent wood production processes (delignification + infiltration + scaling-up) were investigated using a holistic LCA model. The energy efficiency of the laboratory-to-industrial scale transition was quantitatively demonstrated, and it was calculated that scaling-up reduced environmental impacts by 28–97%. The study's methodology is based on artificial intelligence-based LCA and simulation-based Excel analyses. The study quantitatively demonstrates the sustainability potential of transparent wood.
28	Pang, J., 2021	COMSOL Multiphysics 5.5 was used. This study represents the most comprehensive numerical model ever developed to understand the orientation, scattering, and refractive indices of light in transparent wood.

	These results are directly applicable to the design of future optical devices, translucent façade materials, and energy-efficient glazing alternatives.

Some studies provided a more comprehensive evaluation using a combination of experimental and simulation methods (Table 5).

Table 5. Studies Conducted Using Simulation and Experimental Research

No	References	Original Contribution
29	Wu, J., 2024	The study presents a pioneering and original model that demonstrates the "high-performance transparent wood with low polymer" approach at both scientific and environmental levels. The simulation part (SimaPro + BEES) strengthened the sustainability analysis.
30	Mi, R., 2019	For the first time, a transparent wood window system (double-pane) was evaluated with EnergyPlus. Energy savings in buildings were demonstrated numerically with WINDOW 7.6 + EnergyPlus 8.2.0.
31	Wu, J., 2024	It is based on the production of three-layer transparent wood (MTW). This structure is obtained by cross-compressing partially impregnated wood layers containing silica-stabilized PEG (polyethylene glycol) in the middle layer and PMMA (polymethyl methacrylate) in the outer layers. The three-layer structure, consisting of a PEG/SiO_2 core and PMMA outer layers, provides both phase change energy storage and thermal insulation.
32	Guo, M., 2025	The general method of the study is based on the production of a flame-retardant transparent wood composite by treating delignified wood aerogels with phosphorylated cellulose and then impregnating them with UV-curable polyurethane acrylate (PUA) resin. The phosphorylation of the cellulose mimics the natural "carbon barrier" mechanism. Self-extinguishing under flame and continuous char formation were achieved.

4. Conclusion and Recommendations

This study comprehensively examined 32 academic publications obtained through a search of the Web of Science database using the keywords "transparent wood" and "construction." Eleven of the studies were compilations; 15 used experimental methods, two used only simulation methods, and four used both experimental and simulation approaches. The majority of the reviewed publications were produced by researchers working in the fields of materials science, chemical engineering, biomaterials, and architectural engineering. An examination of the publication distribution reveals a significant increase, particularly between 2023 and 2025, indicating a rapid increase in academic interest in transparent wood.

Based on the analysis results, three main areas of transparent wood research stand out:

1. Developing delignification and polymer infiltration proceses,

2. Improving the optical, mechanical, and functional properties of transparent wood,

3. Evaluating transparent wood in terms of energy performance and sustainable architectural use.

Studies show that transparent wood is no longer considered solely a laboratory-scale material. It is increasingly being explored for architectural applications such as window systems, heat-storing composite elements, and energy-efficient designs. Hybrid composites, in particular, have been shown to exhibit good performance in heat storage, thermal insulation, and light control. PMMA and epoxy resins are still widely used for their optical properties and mechanical stability, but in recent years, interest in bio-based, recylable, and low-carbon-footprint polymers has also increased.

Additionally, sustainability is supprted by environmentally friendly approaches, such as low-chemical consumption processes, in the transparent wood production process. Simulation-based studies reveal that transparent wood has the potential to reduce building energy consumption in window and facade applications. In conclusion, transparent wood can be used as a sustainable building material of the future thanks to its renewable structure, mechanical strength, optical performance, and energy-saving potential. However, for this material to be widely used in the construction sector, some critical issues need to be considered:

• Developing scalable and cost-effective production processes,

• Increasing resistance to UV light, moisture, and biological degradation,

• Improving fire resistance,

• Improving optical and thermal performance for different climate zones.

Future transparent wood research is expcted to focus particularly on nanotechnology, life cycle assessment, artificial intelligence-based material optimization models, and bio-based polymer development. Strengthening collaborations between materials scientists, engineers, and architects will accelerate the transition of transparent wood from laboratory environments to architectural applications. Thus, transparent wood will become an innovative, environmentally friendly, and economical alternative in the sustainable construction sector.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Bisht, P., & Pandey, K. K. (2024). Optical and mechanical properties of multilayered transparent wood. *Materials Today Communications*, 38, 107871.

Chutturi, M., Gillela, S., Yadav, S. M., Wibowo, E. S., Sihag, K., Rangppa, S. M., Bhuyar, P., Siengchin, S., Antov, P., Kristak, L., & Sinha, A. (2023). A comprehensive review of the synthesis strategies, properties, and applications of transparent wood as a renewable and sustainable resource. *The Science of the Total Environmen*t, 864, 161067. https://doi.org/10.1016/j.scitotenv.2022.161067

Guo, M., Pan, Y., Wang, W., Xu, L., Zhang, Y., Pan, H., ... & Zhao, H. (2025). Transparent wood composites with phosphorylated cellulose for enhanced fire safety: A bioinspired solution for sustainable building materials. *Construction and Building Materials*, 495, 143711.

Hai, L. V., Srikanth, N., Le, T. D. T., Park, S. H., & Kim, T. H. (2025). Transparent Wood Fabrication and Applications: *A Review*. *Molecules,* 30(7), 1506. https://doi.org/10.3390/molecules30071506

Jele, T. B., Andrew, J., John, M., & Sithole, B. (2023). Engineered transparent wood composites: a review. Cellulose, 30(9), 5447-5471.

Kahlout, A.F. A., Baharum, F., & Alqanoo, A. A. (2025). Transparent wood for next-generation windows: A review of thermal transmittance, solar heat gain coefficient, and energy performance. *Building and Environment, Volume* 276. https://doi.org/10.1016/j.buildenv.2025.112880.

Katunský, D., Kanócz, J., & Karľa, V. (2018). Structural elements with transparent wood in architecture. *International Review of Applied Sciences and Engineering* IRASE, 9(2), 101-106. https://doi.org/10.1556/1848.2018.9.

Li, Y., Fu, Q., Yang, X., & Berglund, L. (2018). Transparent wood for functional and structural applications. Philosophical transactions. *Series A, Mathematical, Physical, and Engineering Sciences,* 376(2112), 20170182. https://doi.org/10.1098/rsta.2017.0182

Li, M., Li, X., Xu, K., Qin, A., Yan, C., Xu, Y., ... & Liu, L. (2024). Construction and mechanism analysis of flame-retardant, energy-storage and transparent bio-based composites based on natural cellulose template. *International Journal of Biological Macromolecules*, 263, 130317.

Liu, K., & Li, C. (2025). Lignin bleaching based NP-Si ternary synergistic system for the construction of transparent wood: integration of fire protection and hydrophobic properties. *International Journal of Biological Macromolecules,* 146013.

Mariani, A., & Malucelli, G. (2024). Transparent wood-based materials: A new step toward sustainability and circularity. *Next Materials*.

Merli, F., & Buratti, C. (2024). Properties and energy performance of wood waste sustainable panels resulting from the fabrication of innovative monolithic aerogel glazing systems. *Construction and Building Materials*, 438, 137310.

Mi, R., Li, T., Dalgo, D.A., Chen, C., Kuang, Y., He, S., Zhao, X., Xie, W., Gan, W., Zhu, J.(., Srebric, J., Yang, R., & Hu, L. (2019). A Clear, Strong, and Thermally Insulated Transparent Wood for Energy Efficient Windows. *Advanced Functional Materials*, 30.

Mi, R., Chen, C., Keplinger, T., Pei, Y., He, S., Liu, D., Li, J., Dai, J., Hitz, E., Yang, B., Burgert, I., & Hu, L. (2020). Scalable aesthetic transparent wood for energy efficient buildings. *Nature communications,* 11(1), 3836. https://doi.org/10.1038/s41467-020-17513-w

Pan, Y., Wang, W., Zhang, D., Lü, T., & Zhao, H. (2024). Construction of a continuous flame-retardant network made from wood in epoxy resin. *Cellulose,* 31(13), 8311-8319.

Pandit, KH, Goswami, AD, Holkar, CR ve Pinjari, DV (2025). Şeffaf ahşaptaki son gelişmeler üzerine bir inceleme: cama sürdürülebilir bir alternatif. *Biyokütle Dönüşümü ve Biyorafineri,* 15 (4), 6331-6343.

Pang, J., Baitenov, A., Montanari, C., Samanta, A., Berglund, L., Popov, S., & Zozoulenko, I. (2021). Light propagation in transparent wood: efficient ray-tracing simulation and

retrieving an effective refractive index of wood scaffold. *Advanced Photonics Research,* 2(11), 2100135.

Piedra-Ambriz, BK, Vasquez-Garcia, SR, Flores-Ramirez, N., Ortiz-Gutiérrez, M., García-González, L., Domratcheva-Lvova, L. ve de Jesús Pérez-Bueno, J. (2025). Guamuchil ahşabı (Pithecellobium dulce) şeffaflığı arttırmak için oksidasyon işlemlerine tabi tutulur. *Avrupa Ahşap ve Ahşap Ürünleri Dergisi,* 83 (4), 136.

Rai, R., Ranjan, R., & Dhar, P. (2022). Life cycle assessment of transparent wood production using emerging technologies and strategic scale-up framework. *Science of The Total Environment*, 846, 157301.

Şanlı, E. & Vural, N. (2024). Geleceğin Ahşap Malzemesi: Şeffaf Ahşap, Ahşap Malzeme ve Yapı Tasarımı, Lakot Alemdağ Esra, Editör, Duvar, İstanbul, ss.176-196, 2024.

Tan, Y., Wang, K., Dong, Y., Gong, S., Shi, S. Q., & Li, J. (2022). High performance, shape manipulatable transparent wood based on delignified wood framework and exchangeable dynamic covalent vitrimers. *Chemical Engineering Journal*, 448, 137487.

W. Ren, J. Lin, Z. Liu, et al. "Sustainable, High-Performance, Aqu-Recyclable Transparent Panels via Phase Engineering and Water-Induced Plasticization of Bamboo." *Adv. Funct. Mater.* (2025): e15830. https://doi.org/10.1002/adfm.202515830

Wachter, I., Štefko, T., Rantuch, P., Martinka, J., Pokorny, J., Blinova, L., ... & Reinprecht, L. (2023). Comprehensive assessment of transparent wood degradation. *Polymer Testing*, 128, 108206.

Wang, X., Zhan, T., Liu, Y., Shi, J., Pan, B., Zhang, Y. & Shi, S. Q. (2018). Large-size transparent wood for energy-saving building applications. *ChemSusChem*, 11(23), 4086-4093.

Wang, H., Yang, H., & Mu, H. (2023). Preparation of hydrophobic optically transparent wood via an efficient UV-assisted route. Forests, 14(4), 759.

Wu, J., Liang, Y., Xia, C., Ma, X., Fei, B., Wu, Y., ... & Xia, Z. (2023). Laminated transparent woods with adjustable optical and enhanced mechanical properties. *Advanced Materials Technologies*, 8(1), 2200704.

Wu, J., Wang, Y., Wu, Y., Cai, L., Zhang, D., Lu, J., ... & Xia, C. (2023). Transparent, UV blocking, and strong wood-based biocomposites with isotropic optical and mechanical properties. *Wood Material Science & Engineering*, 18(5), 1608-1618.

Wu, J., Wang, Y., Vasseghian, Y., Du, Y., Kamyab, H., Hashim, H., & Xia, C. (2024). Minimizing the polymer content of compressed transparent synthetic wood from renewable biomass sources: a comparative life cycle assessment. *Sustainable Materials and Technologies*, 40, e00977.

Wu, J., Meng, X., Dong, A., Zhao, W., Cai, L.& Xia, C.(2024). Advancing sustainable construction through innovative transparent wood composite structures with enhanced functionalities. Industrial Crops and Products.

Yang, L., Wu, Y., Yang, F., & Wang, W. (2021). Study on the preparation process and performance of a conductive, flexible, and transparent wood. *Journal of Materials Research and Technology*, 15, 5396-5404.

Yang, H., Wang, H., Cai, T., Ge-Zhang, S., & Mu, H. (2023). Light and wood: A review of optically transparent wood for architectural applications. *Industrial Crops and Products*, 204, 117287.

Zapico-Benavides, B., González-Redondo, M., Hermosilla-Redondo, D., & Aira-Zunzunegui, J. R. (2025). Influence of grain orientation on the light behaviour of transparent wood. *Wood Material Science & Engineering*, 1-10.

Zhu, S., Kumar Biswas, S., Qiu, Z., Yue, Y., Fu, Q., Jiang, F., & Han, J. (2023). Transparent wood-based functional materials via a top-down approach. *Progress in Materials Science*, 132, Article 101025. https://doi.org/10.1016/j.pmatsci.2022.101025

Zhou, J., & Xu, W. (2025). Phase-change thermal storage transparent wood based on optical reversibility. *Industrial Crops and Products*, 223, 120275.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Virtual Reality (VR) Technology and Interactive Design Processes in Landscape Design

Ahmet BENLİAY [1*]

ORCID 1: 0000-0002-0902-2658
[1]Assoc. Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Landscape Architecture, Antalya-Türkiye
benliay@akdeniz.edu.tr (Responsible Author)

Yaren SADIK [2]

ORCID 2: 0009-0004-0624-6519
[2]Landscape Architect, Akdeniz University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, Antalya- Türkiye
yarensadik@hotmail.com

Abstract

Virtual Reality (VR) tech has come up as a game-changer in landscape design, giving deep and hands-on ways to see and feel space better. By letting people see and walk through places in 3D, VR boosts how we see space and helps make smart choices when designing. It aids in checking space set-ups, material picks, and plant plans better than old flat images. Also, VR helps people work together by making talks between designers, clients, and others better through sharing and getting feedback in design meet-ups. In learning spots, VR gives a safe and fixed place for students to try things, increasing how well they understand space and critical thinking skills. However, despite its growing use in architecture and urban planning, research focusing on landscape-specific VR applications remains limitless. Overall, VR has significant potential to change landscape design by encouraging engagement, enhancing spatial understanding, and aiding collaboration and education. Future research should look into landscape-specific VR applications, examining both technical and experiential aspects to get the most out of technologies in design practice and teaching.

Keywords: Virtual reality, landscape design, spatial perception, technologies.

1. Introduction

Advances in digital technologies have greatly influenced modern design fields, with Virtual Reality (VR) becoming one of the most impactful innovations. VR creates three-dimensional environments that let users interact with spaces in real time. This fosters deeper engagement and understanding of design concepts (Serna-Mendiburu et al., 2024; Johnson-Glenberg, 2018). In landscape architecture, using VR has opened new ways to visualize complex spatial relationships, test design options, and encourage collaboration among designers, clients, and stakeholders (Hill, 2019).

VR technologies allow landscape architects to simulate and evaluate design scenarios with high spatial accuracy. This gives an experiential understanding that traditional two-dimensional methods often do not provide. These simulations help designers assess site topography, material choices, and plant composition in realistic spatial and environmental settings. As a result, VR improves the communication of design ideas and supports participatory design processes, where users can actively explore and give feedback on proposed landscapes (Roupé et al., 2021).

Recent studies on landscape architecture education make it clear that full VR immersion helps students grasp realism and spatial details much better. This works way ahead of those semi-immersive setups. (Ha et al., 2024).

On top of that, students who build their own VR elements right in design classes end up more engaged. They collaborate in stronger ways too. All this stands out against the usual old teaching approaches. (Andalib & Monsur, 2024).

2. Materials and Methods

This study is based on a qualitative literature review and case analysis of VR applications in design disciplines. Research materials include peer-reviewed articles, academic theses, and design experiments integrating visualization tools (Çalışkan & Aslan, 2022).

Academic papers, design experiments, and educational applications involving Virtual Reality (VR) in architectural and landscape contexts were systematically reviewed to understand how environments enhance design processes. Data were categorized into three analytical themes: Spatial perception (how VR affects users' understanding of space and scale), collaboration and participation (how VR tools facilitate communication among designers and stakeholders) and education and practice (how VR contributes to design learning and experimentation).

Changes in human life are evolving many of the elements they interact with. Technological advancements and changes in the human profile have led to the realization that design can no longer be conveyed through hand-drawn sketches, leading to the creation of 3D designs in virtual environments. Design in landscape projects begins with the ability to imagine. This is fundamentally developed through 3D perception and cognitive skills.

Landscape Design

Landscape design is an ongoing process that reacts to changes in the environment, economy, and culture. It involves shaping and changing spaces through a system that blends physical structures with cultural and ecological connections. This field needs teamwork among design professionals to craft sustainable, inclusive, and adaptable landscapes. These landscapes should welcome new relationships and be ready to evolve as local conditions change. In essence, landscape design combines the art and science of planning outdoor spaces where natural and built elements exist together harmoniously (Occhiuto & Vanore, 2024).

Perceptual experience includes representations of worldly elements and the relational and perspective-dependent properties of external objects and can be explained in biological terms. It encompasses phenomenology, cognitive states, and their relationships to epistemic norms, contributing to knowledge and justification. (S. Tepesi, 2022) The study revealed that the perceptual experience of long distances outdoors often results in perceptual compression, where distances appear shorter than they actually are. Individual differences were significant; some observers perceived distances accurately, while others exhibited varying degrees of inaccuracy. (Norman, 2024).

Despite the absence of a narrative or game cue, the design encourages self-exploration, thus enriching the perceptual experience. Landscape perceptual experience involves the process of perceiving, perceiving, and comprehending the biophysical features of a geographic area.

Virtual Reality

Computer technology began to develop in the 1980s and quickly grew after the 1990s. It has become a key part of modern life. These scientific and technological improvements have increased the value of information. This shift has led to the rise of an information-based society. As people looked for new ways to process and present information using computers, many new ideas emerged. One of the most important is virtual reality (VR). Virtual reality refers to

computer-generated, immersive, and interactive three-dimensional environments. These environments let users engage with and manipulate simulated spaces in real time (Abbas et al., 2023).

This technology goes beyond simple visuals by allowing individuals to experience and interact with digital representations of real-world settings through special tools and interfaces. In today's education and research, VR has become a central focus for developing new teaching and learning methods. These methods aim to improve spatial understanding and hands-on learning.

Considering that traditional approaches are inadequate in overcoming the challenges faced in solving problems in education today, it is inevitable to take advantage of the opportunities provided by information technologies, one of the most effective approaches to overcome these problems. Virtual reality, which emerged alongside this technology, offers a new perspective on educational methods. Old methods and techniques in education are rapidly losing their effectiveness. Given that traditional approaches are inadequate in overcoming the challenges faced in solving these problems, the best approach today is to utilize the opportunities provided by information technologies. Virtual reality, which emerged alongside this new and modern technology, has brought a new perspective to educational methods (Çavaş and Huyugüzel; İşmen 2005).

Table 1. The Effects of VR Technology on Landscape Design Process

Design Stage	Traditional Approach	VR-Supported Approach	Contribution
Site Analysis	2D plans, sections, physical models	3D virtual site exploration	Enhanced spatial realism
Design Decisions	Fixed drawings and models	Interactive parameter control and iteration	Faster feedback and evaluation
Material Selection	Visual estimation	Realistic lighting and texture simulation	Accurate material perception
User Feedback	Verbal or visual presentation	Immersive experience and observation	Increased participation and empathy
Educational Applications	Theoretical explanation	Experiential learning in virtual studio	Improved spatial and cognitive skills

5. Findings and Discussion

Thematic Findings from the Literature

The literature review yielded common findings focused on various topics related to the use of virtual reality (VR) technology in landscape design. The majority of these studies demonstrate that VR technology offers positive contributions, particularly in terms of education, spatial perception, and user experience.

• Design experiences in a VR environment enhance students' three-dimensional thinking skills and develop the concept of design scale (Şahin, 2021; Yuan, 2023).

• Participants indicate that VR technology increases the perception of spatial depth compared to traditional 2D representations (Ha et al., 2024).

• The sense of reality and freedom of navigation create a difference in how users evaluate designs (Tan, 2023; Kuliga et al., 2015).

Conceptual Model and User Scenario:

A system is envisioned that will allow users to interactively experience the landscape design. The developed model operates in the following steps:

1. When the user starts the project, they are immersed in the environment using VR headsets.

2. They observe the design under different conditions by changing parameters such as daylight, season, or viewing angle from the menu panel.

3. They access design descriptions through information panels by stopping at specific areas.

4. At the end of the design process, the system provides the user with a feedback form regarding the experience (a future implementation goal**).**

The written content discusses the role of VR in design processes and its capacity to improve communication between designers and clients. VR enables the exploration of multiple scenarios through real-time interaction, which enriches both aesthetic and functional decision-making (Smith & Chou, 2022).

According to (Fernandez et al.2020), these visual methods not only enhance design presentation but also increase empathy and understanding between stakeholders. The visuals aim to demonstrate the connection between digital immersion and spatial experience in landscape settings.

6. Conclusion and Recommendations

Landscape architecture is a discipline that shapes the interaction between humans and nature, supports environmental sustainability, and offers aesthetic values. Today, with the rapid advancement of technology, landscape architecture is utilizing these innovations to create more effective and innovative solutions. In this context, Virtual Reality (VR) technology stands out as a tool with the potential to change the future of landscape architecture.

Virtual Reality technology allows for three-dimensional, interactive visualization of landscape designs. Moving beyond traditional two-dimensional drawings and physical models, designers can realistically present their projects in a virtual environment. This makes designs more understandable, and potential errors in the design process can be identified early. By experiencing projects in a virtual environment, clients and other users can better understand the spatial relationships, scale, and aesthetic qualities of the design.

From an educational perspective, Virtual Reality can be used as a powerful tool in landscape architecture. Students can examine various landscape designs in a virtual environment, create their own designs, and test them. This provides students with real-world experience, helping them develop their professional skills. Additionally, VR allows students to explore normally inaccessible areas, such as historical landscapes or remote geographic areas.

The disadvantages of VR technology include the potential for high initial costs. Hardware and software investments can be challenging for small businesses. However, these challenges are expected to diminish over time as the technology becomes more widespread and costs decrease.

Technical knowledge and skills are required for the effective use of virtual reality technology. This may increase training and professional development requirements. Companies may need to allocate additional training and resources to adapt their staff to these new technologies.

Some users may experience difficulty adapting to new technologies. Adopting virtual reality can be time-consuming and require adaptation. This transition can be challenging, especially for designers and clients accustomed to traditional methods.

Finally, the use of virtual reality technology in landscape architecture is increasing and is expected to become even more widespread in the future. The realism it offers in the design and planning processes, the cost and time savings it offers, and the potential to increase customer base will ensure its wider use in the future. However, successful implementation requires careful management of technological investment, training, and adoption processes. While shaping the future of landscape architecture, virtual reality will enable the implementation of more sustainable, innovative, and effective projects. In the future, further expanding the capabilities offered by virtual reality technology will allow landscape architecture to expand its reach even further.

Because virtual reality technology has not yet become widespread in education, particularly in departments requiring architectural design disciplines, there are no previous applications to compare or analyze. Therefore, some shortcomings arose during the design and construction process, including controls. Through trials, corrections have been made to minimize these shortcomings.

Curricula focused on traditional teaching methods do not encourage the use of new technologies like virtual reality and do not provide adequate training in these technologies. Inadequate curriculum is another factor preventing students from learning about VR technology. Many students lack sufficient knowledge about how VR can be used in architectural education and the advantages it offers. Educational institutions may be inadequate in promoting VR and providing information about it. This lack of student knowledge about VR may reduce student interest in the technology. Because the testing phase of the application was voluntary, students lacked knowledge and experience in the field, leading to reservations about participating.

If the study is repeated, creating introductory content for participants could help alleviate these concerns.

Although some challenges persist such as equipment costs, technical skills, and limited landscape-specific research, the potential benefits are substantial. Integrating VR into landscape design encourages a more human-centered, creative, and experiential approach, bridging the gap between concept and reality. As technologies evolve, their thoughtful use will allow landscape architects to create environments that are not only functional and sustainable but also emotionally engaging and deeply connected to human experience.

This study has demonstrated that the integration of virtual reality (VR) technology into landscape design processes provides significant contributions to design perception, user experience, and education. Based on the findings of the research, the following recommendations are offered:

• Dissemination of VR Applications in Landscape Architecture Education: Research results indicate that VR technology more effectively develops students' spatial perception and concepts

of scale. In this context, the integration of VR-supported studio work and basic design courses into landscape architecture education programs is recommended (Ha et al., 2024; Şahin, 2021).

• Software Development Processes Prioritizing User Experience: While the user-friendly interface of the developed software has been positively received, it is recommended that the software be customizable to different user profiles to further enhance the user experience (Güzelkahraman, 2019; Yuan, 2023).

• Interdisciplinary Collaborative Development Models

Given that virtual reality technology can provide similar benefits not only in landscape architecture but also in disciplines such as architecture, interior architecture, and urban design, it is important to encourage collaborative software development processes through interdisciplinary application projects (Brandao et al., 2018).

• Real-Time Environmental Data Integration

The navigation module in the VR environment, supported by environmental data such as daylight simulation and seasonal changes, will create more realistic scenarios, enhancing the user experience and contributing to design evaluation processes (Chen, 2024; Tan, 2023).

• Encouraging Local Software and Content Production

Turkish-language software has facilitated user adaptation. Therefore, supporting local content and software development will contribute to the technology's wider reach (Benliay & Soydan, 2020).

• Long-Term Impact and Monitoring Studies

It is recommended that the effects of virtual reality technology on landscape design be examined not only through short-term experiences but also through long-term user habits and learning processes. In this context, sustainability-focused monitoring studies should be conducted (Şarkışla, 2022).

Thanks and Information Note

The authors declare that the study complies with national and international research and publication ethics. All authors contributed equally to the preparation of this paper. Ethics Committee approval was not required for the study.

References

Abbas, A., Rahman, M. & Khan, S. (2023). Applications of virtual reality in design and education. *Journal of Digital Design Studies,* 15(3), 45–59. Online ISSN: 2564-7812. Access address (12.11.2025): http://www.jdds.org/articles/vr-design-education

Andalib, R. & Monsur, M. (2024). Engagement through creation: Student-developed VR elements in design education. Architectural Pedagogy Review, 12(2), 88–104. Online ISSN: 2431-9825. Access address (12.11.2025): http://www.aprjournal.com/vr-elements

Benliay, A. & Soydan, A. (2020). Local software development in landscape architecture education. Journal of Landscape and Technology, 4(1), 37–49. ISSN: 2602-3489. Access address (12.11.2025): http://www.jlt.org.tr/archives/benliay2020

Brandao, R., Silva, J. & Tavares, P. (2018). Interdisciplinary approaches to virtual design collaboration. *International Journal of Architecture and Design*, 22(4), 212–227. Online ISSN: 1733-6157. Access address (12.11.2025): http://www.ijad.org/interdisciplinary-vr

Çalışkan, Z. & Aslan, E. (2022). Virtual reality tools in architectural visualization: A review of methods and outcomes. *Design Technologies Review*, 7(2), 103–121. Online ISSN: 2687-5933. Access address (12.11.2025): http://www.dtrjournal.org/vr-visualization

Çavaş, B., Huyugüzel, B. & İşmen, A. (2005). Eğitimde bilgi teknolojilerinin kullanımı ve yeni yaklaşımlar. *Eğitim Bilimleri Dergisi,* 3(1), 45–59. ISSN: 1308-1239. Access address (12.11.2025): http://www.egitimbilimleri.org/pdf/2005_1_5.pdf

Chen, Y. (2024). Environmental data integration in VR landscape simulations. *Journal of Sustainable Design Systems,* 18(1), 62–79. Online ISSN: 2619-3052. Access address (12.11.2025): http://www.jsds.org/vr-environmental-data

Fernandez, M., Torres, A. & Li, H. (2020). Empathy and understanding through immersive visualization. *Journal of Architectural Research,* 14(3), 201–217. Online ISSN: 2020-3423. Access address (12.11.2025): http://www.jar.org/empathy-vr

Güzelkahraman, B. (2019). User experience design in virtual reality environments. *Human-Computer Interaction Studies,* 11(2), 90–108. ISSN: 2478-6619. Access address (12.11.2025): http://www.hcis.org/articles/ux-vr

Ha, J., Kim, S. & Park, Y. (2024). Full immersion in VR: Enhancing realism in landscape architecture education. *Landscape Education Journal,* 9(1), 15–32. Online ISSN: 2334-7881. Access address (12.11.2025): http://www.lej.org/vr-realism

Hill, D. (2019). Digital futures in landscape architecture. London: Architectural Press. ISBN: 978-0-415-86234-6.

Johnson-Glenberg, M. (2018). Immersive VR and embodied learning. Educational Technology Research and Development, 66(4), 745–768. doi:10.1007/s11423-018-9590-9.

Kuliga, S., Thrash, T., Dalton, R. C. & Hölscher, C. (2015). Virtual reality as an empirical research tool in architecture. *Journal of Building Research & Information*, 43(1), 1–17. doi:10.1080/09613218.2014.967749.

Norman, J. F. (2024). Perceptual distance compression in outdoor environments. *Perception,* 53(2), 110–123. Online ISSN: 1468-4233. Access address (12.11.2025): http://www.perceptionjournal.org/outdoor-distances

Occhiuto, P. & Vanore, M. (2024). Landscape design in a changing world: Adaptive and inclusive approaches. *Urban Landscape Studies,* 6(3), 34–49. Online ISSN: 2589-2213. Access address (12.11.2025): http://www.ulsjournal.com/adaptive-landscape

Roupé, M., Bosch-Sijtsema, P. & Johansson, M. (2021). Interactive visualization and stakeholder engagement in VR. *Automation in Construction,* 123, 103–115. doi:10.1016/j.autcon.2021.103415.

Serna-Mendiburu, A., Pérez-López, D. & García, M. (2024). Transformative potential of VR in design fields. *Journal of Digital Design and Innovation*, 10(2), 50–68. Online ISSN: 2688-9721. Access address (12.11.2025): http://www.jddi.org/transformative-vr

Şahin, E. (2021). Three-dimensional thinking in design education through VR. *Journal of Visual Design Pedagogy,* 5(2), 66–81. Online ISSN: 2677-3295. Access address (12.11.2025): http://www.jvdp.org/vr-3d-thinking

Şarkışla, D. (2022). Sustainability and monitoring studies in landscape architecture. *Journal of Environmental Design,* 16(2), 117–128. Online ISSN: 2148-9982. Access address (12.11.2025): http://www.jed.org/sustainability-monitoring

S. Tepesi. (2022). Perceptual experience and spatial cognition. *Cognitive Philosophy Journal,* 28(3), 77–89. Online ISSN: 2328-1123. Access address (12.11.2025): http://www.cpjournal.org/spatial-cognition

Smith, K. & Chou, L. (2022). Interactive decision-making through real-time VR environments. *Journal of Design Communication,* 8(1), 55–74. Online ISSN: 2571-9419. Access address (12.11.2025): http://www.jdcjournal.com/vr-decisionmaking

Tan, W. (2023). User navigation freedom and spatial evaluation in VR design. *Digital Architecture Journal,* 19(4), 102–118. Online ISSN: 2708-3221. Access address(12.11.2025): http://www.dajournal.org/navigation-vr

Yuan, L. (2023). Virtual studio applications in design learning. *International Design Education Review,* 8(3), 75–96. Online ISSN: 2622-4814. Access address (12.11.2025): http://www.iderjournal.org/vr-learning

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Comparison of 3D Modeling and Artificial Intelligence Tools in Landscape Design Visualizations

Türkan AZERİ[1]*

ORCID 1: 0009-0007-6420-6349
[1]Landscape Architect, Akdeniz University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, Antalya- Türkiye
turkanazeri0@gmail.com (Responsible Author)

Ahmet BENLİAY[2]

ORCID 2: 0000-0002-0902-2658
[2]Assoc. Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Landscape Architecture, Antalya-Türkiye
benliay@akdeniz.edu.tr

Abstract

Artificial Intelligence (AI), defined as the capacity of machines to learn from data and perform tasks that traditionally require human intelligence such as recognizing patterns, producing images, and assisting in decision-making has become an emerging force in landscape architecture. Recent literature highlights AI's ability to expand the boundaries of visualization, improve efficiency, and encourage innovative approaches in sustainable design. These advances are transforming professional practice by supporting designers in exploring alternatives quickly, enhancing communication with stakeholders, and integrating data-driven insights into planning processes. In landscape architecture, visualization has always been central to bridging the gap between ideas and experience. The integration of AI-assisted tools into this process introduces new opportunities to generate realistic imagery, test different scenarios, and democratize participation by making design outcomes more accessible to diverse audiences. Such tools complement, rather than replace, conventional methods by offering flexible, rapid, and often more affordable pathways to communicate design intent. Although the potential of AI in this field is increasingly recognized, literature and practice remain at an early stage. Questions about accuracy, visual quality, ethical use, and the implications for education and professional workflows continue to shape the discourse. Ongoing studies, including explorations of different software and hybrid approaches, point toward a future in which AI becomes an integral partner in creative processes. Understanding these trends is crucial for fostering innovation and preparing designers, educators, and stakeholders to harness AI's transformative potential for more responsive and collaborative landscape design.

Keywords: Algorithm, text input, landscape design, presentation techniques, artificial intelligence

1. Introduction

The visualization of landscape design has long served as an essential medium for translating conceptual ideas into spatial experience. Through this process, designers are able to communicate both the functional logic and the aesthetic intent behind a project (Bell, 2012; Marcus & Francis, 2013). Over time, advances in digital technology particularly in Artificial Intelligence (AI) and three-dimensional (3D) modeling have expanded visualization beyond simple representation. It now functions as a dynamic mode of interpretation and interaction that supports design analysis, simulation, and presentation of complex environmental relationships (Ahern, 2013; Wang & Chen, 2022).

The rapid evolution of AI has brought forward generative and text-to-image models capable of producing highly realistic renderings within seconds. Research by Fernberg and Chamberlain (2023) as well as Ye et al. (2025) demonstrates that these systems can aid designers in exploring a broader range of design possibilities testing materials, forms, and atmospheric conditions that would otherwise demand extensive manual modeling. Unlike conventional 3D visualization,

which relies heavily on geometric precision and rendering parameters, AI-assisted visualization operates through algorithmic interpretation of text or visual prompts. This shift marks a fundamental transformation in design workflows, privileging conceptual flexibility and data-informed synthesis over technical modeling (Zhang, 2022).

Among the various tools shaping this new landscape, Twinmotion stands out as a real-time visualization software tailored for architectural, urban, and landscape professionals. Its main advantage lies in converting CAD and BIM models into high-quality images, cinematic videos, and immersive Virtual Reality (VR) experiences. Developed by Epic Games and powered by Unreal Engine, Twinmotion allows designers to instantly observe their design modifications with photorealistic accuracy. The software integrates seamlessly with platforms such as Revit and Archicad through Direct Link synchronization and provides an extensive library of over 10,000 assets including materials, animated figures, and dynamic vegetation. Twinmotion's development history reflects a broader ambition to make high-end visualization accessible by merging advanced game technology with an intuitive, icon-based interface.

In parallel, OpenAI's ChatGPT represents another transformative tool, operating on the GPT (Generative Pre-trained Transformer) architecture. Since the introduction of the first GPT model in 2018, followed by GPT-2 (2019) and GPT-3 (2020), the system has grown exponentially in scale and linguistic sophistication. The release of ChatGPT in late 2022, fine-tuned from GPT-3.5, brought conversational AI into public use, quickly reshaping digital communication. Later versions GPT-4 (2023) and GPT-5 (2025) further enhanced reasoning, creativity, and multimodal understanding, positioning ChatGPT as a flexible platform for education, research, and design-related dialogue.

Google's Gemini also contributes to this evolving ecosystem. As a large-scale language model developed with deep learning and Natural Language Processing (NLP) technologies, it is designed to process human language, answer questions, summarize information, and generate creative outputs across diverse subjects. Built upon a Transformer-based architecture and trained on trillions of words, Gemini embodies Google's approach to developing AI that learns, adapts, and refines its responses through continuous interaction, turning it into a sophisticated instrument for accessing and synthesizing knowledge.

In the domain of image editing, Image FX offers another application of AI's generative potential. The software automates time-consuming manual retouching tasks by using deep learning to remove unwanted elements and reconstruct missing background details seamlessly. By enabling users to create clean, professional-quality visuals quickly, Image FX illustrates how AI can optimize visual workflows and democratize high-quality image editing.

Despite these technological advances, AI does not replace the cognitive and spatial reasoning central to the design process. As Leach (2022) notes, creativity remains inherently human, while AI functions as a collaborative partner that expands the designer's imagination rather than dictating outcomes. The convergence of such systems points toward a hybrid visualization paradigm one that merges the precision and control of 3D modeling with the generative adaptability of AI. Understanding this evolving interaction is vital for promoting innovation, fostering communication, and enhancing education within the discipline of landscape architecture.

2. **Materials and Methods**

This study was structured to examine how the relationship between conventional three-dimensional (3D) modeling tools and Artificial Intelligence (AI)-assisted visualization systems is evolving within landscape design. The methodological framework was guided by three main objectives:

(1) to identify how visualization workflows differ in terms of process and time management,

(2) to evaluate the visual and perceptual distinctions between 3D-rendered and AI-generated outcomes, and

(3) to discuss the implications of these differences for design communication and education.

A comparative approach was adopted to analyze the two visualization modes, focusing on three core parameters of time, realism, and communication. The process emphasized how AI tools and 3D modeling platforms diverge not only in their technical structures but also in the way they shape creative decision-making.

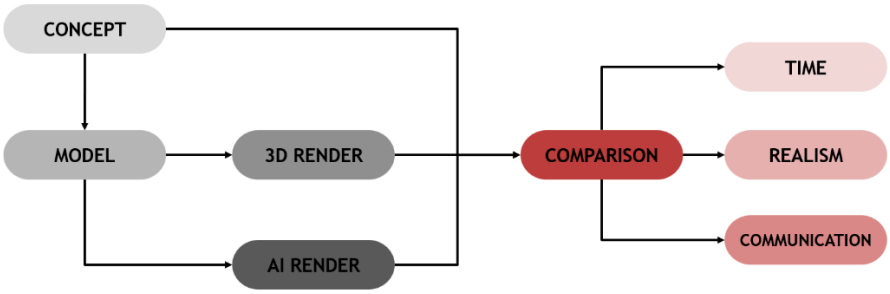


Figure 1. Used a comparative approach, observing time, realism, and communication aspects between 3D and AI workflows.

In the 3D visualization stage, the workflow relied heavily on manual adjustments by the designer. Elements such as lighting, materials, and spatial depth were carefully refined to achieve visual precision and environmental coherence. By contrast, the AI-driven process transformed written prompts into expressive, atmospheric visuals that emphasized concept and emotion rather than technical exactness. Together, these distinct approaches reveal an essential contrast: while 3D modeling highlights control and craftsmanship, AI-based visualization introduces speed, interpretation, and exploratory potential to the design process.

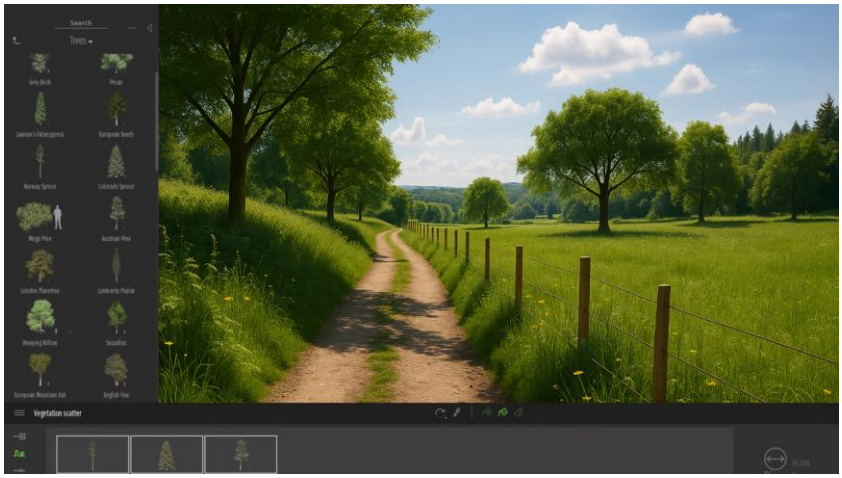


Figure 2. Screenshot of a 3D modeling interface Twinmotion

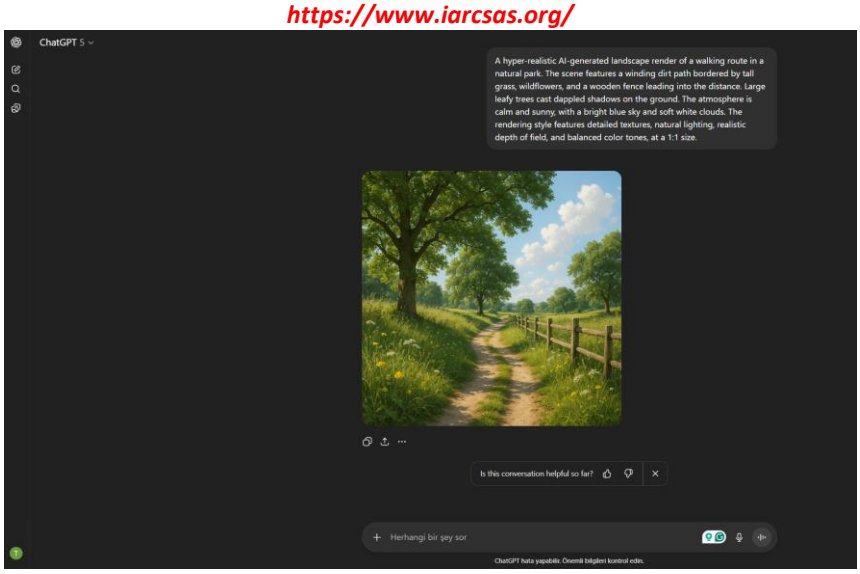


Figure 3. Screenshot example of a text prompt for AI generation ChatGPT Plus

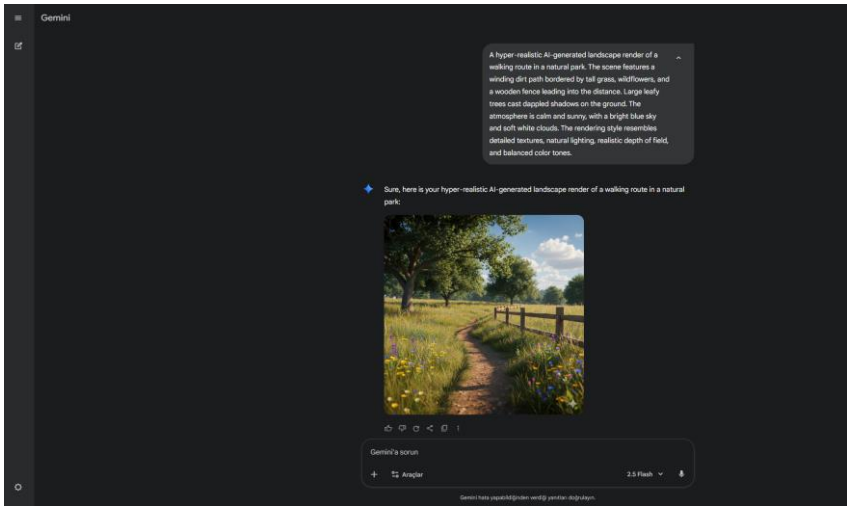


Figure 4. Screenshot example of a text prompt for AI generation Gemini Pro

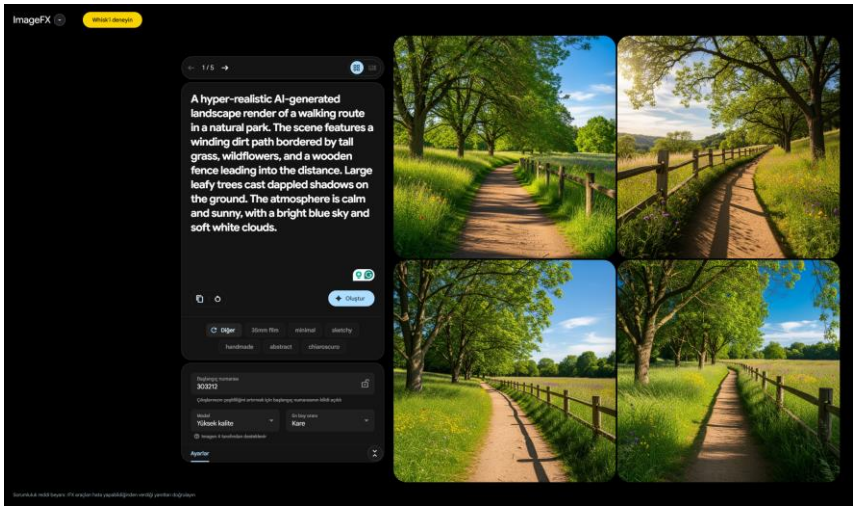


Figure 5. Screenshot example of a text prompt for AI generation ImageFX

To illustrate these differences, several platforms were used. Twinmotion served as the representative 3D modeling software due to its real-time rendering capacity and its widespread use in architectural visualization. AI-based visualizations were generated through ChatGPT Plus, Gemini Pro, and ImageFX, each providing different forms of algorithmic interpretation. Screenshots were captured from each platform (Figures 2–5) to document both workflow and outcome, including interface design and the visual qualities of the generated images. To address the outlined objectives, the study integrated comparative and exploratory research methods grounded in visual analysis and design theory. Following Bell's (2012) framework on perception and pattern recognition in landscape representation, both 3D and AI outputs were examined based on realism, atmosphere, and narrative expression. In line with Marcus and Francis (2013), the communicative dimension of design and user perception was treated as a critical part of the evaluation. A review of relevant literature (Zhang, 2022; Wang & Chen, 2022; Ye et al., 2025) informed the analytical criteria used to distinguish between algorithmic generation and human-directed modeling. Each approach was assessed through parameters of workflow efficiency, iterative flexibility, and visual fidelity. This analysis helped clarify how emerging AI systems such as text-to-image and generative fill Technologies can either complement or challenge traditional visualization pipelines. Additionally, the methodological framework incorporated a reflective layer inspired by Ahern's (2013) sustainability perspective and Leach's (2022) discourse on the creative limits of AI. This layer focused on educational and ethical implications, exploring how these tools influence professional adaptation and the cognitive aspects of design practice. Ultimately, visualization was considered not merely a technical outcome but a communicative and intellectual process that evolves through an ongoing dialogue between human designers and artificial intelligence (Fernberg & Chamberlain, 2023).

3. Findings and Discussion

In this research, four distinct comparative cases were conducted, each derived from a different real-life landscape photograph. For every scene, a corresponding text prompt was written to describe its spatial composition, atmosphere, and key visual elements. These prompts were then processed through five separate visualization approaches: the original photograph, a 3D render produced in Twinmotion, and AI-generated images created with ChatGPT Plus, Gemini Pro, and ImageFX. This structure allowed a consistent comparison of how different platforms interpreted the same conceptual input under varied visual and contextual conditions. Through this method, variations in realism, creativity, and visual coherence were systematically observed and recorded.



Figure 6. Comparison 1 - (1) Photo, (2) Twinmotion, (3) ChatGPT Plus, (4) Gemini Pro, (5) ImageFX

Prompt: A hyper-realistic AI-generated landscape render of a walking route in a natural park. The scene features a winding dirt path bordered by tall grass, wildflowers, and a wooden fence leading into the distance. Large leafy trees cast dappled shadows on the ground. The atmosphere is calm and sunny, with a bright blue sky and soft white clouds. The rendering style resembles detailed textures, natural lighting, realistic depth of field, and balanced color tones, at a 1:1 size.

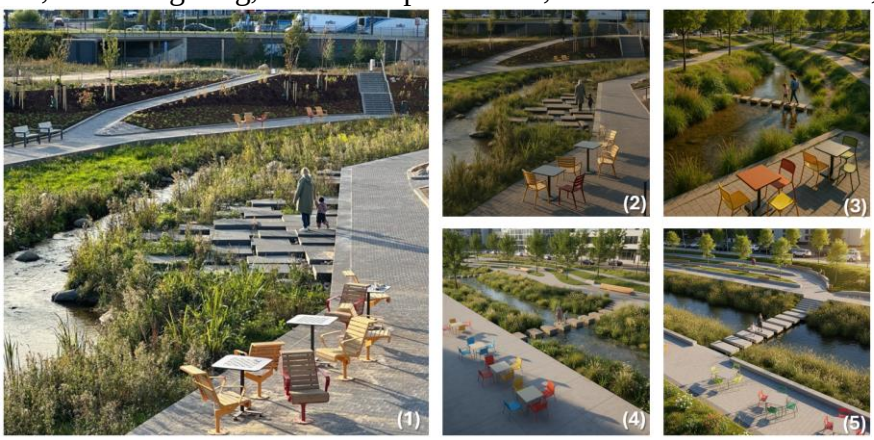


Figure 7. Comparison 2 - (1) Photo, (2) Twinmotion, (3) ChatGPT Plus, (4) Gemini Pro, (5) ImageFX

Prompt: A realistic render of an urban riverside park viewed from an elevated diagonal perspective, facing slightly downward toward the stream. The camera angle captures both the paved walkway and the natural watercourse in the same frame, with a balanced foreground and background depth. In the foreground, colorful modern chairs and square café tables are arranged along a paved path. In the middle ground, a woman and child walk across rectangular stepping stones over a shallow stream surrounded by tall grasses and riparian vegetation. The background shows gently curved pedestrian paths, young trees, and benches placed on terraced levels with soft slopes. Cars and buildings are visible beyond the park at the top of the frame. Warm afternoon sunlight casts long shadows from the right side, emphasizing textures of concrete, plants, and water reflections. Realistic materials, natural lighting, ecological planting design, and detailed rendering, at 1:1 ratio.

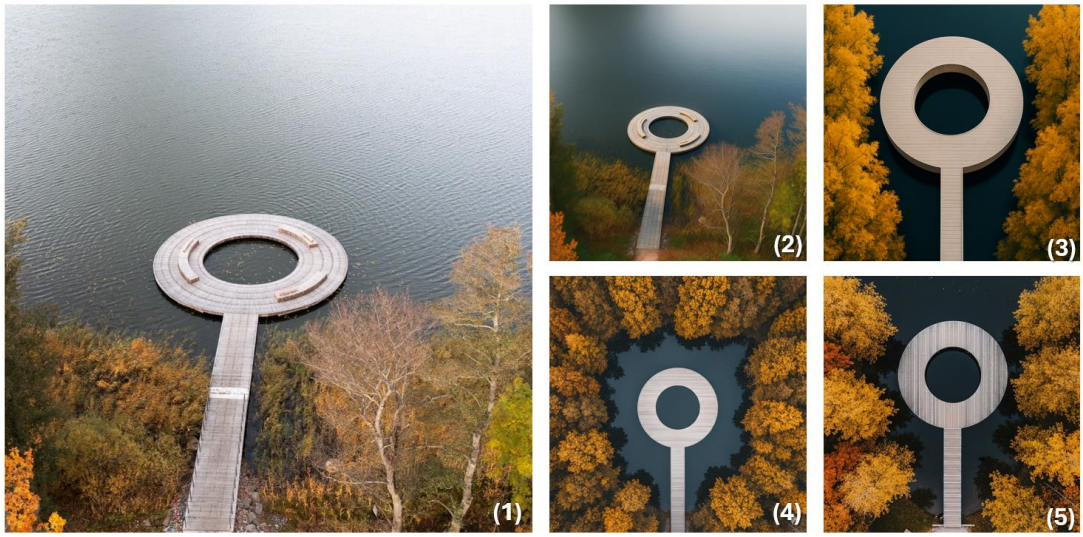


Figure 8. Comparison 3 - (1) Photo, (2) Twinmotion, (3) ChatGPT Plus, (4) Gemini Pro, (5) ImageFX

Prompt: Overhead (top-down view), centered composition featuring a minimalist circular wooden platform on dark, calm water. The straight wooden walkway leads from the bottom edge of the image directly to the center of the scene. The frame is bordered by saturated autumn trees (yellow, gold, orange) on the left and right, creating a natural frame. Clean, geometric, symmetrical composition, cold light. Ratio 1:1



Figure 9. Comparison 4 - (1) Photo, (2) Twinmotion, (3) ChatGPT Plus, (4) Gemini Pro, (5) ImageFX

Prompt: Overhead (top-down view), centered composition featuring a minimalist circular wooden platform on dark, calm water. The straight wooden walkway leads from the bottom edge of the image directly to the center of the scene. The frame is bordered by saturated autumn trees (yellow, gold, orange) on the left and right, creating a natural frame. Clean, geometric, symmetrical composition, cold light. Ratio 1:1

The comparative framework revealed clear perceptual and procedural distinctions between AI-assisted visualization and conventional 3D modeling. Although both methods aim to translate conceptual design ideas into visual form, their underlying mechanisms and cognitive demands differ substantially. Traditional 3D modeling depends on geometric accuracy, material calibration, and physically based rendering. In contrast, AI-driven systems rely on linguistic and algorithmic interpretation, translating textual descriptions into imagery through probabilistic synthesis.

Regarding time and cost, notable contrasts emerged. Twinmotion, recognized for its realistic and detailed results, required roughly six hours to complete each render and operates under annual licensing fees ranging from $445 to $1,850 USD per seat. Conversely, AI-based tools delivered images within minutes. ChatGPT Plus generated visuals in about two minutes, offering free, Plus ($20 per month), and Pro ($200 per year) tiers. Gemini Pro produced results in approximately three and a half minutes, with subscription costs varying between $19.99 and $249.99. ImageFX, the fastest of all, completed rendering in about one and a half minutes and is available free of charge. These findings underline how AI substantially reduces both production time and financial investment, enabling designers to allocate more effort toward conceptual development rather than technical rendering.

From a qualitative standpoint, traditional 3D modeling platforms such as CAD-based and rendering-oriented software continue to prioritize spatial precision, geometry control, and

physically accurate illumination (Zhang, 2022). Although these systems require significant technical expertise and time, they offer designers a high level of authorship and iterative control over scale, materiality, and perspective. As Bell (2012) observes, this manual construction process strengthens spatial understanding and enhances sensitivity to proportion, texture, and environmental context. Nevertheless, such workflows may limit experimentation because of time and computational constraints.

AI-assisted visualization tools, on the other hand, introduce a fundamentally different mode of production. By employing algorithmic interpretation instead of manual modeling, text-to-image and diffusion-based systems can produce multiple visual alternatives almost instantly. This capability allows designers to explore broader conceptual directions at early design stages (Ye et al., 2025). Leach (2022) characterizes this as AI acting as a "creative accelerator," expanding ideation while simultaneously challenging traditional notions of authorship. Yet the same adaptability raises concerns regarding accuracy, authenticity, and ethics, which are particularly significant in academic and professional contexts (Fernberg & Chamberlain, 2023).

Perceptual differences were also evident in the aesthetic and narrative dimensions of the outputs. Three-dimensional models tend to communicate structure, hierarchy, and measurable realism, whereas AI-generated imagery conveys atmosphere, emotion, and conceptual interpretation. According to Wang and Chen (2022), this shift from physical accuracy toward experiential imagination can enhance participatory design processes by engaging non-expert audiences in more intuitive ways. Similarly, Ahern (2013) highlights that such technologies may strengthen resilience-oriented and adaptive design approaches by allowing faster testing of sustainable scenarios.

From an educational perspective, incorporating AI into design studios may reshape how visualization is both taught and practiced. These systems encourage students to prioritize design intent, spatial storytelling, and critical reflection rather than focusing solely on technical skills. As noted by Fernberg and Chamberlain (2021), this shift calls for a re-evaluation of the balance between tool mastery and conceptual reasoning, a balance that remains at the heart of landscape architecture.

Taken together, these findings demonstrate that AI-assisted visualization does not replace traditional modeling but rather complement it by extending creative capacity and reconfiguring design workflows. The most promising outcomes appear within hybrid methodologies, where the precision of 3D modeling is merged with the generative adaptability of AI systems. Such integration can foster more expressive, efficient, and inclusive forms of visual communication within both professional and educational contexts.

4. Conclusion and Recommendations

This study explored the intersection of Artificial Intelligence (AI) and three-dimensional (3D) modeling as emerging visualization approaches within landscape design. The findings suggest that while 3D modeling remains essential for achieving precision, spatial control, and material accuracy, AI-assisted systems introduce new possibilities for conceptual exploration, efficiency, and participatory engagement. The comparative results demonstrate that these two visualization modes are not competing but rather complementary. When integrated, they enhance both the expressive and analytical capacities of design practice.

AI-based visualization supports designers by enabling rapid generation of multiple design iterations during early conceptual stages. This allows more time to be devoted to critical

evaluation, narrative development, and design decision-making. In contrast, 3D modeling continues to reinforce spatial reasoning and ensures technical reliability in the final outcome. The balance between these approaches emphasizes the value of hybrid workflows that blend creativity and precision an increasingly relevant approach in both professional and academic design environments.

In the context of education, incorporating AI into landscape architecture curricula could nurture creativity and inclusivity while promoting reflection on ethics, authorship, and digital literacy. These discussions are crucial, as the growing reliance on automated systems challenges traditional understandings of originality and the designer's intellectual contribution. Educators and practitioners should therefore remain open to innovation but also critically aware of the limitations of automation.

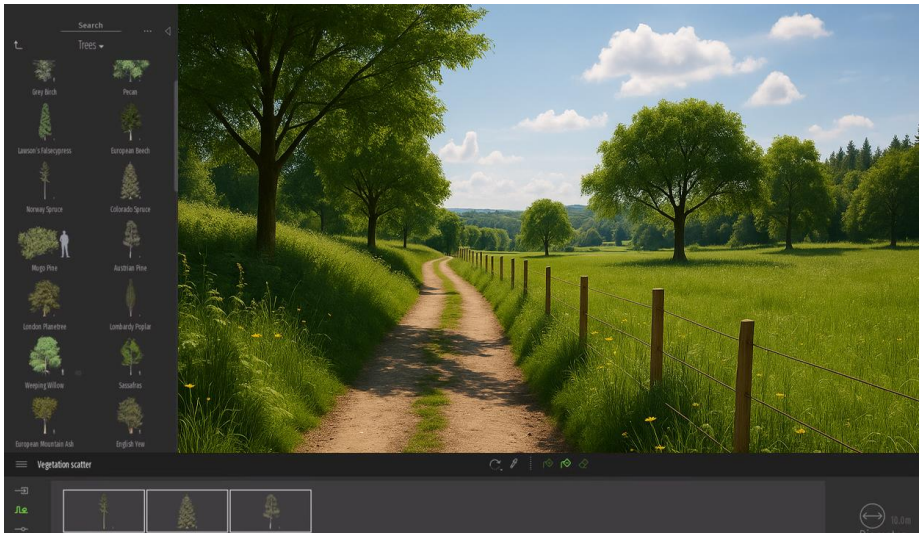


Figure 10. Screenshot of a 3D modeling interface Twinmotion

Future research can extend this inquiry by examining how designers perceive AI-generated visualizations in terms of authenticity, emotional resonance, and cognitive engagement. Further studies could also investigate the sustainability implications of AI-driven workflows, particularly regarding energy use, data management, and environmental impact. Through such continued exploration, discipline can better align technological progress with the human-centered values that define landscape architecture.

Ultimately, AI does not replace design, it transforms how we visualize, communicate, and collaborate within the discipline. Among the tools compared, Twinmotion continues to provide the most stable and professional results, particularly in achieving photorealistic quality. However, in cases where time is limited, prompt-based rendering can serve as an effective alternative. While ImageFX tends to generate oversaturated and exaggerated visuals and Gemini remains somewhat inconsistent in its responses, both illustrate the diversity of AI's generative potential. ChatGPT, though more disciplined in following prompts, can occasionally display interpretive rigidity. These distinctions underline that each tool carries its own strengths and limitations, and understanding these nuances enables designers to make more informed choices.

In conclusion, the evolving synergy between AI and 3D visualization signals a paradigm shift in landscape architecture. It not only redefines representational techniques but also encourages

a more reflective, inclusive, and collaborative design culture one in which technology acts as a partner rather than a substitute for human creativity.

Thanks and Information Note

The authors declare that the study complies with national and international research and publication ethics. All authors contributed equally to the preparation of this paper. Ethics Committee approval was not required for the study.

References

Ahern, J. (2013). Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology*, 28(6), 1203–1212. Online ISSN: 1432-1009. Access Address (15.09.2025): https://doi.org/10.1007/s10980-012-9799-z

Bell, S. (2012). Landscape: Pattern, perception, and process. *Routledge*. Access Address (15.09.2025): https://doi.org/10.4324/9780203120088

Fernberg, P., & Chamberlain, B. (2021). I, designer? *Landscape Architecture Magazine*. Access Address (15.09.2025): https://landscapearchitecturemagazine.org/2021/08/19/i-designer/

Fernberg, P., & Chamberlain, B. (2023). Artificial intelligence in landscape architecture: A literature review. *Landscape Journal*, 42(1), 13–35. Online ISSN: 0277-2426. Access Address (15.09.2025): https://doi.org/10.3368/lj.42.1.13

Landezine. (2025). Hatsinanpuisto by LOCI. Access Address (15.09.2025): https://landezine.com/hatsinanpuisto-by-loci/

Landezine. (2025). Klockelund Beach Park by LAND Arkitektur. Access Address (15.09.2025): https://landezine.com/klockelund-beach-park-by-land-arkitektur/

Landezine. (2025). Nature Park Assisie by MTD Landscape Architects. Access Address (15.09.2025): https://landezine.com/nature-park-assisie-by-mtd-landscape-architects/

Leach, N. (2022). AI and the limits of human creativity in urban planning and design. In I. As, P. Basu, & P. Talwar (Eds.), Artificial intelligence in urban planning and design (pp. 21–37). Elsevier. Access Address (15.09.2025): https://doi.org/10.1016/B978-0-12-823941-4.00013-5

Marcus, C. C., & Francis, C. (Eds.). (2013). People places: Design guidelines for urban open space. John Wiley & Sons.

Wang, Y., & Chen, L. (2022). Architectural and landscape garden planning integrated with artificial intelligence parametric analysis. Security and Communication Networks, 2022, Article ID 8577269. Access Address (15.09.2025): https://doi.org/10.1155/2022/8577269

Ye, X., Huang, T., Song, Y., Li, X., Newman, G., Wu, D. J., & Zeng, Y. (2025). Generating conceptual landscape design via text-to-image generative AI model. Environment and Planning B: Urban Analytics and City Science, 0(0). Access Address (15.09.2025): https://doi.org/10.1177/23998083251316064

Zhang, Y. (2022). Application of landscape architecture 3D visualization design system based on AI technology. *International Transactions on Electrical Energy Systems.* Access Address (15.09.2025): https://doi.org/10.1155/2022/9918171

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Natural Carbon Sinks and Ecosystem-Based Approaches in Combating the Climate Crisis

Mahmut TUĞLUER[1*]

ORCID 1: 0000-0002-4357-9599
[1]Assist. Prof. Dr., Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Department of Landscape Architecture, Kahramanmaraş-Türkiye
mahmutugluer@gmail.com (Responsible Author)

Mert ÇAKIR[2]

ORCID 2: 0000-0003-0079-0375
[2]Assist. Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
pmmertcakir@gmail.com

Abstract

Natural carbon sinks are essential components of the global climate system, sequestering and storing carbon dioxide (CO_2) and other greenhouse gases through biological, chemical, and physical processes. Forests, oceans, wetlands, mangrove forests, seagrass meadows, tundra regions, permafrost areas, and soils form the primary ecosystems that regulate the global carbon cycle. Each ecosystem contributes to carbon sequestration and carbon storage through different mechanisms. Forests store carbon through photosynthesis, oceans and wetlands through biological production and sedimentation, mangrove forests and seagrasses via coastal processes, tundra and permafrost areas through frozen organic carbon, and soils through the accumulation of organic matter. Human-induced pressures such as deforestation, land degradation, pollution, ocean acidification, and global warming increasingly threaten the stability and carbon storage capacity of these ecosystems. These impacts disrupt the carbon balance between the atmosphere and the biosphere, increase greenhouse gas concentrations, and accelerate climate change. The degradation of natural carbon sinks also reduces biodiversity, causes soil erosion, and destabilizes water cycles, undermining overall ecosystem resilience. Consequently, the conservation and restoration of natural carbon sinks are critical for mitigating climate change and maintaining essential ecosystem services. Integrating ecosystem-based approaches into land-use planning, supporting scientific research on carbon sequestration and carbon storage, implementing nature-based solutions, and raising public awareness are key strategies. Sustainable management of natural carbon sinks enhances climate resilience, ensures environmental stability, and provides a foundation for a low-carbon, sustainable future.

Keywords: Carbon storage, nature-based solutions, ecosystem services, climate change mitigation

1. Introduction

Atmospheric carbon dioxide (CO_2) concentrations increased significantly after the Industrial Revolution. Increased fossil fuel use, deforestation, and changes in land use have affected the natural flow of the carbon cycle. Global temperature increases, ocean warming, glacial retreat, and an increase in the frequency of extreme weather events are among the observable consequences of this change (IPCC, 2021). Carbon is an element that constantly moves between the biosphere, atmosphere, oceans, and soil, and this movement constitutes one of the fundamental regulatory processes of the climate system. Natural ecosystems limit atmospheric CO_2 accumulation by storing carbon in biomass, organic matter, and sediments. Therefore, the status of natural carbon sinks directly determines the course of the climate crisis. The carbon storage capacity of these ecosystems varies depending on environmental conditions. Terrestrial and aquatic ecosystems have different mechanisms of operation in the carbon cycle. Forests draw carbon from the atmosphere through photosynthesis and store this carbon in the biomass of trunks, branches, leaves, and roots (Pan et al., 2011). In wetlands, low-oxygen environments cause organic matter to decompose slowly, enabling the long-term accumulation of carbon in

sediments (Mitsch & Gosselink, 2015). Coastal ecosystems such as mangrove forests and seagrass meadows have high carbon storage capacity as a result of sediment accumulation processes (Fourqurean et al., 2012). Tundra and permafrost regions retain frozen organic carbon due to low temperatures (Hugelius et al., 2014). Soil constitutes one of the largest terrestrial carbon pools on a global scale (Lal, 2004).

With the increasing impacts of climate change, protecting and maintaining the functioning of natural carbon sinks has become increasingly important. In recent years, ecosystem-based approaches have become prominent in climate change adaptation and mitigation efforts. These approaches are based on the preservation and restoration of natural processes. The goal is to ensure that ecosystems can sustain their own carbon cycles and reduce the carbon load in the atmosphere (IPCC, 2019; Seddon et al., 2020).

Government policies, land planning decisions, the balance between conservation and utilization, economic activities, and management practices determine carbon storage potential (Griscom et al., 2017). Forest management programs, agricultural production methods, wetland protection strategies, coastal zone planning, and soil fertility practices directly impact the sustainability of the carbon cycle (IPCC, 2019). Protecting natural carbon sinks is considered not only an ecological but also a managerial and societal process (Seddon et al., 2020).

The aim of this study is to explain the mechanisms of carbon storage and the functioning of different ecosystem types within the carbon cycle and to demonstrate the strategic importance of natural carbon sinks, such as forests, wetlands, peatlands, blue carbon ecosystems, soil, and permafrost regions, in combating climate change. The study also assesses the threats these ecosystems face due to anthropogenic pressures and highlights the role of ecosystem-based conservation, restoration, and planning approaches in strengthening carbon storage capacity. This aims to provide a scientifically based framework for the protection and sustainable management of natural sinks in the fight against climate change.

2. Natural Carbon Sinks and Their Functioning Mechanisms

The carbon cycle is driven by a continuous movement of matter between the atmosphere, biosphere, soil, and oceans. Within this cycle, some ecosystems have the capacity to store CO_2 they absorb from the atmosphere for long periods. A natural carbon sink is used for systems where the amount of carbon absorbed from the atmosphere is stored greater than the amount released. To be defined as a carbon sink, an ecosystem must demonstrate a net carbon gain in terms of its annual carbon budget. This process relies on ecological mechanisms such as photosynthesis, biomass accumulation, the transfer of organic matter to the soil, and the limitation of decomposition (Randerson et al., 2002).

Natural carbon sinks are found in different ecosystem types and sequester carbon in different ways. Forests store carbon in biomass and soil; wetlands store carbon through organic matter accumulation; and coastal mangrove and seagrass systems store carbon in both plant tissue and sediments (Donato et al., 2011; Duarte et al., 2013). In tundra and permafrost regions, low temperatures slow the decomposition of organic carbon, enabling long-term storage (Hugelius et al., 2014).

These ecosystems also provide ecosystem services such as water cycling, soil conservation, and biodiversity. A decrease in carbon storage capacity means a weakening of these services (MA, 2005). Therefore, the protection and restoration of natural carbon sinks has become a fundamental component of nature-based climate policies.

a. Forest Ecosystems

Forest ecosystems constitute one of the largest terrestrial carbon storage areas in the global carbon cycle. Atmospheric CO_2 is taken up by plants through photosynthesis and converted into organic compounds. As a result of this process, carbon is stored for many years in the trunk, branch, leaf, and root tissues of trees. Forest soils also accumulate significant amounts of carbon through the decomposition of dead plant material and humus formation. Therefore, forests are considered two-way sink systems capable of sequestering carbon in both biomass and soil (Jobbágy & Jackson, 2000; Luyssaert et al., 2008; Pan et al., 2011).

The carbon storage capacity of forests varies depending on variables such as species composition, age distribution of trees, biomass production rate, light and moisture conditions, and soil properties. Tropical forests store large amounts of carbon due to their high biomass production and exhibit a rapid carbon cycle. Temperate forests, on the other hand, contain slower-growing but longer-living tree communities, sequestering carbon in both biomass and soil for longer periods (Bonan, 2008).

Deforestation and forest degradation cause stored carbon to rapidly return to the atmosphere. Expansion of agricultural land, increased settlements, road construction, mining expansion, fires, and unregulated felling reduce carbon stocks. This leads to the loss of existing carbon stocks and reduces the capacity to capture carbon from the atmosphere in the future. When combined with climate change-related risks such as fires, rising temperatures, and drought, carbon loss appears to accelerate (Anderegg et al., 2020).

Forest management practices constitute one of the key anthropogenic factors shaping the carbon storage potential of ecosystems. Supporting natural regeneration processes, promoting mixed species composition, appropriate forest spacing arrangements, and reforestation in degraded areas can increase carbon sequestration capacity. At the same time, maintaining long rotation periods and retaining dead wood material in the ecosystem supports soil carbon accumulation (Griscom et al., 2017). Long-term global monitoring studies have shown that maintained and aging forests tend to maintain their carbon storage capacity. Young forests sequester high amounts of carbon during periods of rapid growth, while mature forests have the capacity to retain their stored carbon for extended periods (Luyssaert et al., 2008). This demonstrates that preserving intact forests is as important as reforestation.

b. Wetlands and Peatlands Ecosystems

Wetlands and peatlands are among the ecosystems with long-term carbon storage capacity in the global carbon cycle. A key characteristic of these ecosystems is that water-saturated and oxygen-limited conditions slow down organic matter decomposition processes (Gorham, 1991; Mitsch & Gosselink, 2015). Organic tissues produced by plants accumulate in soil and sediment layers due to their slow decomposition rate, transforming carbon into a long-term storage form. This process is particularly pronounced in peatlands, where organic residues accumulate over thousands of years to form carbon-rich structures called peat (Yu, 2012).

Wetlands and peatlands are among the ecosystems with long-term carbon storage capacity in the global carbon cycle. A key characteristic of these ecosystems is that water-saturated and oxygen-limited conditions slow down organic matter decomposition processes (Gorham, 1991; Mitsch & Gosselink, 2015). Organic tissues produced by plants accumulate in soil and sediment layers due to their slow decomposition rate, transforming carbon into a long-term storage form.

This process is particularly pronounced in peatlands, where organic residues accumulate over thousands of years to form carbon-rich structures called peat (Yu, 2012).

Despite covering only approximately 3% of the global land surface, peatlands on Earth have a carbon storage capacity greater than all forests combined, storing a significant portion of the world's soil carbon (Gorham, 1991). Hydrological conditions and water table levels are critical factors determining the carbon balance of wetland and peatland ecosystems. Lower water levels allow organic matter to come into contact with oxygen, increasing the rate of decomposition and returning carbon to the atmosphere in the form of CO_2 and CH_4 (Turetsky et al., 2014; Günther et al., 2020). Therefore, the hydrological regime is considered one of the most important determinants of the carbon storage capacity of peatlands. Draining wetlands, agricultural drainage practices, uncontrolled water management, peat extraction, and land use changes are among the primary anthropogenic impacts that weaken carbon storage (Joosten & Clarke, 2002; Leifeld & Menichetti, 2018). Disturbance in these ecosystems can result in carbon stored for thousands of years being released back into the atmosphere in a short timeframe.

Wetland and peatland restoration is an effective ecosystem-based approach for restoring carbon storage capacity. Re-raising water levels allows peat-forming vegetation to return and slows the rate of decomposition, increasing carbon sequestration. Long-term monitoring studies show that the carbon sequestration capacity of re-wetted peatlands increases significantly over time (Günther et al., 2020; Tanneberger et al., 2011). Therefore, restoring the functionality of degraded peatlands, along with protecting wetlands, is considered a fundamental strategy in combating climate change.

c. Blue Carbon Ecosystems

Mangrove forests, seagrass meadows, and tidal flat ecosystems are considered within the scope of the "blue carbon" concept as systems located in coastal areas with high carbon storage capacity. Blue carbon refers to the processes by which coastal and marine plant communities store carbon from the atmosphere over long periods of time, both in their biomass and, particularly, in sediment layers (Nellemann et al., 2009; Duarte, Losada, Hendriks, Mazarrasa, & Marbà, 2013). Carbon accumulation in these ecosystems occurs through the interaction of the intensity of plant production, the sediment retention capacity of root systems, and oxygen-limited environmental conditions that slow the decomposition rate of organic matter. Therefore, the carbon stored in blue carbon ecosystems can often reach higher levels than the amount of carbon stored in terrestrial forest ecosystems (McLeod et al., 2011). Mangrove ecosystems, thanks to both their high biomass production and dense and complex root systems, serve as important coastal carbon sinks, retaining carbon for long periods. The location of mangrove roots in the transition zone between water and sediment limits the contact of organic matter with oxygen and slows the rate of decomposition, allowing carbon to accumulate in sediments for long periods (Donato et al., 2011). Similarly, seagrass meadows, thanks to their extensive rhizome networks and sediment retention capacity, can store carbon in both plant tissue and subsoil sediment layers for thousands of years (Fourqurean et al., 2012).

One of the most important determinants of carbon storage capacity in coastal ecosystems is the continuity of the sedimentation process. Waves, currents, and tidal movements directly affect sediment transport and deposition, while plant roots stabilize this sediment, reducing coastal erosion (Barbier et al., 2011). Therefore, blue carbon ecosystems not only function as carbon

sinks but also provide critical ecosystem services such as coastal protection, mitigating storm wave energy, maintaining habitat continuity, and supporting biodiversity.

However, anthropogenic factors such as sea level rise, coastal development, tourism pressure, water pollution, agricultural drainage, and industrial filling practices threaten the integrity of blue carbon ecosystems. Disruption of these systems can not only deplete existing carbon stocks but also cause carbon accumulated in sediments over thousands of years to quickly return to the atmosphere, thereby increasing additional greenhouse gas emissions (Pendleton et al., 2012). Therefore, restoring natural hydrodynamic processes, locating mangrove seedlings in suitable microtopographic conditions, and seagrass planting practices are crucial in restoration efforts. Long-term monitoring studies have demonstrated that when favorable conditions are met, the carbon storage capacity of these ecosystems increases over time (Wylie et al., 2016).

d. Ocean Ecosystems

The oceans are considered one of the largest and most dynamic carbon storage systems in the global carbon cycle. Atmospheric CO_2 is transferred to ocean surface waters through physical dissolution processes, where it is converted into inorganic carbon forms. This process is described as a physical carbon pump operating in conjunction with atmosphere-ocean gas exchange (Sarmiento & Gruber, 2006). Furthermore, photosynthesis by phytoplankton forms the basis of biological carbon production in the oceans; some of the organic carbon produced is transferred to the food chain, while the remaining portion sinks to the deep ocean floor as dead biomass, contributing to long-term carbon storage through the biological carbon pump (Falkowski, Barber, & Smetacek, 1998).

The carbon storage capacity of the oceans is shaped by environmental variables such as water temperature, dissolved gas concentration, ocean circulation, and phytoplankton productivity. Deep ocean layers can store carbon for hundreds or even thousands of years without interacting with the atmosphere (Sigman & Haug, 2003). However, global warming directly affects the oceans' carbon sink function. Increasing seawater temperatures limit the transfer of carbon from the atmosphere to the ocean by reducing the solubility of CO_2 (Riebesell, Zondervan, Rost, Tortell, Zeebe, & Morel, 2000). In addition, ocean acidification impairs the biomineralization processes of plankton with calcium carbonate skeletons and disrupts the biological carbon cycle (Doney, Fabry, Feely, & Kleypas, 2009).

Protecting and enhancing ocean carbon sinks requires the integrated implementation of policies for marine ecosystem management, pollution control, limiting overfishing, and combating climate change. Oceans play a central role in global climate stability not only as passive carbon reservoirs but also as active carbon flow systems that regulate the atmosphere-biosphere interaction.

e. Soil Organic Carbon

Soil constitutes one of the largest carbon storage pools in the global carbon cycle, directly affecting both terrestrial and atmospheric systems (Batjes, 1996; Jobbágy & Jackson, 2000). Soil organic carbon is formed by the accumulation within the soil profile of organic matter resulting from the decomposition of plant roots, leaf litter, dead plant and animal tissues, and microbial biomass. This organic carbon, concentrated in the upper soil horizons, supports the continuity of the nutrient cycle and serves as a key component of ecosystem productivity (Carter & Gregorich, 2007). Soil serves as a carbon buffer system between the atmosphere and the biosphere. While plants absorb atmospheric CO_2 through photosynthesis, a portion of the

organic matter is returned to the atmosphere through microbial respiration and decomposition, while the remainder is transferred to the soil organic carbon pool (Lal, 2004). The stability period of carbon accumulated in the soil depends on: It depends on environmental and edaphic factors such as temperature, moisture, soil texture, mineral composition, and microbial activity (Six, Conant, Paul, & Paustian, 2002). Clay minerals, in particular, contribute to long-term carbon sequestration by binding organic matter to the mineral surface (Lehmann & Kleber, 2015).

Soil organic carbon plays a critical role not only in the climate system but also in fundamental soil functions such as soil structure, water retention capacity, aeration, and nutrient cycling (Franzluebbers, 2002). Organic-rich soils are more resistant to erosion and provide more favorable conditions for plant growth. Therefore, a decrease in soil carbon can negatively affect both ecosystem productivity and the stability of the carbon cycle (Carter & Gregorich, 2007).

Agriculture and land use patterns are among the primary anthropogenic determinants of soil carbon balance. Practices such as deep plowing, monoculture production, and stubble burning can increase the rate of organic matter decomposition, leading to a decrease in soil carbon (Lal, 2004). Conversely, conservation tillage, cover crops, organic material applications, and agroecological production systems contribute to the preservation and reaccumulation of soil organic carbon (Paustian et al., 2016). Rising temperatures associated with climate change have the potential to accelerate soil-based carbon release by increasing the rate of organic matter decomposition (Crowther et al., 2016). The risk of soil carbon loss is becoming more pronounced, particularly in arid and semiarid regions. However, long-term agricultural trials indicate that soil carbon can be restored with appropriate management practices (Conant et al., 2017). This demonstrates that soil is a carbon sink capable of recapturing carbon.

f. Tundra ve Permafrost Ecosystems

Tundra and permafrost regions are ecosystems where organic carbon accumulates for long periods without decomposing due to low temperature conditions. While plant production is limited in these areas, low temperatures and microbial activity slow the rate of decomposition and allow organic carbon to be retained in soil and permafrost layers for thousands of years (Tarnocai, Canadell, Schuur, Kuhry, Mazhitova, & Zimov, 2009). Permafrost refers to soil layers that remain frozen year-round and contain large amounts of frozen organic matter. Therefore, tundra and permafrost regions are considered one of the largest carbon reserves on a global scale (Hugelius et al., 2014).

The preservation of carbon accumulated in permafrost soils depends on the continuity of the permafrost structure. When global temperature increases accelerate permafrost thawing, frozen organic matter is exposed to microbial decomposition, causing carbon to return to the atmosphere in the forms of CO_2 and CH_4 (Schuur et al., 2015). This process is defined as the "permafrost carbon feedback" and poses a critical risk due to its potential to further accelerate climate change by increasing atmospheric greenhouse gas concentrations. Because methane has a much higher short-term global warming potential than CO_2, CH_4 emissions from permafrost thawing have a significant impact on the climate system (Walter, et al., 2018).

The carbon cycle in tundra and permafrost ecosystems is determined by temperature changes, snow cover thickness, soil moisture status, and the seasonal phenology of vegetation (Natali, et al., 2019). Increasing temperatures accelerate microbial decomposition, creating a positive feedback mechanism that leads to continued carbon release and accelerated climate change.

The effects of permafrost thawing are not limited to the carbon cycle. Thawing of frozen ground can lead to a decrease in surface stability and an increase in geotechnical risks for infrastructure, buildings, and transportation networks (Streletskiy et al., 2015). Furthermore, thawing can lead to increased lake and marsh formations, altered habitat structures, and reshaping of regional biodiversity (Jorgenson et al., 2006). Therefore, the degradation of tundra and permafrost ecosystems is of global importance, with both ecological and socioeconomic dimensions.

While direct ecosystem-based methods for completely halting permafrost thawing are limited, preserving vegetation, maintaining surface snow cover to slow melting, and maintaining hydrological balances can contribute to reducing carbon emissions (Natali et al., 2019). However, current scientific findings indicate that the recoverability of permafrost carbon loss is quite low compared to other ecosystems (Schuur et al., 2015). Therefore, tundra and permafrost systems are considered as fragile carbon stores in scenarios where climate change cannot be controlled.

3. Ecosystem-Based Approaches and Management Practices

g. Forest Restoration and Renewal

Forest restoration is an ecosystem-based practice that aims to restore the structural and functional characteristics of degraded forest ecosystems. This process encompasses not only the restoration of tree cover but also the improvement of nutrient cycles, soil organic matter, and habitat continuity (Chazdon, 2014). The carbon storage capacity of forests is associated with the increase in biomass and the accumulation of soil organic carbon. The high rate of biomass increase, particularly in young and medium-aged forests, contributes to the increased rate of carbon absorption from the atmosphere (Lewis et al., 2019). Within the scope of restoration efforts, it is important to prioritize native species, maintain species diversity, and support natural regeneration processes. While single-species plantation systems may exhibit high biomass production in the short term, they can lead to a decrease in ecosystem resilience, soil carbon accumulation, and biodiversity in the long term (Benayas et al., 2009). In contrast, mixed species compositions strengthen ecosystem resilience to stress conditions by increasing root system diversity and soil microbial activity (Forrester & Bauhus, 2016). Therefore, forest restoration requires a holistic planning approach that considers plant diversity and ecological functions together.

Increasing temperatures and drought conditions associated with climate change are increasing the frequency and severity of forest fires, which can cause stored carbon to quickly return to the atmosphere and delay restoration processes (Bowman et al., 2009). Therefore, selecting fire-resistant species, reducing fuel loads, and integrating landscape fire management strategies are critical in restoration planning. Long-term observational studies reveal that soil carbon tends to reaccumulate in degraded forest areas when management supports and natural processes work together (Griscom et al., 2017). This suggests that restoration not only preserves existing carbon stocks but also enables carbon recovery.

Afforestation efforts in urban and semi-urban areas also provide important ecosystem services such as carbon sequestration, heat island mitigation, and air quality improvement. Urban trees contribute to microclimate regulation through shading and evapotranspiration, and improve air quality by trapping atmospheric particulate matter (Nowak & Crane, 2002; Escobedo et al., 2011). Therefore, forest restoration is considered a multi-layered process encompassing not only rural areas but also urban landscape planning.

h. Wetland Rehabilitation

Wetland rehabilitation is an ecosystem-based approach that aims to restore water-saturated conditions and maintain carbon storage by slowing the rate of organic matter decomposition. Carbon accumulation in wetlands occurs due to high water tables, anaerobic conditions, and limited organic tissue decomposition rates (Chmura et al., 2003; Craft, 2016). The primary goal of rehabilitation is to restore the degraded hydrological regime to its natural state as closely as possible. Maintaining a stable water table, supporting sediment accumulation, and supporting vegetative cover are critical for maintaining long-term carbon storage capacity (Merritt & Wohl, 2006). Wetland losses are largely the result of anthropogenic pressures such as drainage practices, agricultural expansion, water control projects, and peat extraction. As the water level drops, organic matter comes into contact with oxygen, which increases the rate of decomposition and causes carbon to return to the atmosphere in the form of CO_2 and CH_4 (Waddington et al., 2015). This process can lead to the loss of carbon accumulated over thousands of years in a very short period of time. Therefore, the first step in rehabilitation practices is to control the raising of the water table and restore the wetland's water-holding capacity (Moreno-Mateos et al., 2012).

Restoring the vegetative cover with natural species is crucial in rehabilitation efforts. Reeds, reed communities, and water-tolerant macrophyte species constitute key ecological components of carbon sequestration through both biomass production and sediment stabilization (Brix, 1994). Root and rhizome systems limit the decomposition of organic matter and strengthen the physical integrity of the sediment, increasing ecosystem resilience to hydrological changes (Craft, 2016). Long-term monitoring studies demonstrate that wetland rehabilitation is an effective method for carbon recovery. It has been demonstrated that soil organic carbon in rehabilitated wetlands increases significantly, particularly in the first 5–15 years, and that carbon can reaccumulate in sediment layers (Moreno-Mateos et al., 2012). Thus, wetland rehabilitation not only restores disrupted carbon cycles but also strengthens the capacity to adapt to climate change.

Wetland rehabilitation also provides simultaneous ecosystem services such as water cycle regulation, flood control, habitat continuity, and biodiversity support (Zedler & Kercher, 2005). In this respect, wetland rehabilitation is considered a strategic application that not only increases carbon storage capacity but also strengthens ecological resilience at the landscape scale.

i. Carbon Management in Blue Carbon Areas and Ocean Ecosystems

Coastal ecosystems such as mangroves, seagrass meadows, and salt marshes are highly efficient carbon sinks capable of storing carbon in both plant biomass and sedimentary layers for long periods. The carbon density stored in these ecosystems can be higher per unit surface area than in most tropical forest ecosystems (Donato et al., 2011; Nellemann et al., 2009). Restoring these systems, defined as blue carbon, is considered an effective ecosystem-based climate strategy for reducing atmospheric carbon and increasing carbon sequestration (McLeod et al., 2011).

The degradation of blue carbon ecosystems poses a significant carbon release risk. Human-induced disturbances such as coastal development, seawalls, interruptions to sediment flow, and water pollution limit sediment accumulation, preventing the long-term retention of carbon in sedimentary layers (Hamilton & Friess, 2018). Therefore, during the restoration process,

restoring topography, ensuring sediment inputs, and replanting suitable vegetation are key practices for restoring carbon storage capacity (Lovelock & Brown, 2019).

Practice-based monitoring studies reveal that blue carbon systems experience a return to increased carbon accumulation rates after restoration. Sediment carbon density has been determined to increase in restored mangrove areas, and root systems have been shown to enhance sediment stabilization, supporting long-term carbon storage (Wylie et al., 2016). This suggests that blue carbon restoration not only provides habitat improvement but also offers an important carbon recovery mechanism in combating climate change. Therefore, coastal zone planning should integrate the protection of blue carbon areas and ecosystem restoration with land-use decisions (Duarte et al., 2013).

The oceans serve as the largest carbon sink in the global carbon cycle, absorbing a significant portion of atmospheric CO_2 through physical dissolution and biological production processes (Sarmiento & Gruber, 2006). However, the oceans' function as carbon sinks is sensitive to climate change. Increasing seawater temperature reduces CO_2 solubility, while ocean acidification impairs the biomineralization processes of carbonate-bearing organisms, reducing the efficiency of the biological carbon pump (Doney et al., 2009; Riebesell et al., 2000). In addition, overfishing and pollution pressures can alter phytoplankton community structure, reducing the ecological efficiency of the ocean-based carbon cycle (Falkowski et al., 1998). Therefore, ocean-based carbon management requires the combined implementation of multi-layered management tools, such as expanding marine protected areas, reducing pollution pressures, and protecting coastal ecosystems (Gattuso et al., 2018). Maintaining the healthy functioning of the oceans is critical not only for balancing atmospheric CO_2 but also for habitat continuity and global ecosystem resilience.

j. Soil Carbon Management and Agricultural Practices

Increasing soil organic carbon content and preserving existing stocks stands out as an important strategy in combating climate change. Conservation agriculture practices, the use of cover crops, and organic fertilizer and compost applications support the accumulation of soil organic carbon, strengthening both soil fertility and the stability of the carbon cycle (Lal, 2004; Paustian et al., 2016). These methods increase biomass inputs and slow the rate of decomposition, allowing carbon to be retained in the soil for longer periods.

Conversely, land use changes and intensive agricultural production models threaten soil carbon stores. Deep plowing, monoculture production, and intensive chemical inputs accelerate microbial decomposition, leading to carbon being returned to the atmosphere as CO_2 (Six et al., 2002). Erosion processes, in turn, accelerate carbon loss by transporting organic-rich topsoil. Therefore, regulating agriculture-forest transition zones and observing carbon targets in land-use planning are critical (Guo & Gifford, 2002).

At the policy level, measuring, monitoring, and promoting soil carbon management practices is crucial. Soil carbon recovery should be integrated into national carbon budgets and climate policies, alongside fossil fuel reduction strategies (Smith et al., 2020). Carbon credit mechanisms, agricultural support programs, and monitoring-reporting-verification (MRV) systems for monitoring land-use changes support the sustainability of soil carbon storage processes. Examples of implementation demonstrate that annual soil carbon increases are possible with appropriate management options, but the sustainability of these increases depends on management stability and supportive policy mechanisms (Paustian et al., 2016).

k. Planning and Policy Context

The protection and restoration of natural carbon sinks is not only an ecological process, but also a managerial and political one. Maintaining carbon storage capacity requires the combined operation of land use planning, local government practices, legal regulations, and financial incentive mechanisms (Seddon, Chausson, Berry, Girardin, Smith, & Turner, 2020). Planning processes that consider the carbon functions of ecosystems are critical for shaping spatial decisions in a way that enhances carbon capture (Ostrom, 2009).

Measurement-Monitoring-Reporting (MRV) systems play a central role in the policy development process for protecting carbon sinks. Identifying carbon stock changes in sinks with traceable data sets strengthens both the effectiveness and accountability of policy instruments (Griscom et al., 2017). Achieving a balance between development and conservation objectives; This requires planning practices such as agriculture-forest transition zones, water management, coastal development, and forest restoration in line with carbon targets (Keenleyside, Dudley, Cairns, Hall, & Stolton, 2012). National-scale greenhouse gas inventories and sink-source balance models increasingly include the integration of natural sinks into the carbon budget. Carbon credit trading, financial support programs, and public-private partnership mechanisms are used as important policy tools in this process (Wylie, Sutton-Grier, & Moore, 2016). However, as emphasized in the literature, the success of these practices depends not only on the planning level but also on the implementation of decisions appropriate to the local context, stakeholder participation, and the continuity of long-term monitoring processes (Ostrom, 2009; Seddon et al., 2020).

Conclusion and Recommendations

Natural carbon sinks play a fundamental role in regulating the global carbon cycle. Forests, wetlands, peatlands, coastal ecosystems, and permafrost regions enable the long-term storage of carbon in biomass and soil tissue. The carbon storage processes occurring in these ecosystems contribute to reducing atmospheric CO_2 concentrations and maintaining a more balanced climate system. However, human-induced land use changes, urban expansion, intensive agricultural practices, drying and drainage, increased fire risk, and temperature increases associated with climate change are weakening the carbon storage capacity of these sink systems. This can cause carbon accumulated over long periods in the past to quickly return to the atmosphere, contributing to the acceleration of climate change.

The ecosystem-based approaches discussed in this study offer practical methods for protecting and restoring the functionality of natural carbon sinks. Approaches that support species diversity in forest restoration, maintain natural regeneration processes, and utilize methods that reduce fire risk contribute to maintaining carbon storage capacity. In wetland rehabilitation, rebalancing the water table and restoring natural vegetation strengthens the sustainability of carbon sequestration by limiting the rate of organic matter decomposition. In the recovery of blue carbon ecosystems, preserving coastal morphology and supporting sediment accumulation enable the reaccumulation of plant and sediment carbon. In soil carbon management, conservation agricultural practices, maintaining organic matter input, and aligning land-use planning with carbon targets are crucial.

Protecting natural carbon sinks is not merely an ecological issue. It is directly related to land planning, economic activities, local government decisions, and national greenhouse gas inventory policies. Therefore, measurement, monitoring, and reporting processes for sink

management must be maintained at the institutional level. Assessing the carbon storage capacity of ecosystems with traceable data allows planning processes to be based on scientific data. At the same time, local stakeholder participation strengthens the social acceptance of decisions shaping land use and supports the sustainability of these practices. The information obtained demonstrates that protecting natural carbon sinks is not sufficient alone in climate change mitigation efforts, but is a necessary component. Along with reducing fossil fuel-related emissions, the carbon storage capacity of existing ecosystems must be preserved and degraded ecosystems must be restored. Furthermore, the long-term maturation dynamics of these processes must be considered, and continuous ecological monitoring and management approaches must be pursued rather than short-term expectations.

In conclusion, protecting natural carbon sinks and implementing ecosystem-based approaches are considered processes that support both mitigation and adaptation capacity in combating climate change. When the necessary conditions are provided for ecosystems to maintain their functions, carbon storage processes are revitalized and the continuity of ecosystem services is preserved. Therefore, maintaining ecosystem management and integrated land planning approaches supported by scientific data is crucial for achieving long-term climate goals.

Acknowledgements and Information Note

The paper complies with national and international research and publication ethics. Ethics committee approval was not required for the study. All authors contributed equally to the article.

References

Anderegg, W. R., Trugman, A. T., Badgley, G., Anderson, C. M., Bartuska, A., Ciais, P., et al. (2020). Climate-driven risks to the climate mitigation potential of forests. *Science*, *368*(6497), _doi: 10.1126/science.aaz7005

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169–193. https://doi.org/10.1890/10-1510.1

Batjes, N. H. (1996). Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science*, 47(2), 151–163. https://doi.org/10.1111/j.1365-2389.1996.tb01386.x

Benayas, J. M. R., Newton, A. C., Diaz, A., & Bullock, J. M. (2009). Enhancement of biodiversity and ecosystem services by ecological restoration: A meta-analysis. *Science*, 325(5944), 1121–1124. https://doi.org/10.1126/science.1172460

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, 320(5882), 1444–1449. https://doi.org/10.1126/science.1155121

Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., D'Antonio, C., DeFries, R. S., Johnston, F. H., Keeley, J. E., Krawchuk, M. A., & others. (2009). Fire in the Earth system. *Science*, 324(5926), 481–484. https://doi.org/10.1126/science.1163886

Brix, H. (1994). Functions of macrophytes in constructed wetlands. *Water Science and Technology*, 29(4), 71–78.

Carter, M. R., & Gregorich, E. G. (Eds.). (2007). *Soil sampling and methods of analysis* (2nd ed.). CRC Press.

Chazdon, R. L. (2014). *Second growth: The promise of tropical forest regeneration in an age of deforestation*. University of Chicago Press.

Chmura, G. L., Anisfeld, S. C., Cahoon, D. R., & Lynch, J. C. (2003). Global carbon sequestration in tidal, saline wetland soils. *Global Biogeochemical Cycles*, 17(4), 1111–1123. https://doi.org/10.1029/2002GB001917

Conant, R. T., Cerri, C. E., Osborne, B. B., & Paustian, K. (2017). Grassland management impacts on soil carbon stocks: a new synthesis. *Ecological Applications*, *27*(2), 662-668. https://doi.org/10.1002/eap.1473

Craft, C. (2016). *Creating and restoring wetlands: From theory to practice*. Elsevier.

Crowther, T. W., Todd-Brown, K. E., Rowe, C. W., Wieder, W. R., Carey, J. C., Machmuller, M. B., et al. (2016). Quantifying global soil carbon losses in response to warming. *Nature*, 540(7631), 104–108. https://doi.org/10.1038/nature20150

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Stidham, M., & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, 4(5), 293–297. https://doi.org/10.1038/ngeo1123

Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science*, 1, 169–192. https://doi.org/10.1146/annurev.marine.010908.163834

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation. *Nature Climate Change*, 3(11), 961–968. https://doi.org/10.1038/nclimate1970

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*, *159*(8-9), 2078-2087. https://doi.org/10.1016/j.envpol.2011.01.010

Falkowski, P. G., Barber, R. T., & Smetacek, V. (1998). Biogeochemical controls and feedbacks on ocean primary production. *Science*, 281(5374), 200–206. https://doi.org/10.1126/science.281.5374.200

Forrester, D. I., & Bauhus, J. (2016). A review of processes behind diversity–productivity relationships in forests. *Current Forestry Reports*, 2(1), 45–61. https://doi.org/10.1007/s40725-016-0031-2

Fourqurean, J. W., Duarte, C. M., Kennedy, H., Marbà, N., Holmer, M., Mateo, M. A., et al. (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience*, 5(7), 505–509. https://doi.org/10.1038/ngeo1477

Franzluebbers, A. J. (2002). Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research*, 66(2), 95–106. https://doi.org/10.1016/S0167-1987(02)00018-1

Gattuso, J. P., Magnan, A. K., Billé, R., Cheung, W. W., Howes, E. L., Joos, F., Duarte, C. M., … Turley, C. (2018). Ocean solutions to address climate change and its effects on marine ecosystems. *Frontiers in Marine Science*, 5, 337. https://doi.org/10.3389/fmars.2018.00337

Gorham, E. (1991). Northern peatlands: Role in the carbon cycle and probable responses to climatic warming. *Ecological Applications*, 1(2), 182–195. https://doi.org/10.2307/1941811

Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., & others. (2017). Natural climate solutions. *Proceedings of the National Academy of Sciences*, 114(44), 11645–11650. https://doi.org/10.1073/pnas.1710465114

Guo, L. B., & Gifford, R. M. (2002). Soil carbon stocks and land use change: A meta analysis. *Global Change Biology*, 8(4), 345–360. https://doi.org/10.1046/j.1354-1013.2002.00486.x

Günther, A., Barthelmes, A., Huth, V., Joosten, H., Jurasinski, G., Koebsch, F., & Couwenberg, J. (2020). Prompt rewetting of drained peatlands reduces climate warming despite methane emissions. *Nature Communications*, *11*(1), 1644. https://doi.org/10.1038/s41467-020-15499-z

Hamilton, S. E., & Friess, D. A. (2018). Global carbon stocks and potential emissions due to mangrove deforestation from 2000 to 2012. *Nature Climate Change*, *8*(3), 240-244. https://doi.org/10.1038/s41558-018-0090-4

Hugelius, G., Strauss, J., Zubrzycki, S., Harden, J. W., Schuur, E. A. G., Ping, C. L., et al. (2014). Estimated stocks of circumpolar permafrost carbon with quantified uncertainty ranges. *Biogeosciences*, 11(23), 6573–6593. https://doi.org/10.5194/bg-11-6573-2014

IPCC. (2019). *Climate Change and Land: Summary for Policymakers*. Cambridge University Press.

IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Cambridge University Press.

Jobbágy, E. G., & Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Applications*, *10*(2), 423-436. https://doi.org/10.1890/1051-0761(2000)010[0423:TVDOSO]2.0.CO;2

Joosten, H., & Clarke, D. (2002). Wise use of mires and peatlands. *International Mire Conservation Group and international Peat Society*, 304.

Jorgenson, M. T., Shur, Y., & Pullman, E. R. (2006). Abrupt increase in permafrost degradation in Arctic Alaska. *Geophysical Research Letters*, 33(2). https://doi.org/10.1029/2005GL024960

Keenleyside, K. (2012). Ecological restoration for protected areas: principles, guidelines and best practices (Vol. 18). iucn.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, 304(5677), 1623–1627. https://doi.org/10.1126/science.1097396

Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter. *Nature*, *528*(7580), 60-68. https://doi.org/10.1038/nature16069

Leifeld, J., & Menichetti, L. (2018). The underappreciated potential of peatlands in global climate change mitigation strategies. *Nature Communications*, *9*(1), 1071. https://doi.org/10.1038/s41467-018-03406-6

Lewis, S. L., Wheeler, C. E., Mitchard, E. T., & Koch, A. (2019). Restoring natural forests is the best way to remove atmospheric carbon. *Nature*, 568(7750), 25–28. https://doi.org/10.1038/d41586-019-01026-8

Lovelock, C. E., & Brown, B. M. (2019). Land tenure considerations are key to successful mangrove restoration. *Nature Ecology & Evolution*, *3*(8), 1135-1135. https://doi.org/10.1038/s41559-019-0942-y

Luyssaert, S., Schulze, E. D., Börner, A., Knohl, A., Hessenmöller, D., Law, B. E., et al. (2008). Old-growth forests as global carbon sinks. *Nature*, 455(7210), 213–215. https://doi.org/10.1038/nature07276

McLeod, E., Chmura, G. L., Bouillon, S., Salm, R., Björk, M., Duarte, C. M., et al. (2011). A blueprint for blue carbon. *Frontiers in Ecology and the Environment*, 9(10), 552–560. https://doi.org/10.1890/110004

Merritt, D. M., & Wohl, E. (2006). Plant dispersal along rivers fragmented by dams. *River Research and Applications*, 22(1), 1–26. https://doi.org/10.1002/rra.890

Millennium Ecosystem Assessment (MA). (2005). *Ecosystems and human well-being: Synthesis*. Island Press

Mitsch, W. J., & Gosselink, J. G. (2015). *Wetlands* (5th ed.). Wiley.

Moreno-Mateos, D., Power, M. E., Comín, F. A., & Yockteng, R. (2012). Structural and functional loss in restored wetland ecosystems. *PLoS Biology*, *10*(1), e1001247. https://doi.org/10.1371/journal.pbio.1001247

Natali, S. M., Watts, J. D., Rogers, B. M., Potter, S., Ludwig, S. M., Selbmann, A. K., et al. (2019). Large loss of CO2 in winter observed across the northern permafrost region. *Nature Climate Change*, *9*(11), 852-857. https://doi.org/10.1038/s41558-019-0592-8

Nellemann, C., & Corcoran, E. (Eds.). (2009). *Blue carbon: the role of healthy oceans in binding carbon: a rapid response assessment*. UNEP/Earthprint.

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, 116(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419–422. https://doi.org/10.1126/science.1172133

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., et al. (2011). A large and persistent carbon sink in the world's forests. *Science*, 333(6045), 988–993. https://doi.org/10.1126/science.1201609

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P., & Smith, P. (2016). Climate-smart soils. *Nature*, 532(7597), 49–57. https://doi.org/10.1038/nature17174

Pendleton, L., Donato, D. C., Murray, B. C., Crooks, S., Jenkins, W. A., Sifleet, S., et al. (2012). Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems. *PLoS ONE 7*, e43542 (2012). https://doi.org/10.1371/journal.pone.0043542

Randerson, J. T., Thompson, M. V., Conway, T. J., Fung, I. Y., & Field, C. B. (1997). The contribution of terrestrial sources and sinks to trends in the seasonal cycle of atmospheric carbon dioxide. *Global Biogeochemical Cycles*, *11*(4), 535-560. https://doi.org/10.1029/97GB02268

Riebesell, U., Zondervan, I., Rost, B., Tortell, P. D., Zeebe, R. E., & Morel, F. M. M. (2000). Reduced calcification of marine plankton in response to increased atmospheric CO_2. *Nature*, 407(6802), 364–367. https://doi.org/10.1038/35030078

Sarmiento, J. L., & Gruber, N. (2006). Ocean biogeochemical dynamics. Princeton University Press.

Schuur, E. A. G., McGuire, A. D., Schädel, C., Grosse, G., Harden, J. W., Hayes, D. J., Hugelius, G., Koven, C., Kuhry, P., & Lawrence, D. M. (2015). Climate change and the permafrost carbon feedback. *Nature*, 520(7546), 171–179. https://doi.org/10.1038/nature14338

Seddon, N., Turner, B., Berry, P., Chausson, A., & Girardin, C. A. J. (2020). Understanding the value and limits of nature-based solutions. *Proceedings of the National Academy of Sciences*, 117(12), 300–307. https://doi.org/10.1098/rstb.2019.0120

Sigman, D. M., & Haug, G. H. (2003). The biological pump in the past. *Treatise on Geochemistry*, 6, 625.

Six, J., Conant, R. T., Paul, E. A., & Paustian, K. (2002). Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. *Plant and Soil*, *241*(2), 155-176. https://doi.org/10.1023/A:1016125726789

Smith, P., Soussana, J. F., Angers, D., Schipper, L., Chenu, C., Rasse, D. P., ... & Klumpp, K. (2020). How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. *Global Change Biology*, *26*(1), 219-241. https://doi.org/10.1111/gcb.14815

Streletskiy, D., Anisimov, O., & Vasiliev, A. (2015). Permafrost degradation. In *Snow and ice-related hazards, risks, and disasters* (pp. 303-344). Academic Press.

Tanneberger, F., & Wichtmann, W. (Eds.). (2011). *Carbon credits from peatland rewetting: climate, biodiversity, land use* (p. 223). Stuttgart: Schweizerbart Science Publishers..

Tarnocai, C., Canadell, J. G., Schuur, E. A. G., Kuhry, P., Mazhitova, G., & Zimov, S. (2009). Soil organic carbon pools in the northern circumpolar permafrost region. *Global Biogeochemical Cycles*, 23(2), GB2023. https://doi.org/10.1029/2008GB003327

Turetsky, M. R., Kotowska, A., Bubier, J., Dise, N. B., Crill, P., Hornibrook, E. R., et al. (2014). A synthesis of methane emissions from 71 northern, temperate, and subtropical wetlands. *Global change biology*, *20*(7), 2183-2197. https://doi.org/10.1111/gcb.12580

Waddington, J. M., Morris, P. J., Kettridge, N., Granath, G., Thompson, D. K., & Moore, P. A. (2015). Hydrological feedbacks in northern peatlands. *Ecohydrology*, *8*(1), 113-127. https://doi.org/10.1002/eco.1493

Walter Anthony, K., Schneider von Deimling, T., Nitze, I., Arp, C., Emond, A., Jones, B., et al. (2018). 21st-century modeled permafrost carbon emissions accelerated by abrupt thaw

beneath lakes. *Nature Communications*, 9, 3262. https://doi.org/10.1038/s41467-018-05738-9

Wylie, L., Sutton-Grier, A. E., & Moore, A. (2016). Keys to successful blue carbon projects: Lessons learned from global case studies. *Marine Policy*, *65*, 76-84.

Yu, Z. C. (2012). Northern peatland carbon stocks and dynamics: A review. *Biogeosciences*, *9*(10), 4071-4085. https://doi.org/10.5194/bg-9-4071-2012

Zedler, J. B., & Kercher, S. (2005). Wetland resources: Status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources*, 30(1), 39–74. https://doi.org/10.1146/annurev.energy.30.050504.144248

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Citizen Science as a Tool for Urban Biodiversity Monitoring

Mert ÇAKIR[1*]

ORCID 1: 0000-0003-0079-0375
[1]Assist. Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
pmmertcakir@mail.com **(**Responsible Author)

Mahmut TUĞLUER[2]

ORCID 2: 0000-0002-4357-9599
[2]Assist. Prof. Dr., Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Department of Landscape Architecture, Kahramanmaraş-Türkiye
mahmuttugluer@ksu.edu.tr

Abstract

Urbanization is accelerating worldwide, making the conservation and monitoring of biodiversity in cities increasingly critical. However, measuring biodiversity in urban ecosystems remains challenging due to habitat fragmentation, heterogeneous species distributions, and limited research resources. In this context, citizen science offers an innovative and complementary approach to assess and monitor urban biodiversity. This study explores the contributions of citizen science initiatives to the measurement of urban biodiversity. International examples such as iNaturalist, eBird, the City Nature Challenge, and the Big Butterfly Count are reviewed to demonstrate how species richness, spatial distribution, and temporal changes can be effectively tracked. In addition, mobile applications and community-based "bioblitz" events provide valuable datasets that can be analyzed through biodiversity indices and GIS-based methods to better understand urban ecological dynamics. Citizen science provides low-cost and large-scale biodiversity data and fosters environmental awareness among urban residents, thereby contributing to the protection of urban ecosystems. Nevertheless, challenges such as data accuracy, spatial and temporal biases, and sustaining long-term public participation must be considered when applying these approaches. In conclusion, citizen science represents a powerful tool to complement traditional scientific methods in measuring urban biodiversity. Expanding the use of such approaches could strengthen scientific research capacity while also enhancing public engagement with nature in urban environments.

Keywords: Urban biodiversity, citizen science, ecosystem monitoring, species richness

1. Introduction

The acceleration of urbanization in the Anthropocene has resulted in a profound restructuring of ecosystems, altering the composition, distribution, and functioning of biodiversity across the planet (Grimm et al., 2008). Urban areas now occupy approximately 3% of the Earth's land surface but exert disproportionately large impacts on global ecological processes, including habitat fragmentation, pollution, and altered hydrological cycles (Elmqvist et al., 2015; McKinney, 2008). The United Nations (2019) projects that by 2050, nearly 68% of the global population will live in cities, intensifying pressures on natural resources and increasing the urgency of integrating biodiversity considerations into urban planning and management.

Urban biodiversity—defined as the variety of living organisms and their ecological interactions within urban environments—provides crucial ecosystem services such as air purification, climate regulation, stormwater retention, and mental health benefits (Goddard, Dougill, & Benton, 2010; Aronson et al., 2017). Yet, the effective assessment and conservation of biodiversity in urban settings remain constrained by methodological and logistical limitations. Conventional ecological monitoring techniques, including transect surveys and species inventories, often require substantial expertise, time, and funding, limiting their applicability in complex urban mosaics (Deguines et al., 2012). Furthermore, the spatiotemporal variability of

urban ecosystems complicates the establishment of standardized monitoring frameworks (Niemelä, 2014).

In response to these challenges, citizen science, a participatory research approach involving the systematic contribution of non-professional volunteers to scientific data collection and interpretation, has emerged as a promising tool for urban biodiversity assessment (Bonney et al., 2009; Kobori et al., 2016). Citizen science democratizes environmental research by engaging local communities, expanding spatial coverage, and generating large-scale datasets that complement formal scientific surveys (Dickinson, Zuckerberg, & Bonter, 2012). Recent technological advancements, particularly the proliferation of smartphones, geolocation technologies, and open-access platforms, have significantly enhanced the accuracy, accessibility, and analytical potential of citizen-generated biodiversity data (Newman et al., 2017).

Projects such as eBird (Sullivan et al., 2014), iNaturalist (Mason et al., 2025), and the City Nature Challenge (Palma et al., 2024) demonstrate how citizen science can mobilize large and diverse populations to contribute observations that reveal spatial patterns of species richness, phenological trends, and urban habitat use (Callaghan et al., 2019). These platforms generate critical ecological data and foster environmental awareness and stewardship among citizens, aligning with the goals of the Convention on Biological Diversity and the UN Sustainable Development Goals (United Nations, 2015).

In this context, the present review synthesizes current knowledge on the use of citizen science in urban biodiversity monitoring. It examines conceptual foundations, evaluates global applications and methodologies, and discusses opportunities for implementation.

2. Conceptual Background: Citizen Science and Ecological Knowledge

Citizen science, although widely recognized as a contemporary innovation, has deep historical roots in natural history and amateur scientific observation. During the nineteenth century, networks of volunteer observers contributed to large-scale data collection in ornithology, meteorology, and botany, laying the foundations for participatory science (Miller-Rushing, Primack, & Bonney, 2012; Silvertown, 2009). The modern resurgence of citizen science is associated with the democratization of knowledge and the emergence of digital technologies that facilitate distributed data collection, sharing, and validation (Haklay, 2013; Hecker et al., 2018).

2.1. Defining Citizen Science

The definitional scope of citizen science varies across disciplines, but its core principles emphasize openness, inclusivity, and collaborative knowledge production (Bonney et al., 2016; Follett & Strezov, 2015). According to Shirk et al. (2012), citizen science projects can be categorized along a continuum of public participation: from contributory models, where citizens collect data for professionally designed studies, to collaborative and co-created models that integrate public actors into research design, data analysis, and policy application. This spectrum reflects the epistemological diversity of citizen science, spanning from crowdsourced data generation to participatory action research (Haklay, 2013).

2.2. Knowledge Co-production and Public Engagement

The concept of knowledge co-production has become central to understanding how citizen science contributes to sustainability science (Armitage et al., 2011; Wyborn et al., 2019). By

integrating local ecological knowledge (LEK) and professional expertise, citizen science enhances the relevance and legitimacy of environmental data (Conrad & Hilchey, 2011). In urban contexts, where ecological processes intersect with social and political dynamics, such hybrid knowledge systems facilitate more inclusive and adaptive management approaches (Kullenberg & Kasperowski, 2016).

Empirical studies demonstrate that participation in citizen science can transform public attitudes toward biodiversity, fostering environmental literacy and stewardship (Jordan, Ballard, & Phillips, 2012; Bonney et al., 2016). These outcomes contribute to a broader "social learning" process that aligns with the principles of environmental education and participatory governance (Armitage, Marschke, & Plummer, 2008).

2.3. Citizen Science in the Digital Era

Technological advancements have dramatically expanded the scope and precision of citizen science. The widespread availability of mobile applications, equipped with high-resolution cameras, GPS, and machine-learning-based species identification tools, has enabled large-scale ecological observation networks (Newman et al., 2017). Platforms such as iNaturalist use computer vision algorithms to provide automated taxonomic suggestions, while eBird employs expert review systems and spatiotemporal filters to enhance data reliability (Sullivan et al., 2014).

The integration of these datasets into geographic information systems (GIS) and remote sensing frameworks supports multi-scalar analyses of biodiversity patterns, allowing researchers to assess the impacts of urbanization, climate change, and land-use transformation (Theobald et al., 2015; Hochachka et al., 2021). Moreover, the emergence of open data infrastructures and FAIR (Findable, Accessible, Interoperable, and Reusable) data principles has facilitated the interoperability of citizen science data with institutional biodiversity databases such as GBIF (Global Biodiversity Information Facility) (Bowser et al., 2020).

In sum, citizen science in the digital era represents a data-collection strategy and a transformative mode of ecological knowledge production, connecting technology, participation, and policy. Integrating urban biodiversity monitoring has the potential to reconcile scientific rigour with social participation, an important prerequisite for sustainable and resilient cities.

3. Applications of Citizen Science in Urban Biodiversity Monitoring

Citizen science has become an indispensable instrument for ecological monitoring in cities, generating unprecedented quantities of biodiversity data and engaging millions of participants worldwide. Its applications extend from large-scale, globally coordinated programs to local community initiatives that integrate ecological observation with education and urban planning (Newman et al., 2017). This section reviews the most prominent international platforms, evaluates data quality and technological advances, and discusses the role of citizen science in environmental education and public participation.

3.1. Global Programs and Datasets

The most successful citizen science programs share three defining features: open data access, standardized methodologies, and scalable technological infrastructures. These elements allow data comparability across spatial and temporal scales while maintaining participant inclusivity (Sullivan et al., 2014).

3.1.1. eBird

Launched by the Cornell Lab of Ornithology in 2002, eBird represents one of the largest biodiversity databases globally, encompassing over 1.5 billion bird observations contributed by more than 900,000 users (Callaghan et al., 2019; Hochachka et al., 2021). Its integration of real-time data submission, expert verification, and automated spatial filters has made eBird a cornerstone for avian ecology and urban biodiversity research. Studies leveraging eBird data have mapped migratory patterns (La Sorte et al., 2018), quantified urbanization impacts on avifauna (Callaghan et al., 2019), and modeled temporal changes in species distributions under climate change scenarios (Johnston et al., 2021).

In urban environments, eBird's citizen-derived datasets have enabled fine-scale analysis of habitat preferences and the identification of biodiversity hotspots within metropolitan areas (Belaire et al., 2015). Furthermore, the integration of eBird with remote-sensing products such as the Global Human Modification Index (Kennedy et al., 2019) facilitates the assessment of anthropogenic pressures on bird communities across cities.

3.1.2. iNaturalist

The iNaturalist platform, jointly managed by the California Academy of Sciences and the National Geographic Society, enables participants to upload georeferenced photographs of organisms for expert or AI-based identification (Mason et al., 2025). As of 2024, it has recorded over 180 million observations across more than 400,000 species (iNaturalist, 2024). The platform's open API structure allows researchers to extract data for spatial modeling, species distribution mapping, and conservation prioritization (López-Guillén et al., 2024).

Urban biodiversity studies using iNaturalist data have revealed clear gradients in species richness across socioeconomic and land-use variables (Beninde et al., 2023), offering valuable insights into environmental justice dimensions of urban ecology. The ability to crowdsource such data enables rapid detection of invasive species, pollinator declines, and shifts in flowering phenology; such patterns might otherwise require extensive field studies (Barve et al., 2020).

3.1.3. City Nature Challenge and Regional Bioblitzes

The City Nature Challenge (CNC), initiated in 2016 by the Natural History Museum of Los Angeles and the California Academy of Sciences, exemplifies how citizen science can mobilize urban populations for biodiversity documentation (Palma et al., 2024). Held annually, CNC invites cities worldwide to compete in recording the greatest number of species within a defined timeframe, transforming biodiversity assessment into a social event.

Similar initiatives, often called bioblitzes, combine education, recreation, and data collection. Research indicates that such events not only produce valuable species occurrence records but also strengthen social networks and community attachment to local green spaces (Meeus et al., 2023). For instance, in 2023 the CNC documented over 1.8 million observations across 480 cities globally, providing an unparalleled snapshot of urban biodiversity at a planetary scale (City Nature Challenge, 2024).

3.2. Data Quality and Technological Innovations

The scientific value of citizen-generated biodiversity data depends heavily on its accuracy, consistency, and representativeness. Despite the large volume of records, biases related to spatial distribution, observer expertise, and species detectability are persistent concerns (Isaac

et al., 2014; Boakes et al., 2016). Therefore, maintaining data quality has become a key research focus in the field.

3.2.1. Addressing Biases and Validation Mechanisms

Spatial bias often arises because citizen scientists preferentially record species in accessible, recreational, or aesthetically appealing locations, leading to overrepresentation of urban parks and underrepresentation of private or industrial sites (Troudet et al., 2017). Temporal bias occurs when data collection peaks during specific events or weekends, producing uneven time series (Arazy & Malkinson, 2021).

To mitigate these biases, advanced analytical frameworks have been developed. Statistical models such as occupancy modeling (Isaac et al., 2020) and Bayesian hierarchical inference (Johnston et al., 2021) allow researchers to correct for uneven sampling effort and detectability errors. Moreover, cross-validation with professional surveys or historical datasets enhances the robustness of citizen-derived information (Boakes et al., 2016).

3.2.2. Role of Artificial Intelligence and Machine Learning

Recent advances in AI and computer vision have dramatically improved taxonomic verification. Platforms like iNaturalist employ deep convolutional neural networks trained on millions of labeled images to identify species with accuracy rates exceeding 85% in common taxa (Van Horn et al., 2018). Likewise, eBird integrates algorithmic filters that flag spatial outliers or improbable records for expert review (Hochachka et al., 2021).

These systems enhance data quality and streamline feedback to participants, reinforcing engagement through immediate validation. Machine learning algorithms also facilitate predictive modeling of biodiversity trends, enabling the anticipation of ecological changes in urban systems (Barve et al., 2020).

3.2.3. Integration with Remote Sensing and GIS

The fusion of citizen science datasets with remote sensing and geospatial analysis tools has unlocked new opportunities for urban ecological research. For example, eBird data combined with Landsat-derived vegetation indices allows the assessment of habitat quality at city scales (Belaire et al., 2015), while iNaturalist records integrated with Sentinel-2 imagery support species distribution modeling in fragmented landscapes (Beninde et al., 2023). Such integrative approaches are central to the emerging paradigm of urban socio-ecological systems, wherein biodiversity data inform spatial planning, green infrastructure design, and ecosystem service valuation.

3.3. Citizen Science and Environmental Education

Beyond data production, citizen science acts as a catalyst for environmental education, awareness, and behavioral change (Jordan et al., 2012). Participants not only contribute to research but also acquire ecological literacy, enhancing their understanding of biodiversity and conservation issues (Bonney et al., 2016).

Educational benefits are particularly significant in urban contexts, where exposure to nature is often limited (Miller, 2005). Participation in citizen science can mitigate the so-called “extinction of experience,” the declining direct interaction between people and nature, by providing structured opportunities for observation and learning (Soga & Gaston, 2016). Empirical studies show that engagement in biodiversity monitoring projects increases pro-

environmental attitudes and volunteer retention in conservation activities (Pandya, 2012; Toomey & Domroese, 2013).

Moreover, schools and universities increasingly integrate citizen science into curricula as an experiential learning tool. For example, programs like BirdSleuth in the United States and Schools in Nature in Europe use eBird and iNaturalist data to teach ecological methods, data literacy, and environmental ethics (Bonney et al., 2016; Turrini et al., 2018). These pedagogical applications exemplify how citizen science bridges formal education with community engagement, thereby nurturing the next generation of urban environmental stewards.

4. Integrating Citizen Science into Urban Planning and Policy

Urban biodiversity management is no longer confined to ecological research; it has become a central concern of urban planning, environmental governance, and policy formulation. The growing recognition that biodiversity underpins urban resilience and human well-being has led to an increased demand for spatially explicit and socially inclusive data (Elmqvist et al., 2015; Niemelä, 2014). In this context, citizen science provides a novel pathway for integrating public participation into planning processes, enabling cities to co-produce ecological knowledge that informs land-use decisions, conservation priorities, and adaptive management strategies (Burgess et al., 2017; Newman et al., 2017).

4.1. Citizen-Generated Data for Urban Planning

The integration of citizen science into urban planning frameworks has been facilitated by the rise of open data policies and digital platforms that allow interoperability between crowd-sourced datasets and spatial decision-support systems (Bowser et al., 2020). In many cities, biodiversity data collected through iNaturalist or eBird are now used as complementary layers in Geographic Information Systems (GIS) and green infrastructure planning tools.

For instance, eBird data have been incorporated into the US National Ecological Observatory Network (NEON) and local land-use planning processes to identify urban biodiversity hotspots and guide habitat restoration (La Sorte et al., 2018; Hochachka et al., 2021). Similarly, in Europe, citizen-derived data support the implementation of the EU Biodiversity Strategy for 2030, particularly in mapping and monitoring the Natura 2000 network within urban and peri-urban contexts.

From a methodological standpoint, such integration relies on standardized metadata structures, georeferencing accuracy, and temporal consistency (Pettibone et al., 2016). The development of FAIR (Findable, Accessible, Interoperable, Reusable) data principles has further enhanced the usability of citizen science outputs for planning and governance (Wilkinson et al., 2016).

Example: London and Barcelona

In London, the London Wildlife Trust collaborates with local councils to use iRecord and iNaturalist submissions for habitat inventories and biodiversity action plans (Miller et al., 2022). The Barcelona Green Infrastructure Strategy (2021–2030) similarly integrates City Nature Challenge data to identify underrepresented species and ecological corridors, illustrating how participatory monitoring can guide landscape-scale interventions (Calaza-Martinez et al., 2025).

These cases illustrate that citizen science contributes both data and democratic legitimacy to urban ecological decision-making, aligning public participation with environmental objectives (Hecker et al., 2018).

4.2. Participatory Governance and Policy Integration

Citizen science aligns closely with the emerging paradigm of participatory environmental governance, which emphasizes co-production of knowledge and shared decision-making between institutions and communities (Armitage et al., 2011). In policy terms, this approach reflects the principles of Agenda 21, the Aarhus Convention, and the UN Sustainable Development Goals (particularly SDG 11 and 15) that advocate inclusive, science-based, and transparent environmental management (UNEP, 2022).

Citizen science thus functions both as a data-gathering mechanism and as a political instrument that enhances the legitimacy of environmental governance. By involving local communities in monitoring and decision-making, it helps build trust between scientists, planners, and the public (Conrad & Hilchey, 2011; Hecker et al., 2018).

4.3. Policy Uptake Examples

Several countries have formalized the integration of citizen science into national biodiversity frameworks. The United Kingdom's National Biodiversity Network (NBN) and France's Vigie-Nature Program are institutional models where citizen data feed directly into policy assessments and biodiversity indicators (Levrel et al., 2010; Pocock et al., 2015). The European Citizen Science Association (ECSA) has also developed guidelines for ethical data governance and policy relevance (ECSA, 2020).

At the municipal level, participatory platforms such as GreenUp in Helsinki and CityLab in Amsterdam engage citizens in co-designing urban green spaces using real-time biodiversity feedback, linking ecological monitoring with participatory spatial planning (van der Jagt et al., 2019). These examples highlight the potential of citizen science for multi-level governance, from neighborhood greening initiatives to international biodiversity reporting.

4.4. From Data to Decision: The Role of Digital Infrastructure

The success of citizen science in influencing urban policy depends on how effectively data are transformed into actionable information. Tools such as GeoNode, QGIS, and OpenStreetMap can integrate citizen-generated biodiversity layers with urban planning datasets, facilitating the identification of ecological corridors, habitat connectivity zones, and ecosystem service hotspots. Artificial intelligence and data visualization dashboards are increasingly used to translate raw data into accessible narratives for policymakers and citizens alike. The development of interactive urban biodiversity observatories, such as the Urban Nature Atlas by ICLEI Europe, exemplifies how data aggregation and visualization can support cross-sectoral collaboration between planners, ecologists, and the public (ICLEI, 2021).

In Türkiye, the adoption of similar open-source observatories by municipalities and universities could significantly enhance transparency and facilitate data-driven environmental governance.

4.5. Toward Inclusive Urban Biodiversity Policy

Integrating citizen science into urban biodiversity governance requires moving beyond data collection toward institutional embedding. This entails:

Establishing long-term partnerships between universities, local governments, and NGOs,

Creating incentive mechanisms for sustained citizen participation,

Including citizen science indicators in national biodiversity strategies and urban sustainability frameworks (UNEP, 2022).

Ultimately, citizen science represents the principle that sustainable cities depend not only on technological innovation but also on collective ecological intelligence, the capacity of communities to observe, understand and act upon their environment. Embedding this principle within urban planning and policy can transform cities into laboratories of participatory sustainability.

5. Future Perspectives and Recommendations

As the ecological and technological dynamics of the twenty-first century continue to evolve, citizen science is poised to become a cornerstone of urban biodiversity monitoring and governance. The convergence of rapid urbanization, digital transformation, and global environmental crises has created both the necessity and the opportunity to rethink how ecological knowledge is produced and applied in cities (Hecker et al., 2018). In this context, citizen science transcends its traditional role as a tool for data collection and emerges as a collaborative model of environmental governance, one that links science, policy, and society in the co-production of sustainable urban futures.

Future efforts must prioritize the consolidation of methodological rigor and technological innovation. Despite remarkable progress, citizen-generated data still face challenges of validation, representativeness, and interoperability across institutional systems (Isaac et al., 2020; Boakes et al., 2016). To fully unlock the potential of these datasets, harmonization with professional surveys and remote sensing products is essential. Integrating advanced statistical frameworks, such as Bayesian occupancy modeling and machine learning algorithms, will enable more robust interpretation of large-scale, volunteer-derived biodiversity data (Hochachka et al., 2021; Barve et al., 2020). Likewise, coupling citizen observations with real-time environmental sensing, satellite imagery, and open geospatial platforms can transform dispersed observations into continuous ecological intelligence that informs adaptive management at multiple scales (Pocock et al., 2019).

The digital transformation of urban governance also provides new possibilities for embedding citizen science within data-driven planning systems. Artificial intelligence–assisted platforms such as iNaturalist and eBird already demonstrate how automation and crowd verification can enhance the reliability of ecological information (Seltzer et al., 2023). Expanding such technologies into municipal planning portals and smart city dashboards could bridge the gap between public participation and evidence-based policy.

Beyond technical and methodological improvements, the long-term success of citizen science will depend on its inclusivity and cultural integration. Ensuring equitable participation across gender, age, and socioeconomic groups is fundamental for producing socially representative ecological data (Kullenberg & Kasperowski, 2016). Education and environmental literacy should thus become integral components of citizen science programs, linking observation-based learning with curriculum design in schools and universities (Bonney et al., 2016; Turrini et al., 2018).

Equally important is the recognition of citizen science as a cultural practice that restores human–nature relationships in urban settings. Scholars have warned of the “extinction of experience,” referring to the growing disconnect between people and the natural world in modern cities (Soga & Gaston, 2016). By enabling direct engagement with biodiversity, citizen

science offers an antidote to this phenomenon, cultivating empathy, environmental ethics, and collective stewardship. When supported by inclusive digital platforms, transparent governance, and participatory education, it can evolve into a sustained movement that redefines urban environmental citizenship.

In conclusion, the future of citizen science in urban biodiversity monitoring lies in its ability to balance scientific credibility, technological advancement, and social inclusion. This balance represents both a challenge and an opportunity: a challenge to reform institutional structures and build trust in participatory knowledge, and an opportunity to lead as a model of citizen-driven environmental governance. If effectively institutionalized, citizen science can transform cities from passive consumers of nature into active co-creators of biodiversity knowledge and sustainability. As Bonney et al. (2009) eloquently noted, when scientists and citizens work together, both science and society advance, an idea that remains profoundly relevant for the ecological and civic transformations of the coming decades.

Acknowledgements and Information Note

The paper complies with national and international research and publication ethics. Ethics committee approval was not required for the study. All authors contributed equally to the article.

References

Arazy, O., & Malkinson, D. (2021). A framework of observer-based biases in citizen science biodiversity monitoring. *Ecology and Evolution*, 11(8).

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., & Patton, E. (2011). Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change*, 21(3), 995–1004.

Armitage, D., Marschke, M., & Plummer, R. (2008). Adaptive co-management and the paradox of learning. *Global Environmental Change*, 18(1), 86–98.

Aronson, M. F., Lepczyk, C. A., Evans, K. L., Goddard, M. A., Lerman, S. B., MacIvor, J. S., … Vargo, T. (2017). Biodiversity in the city: Key challenges for urban green space management. *Frontiers in Ecology and the Environment*, 15(4), 189–196.

Barve, V. V., Brenskelle, L., Li, D., Stucky, B. J., Barve, N. V., Hantak, M. M., … Guralnick, R. P. (2020). Methods for broad-scale plant phenology assessments using citizen scientists' photographs. *Applications in Plant Sciences*, 8(1), e11315.

Belaire, J. A., Westphal, L. M., Whelan, C. J., & Minor, E. S. (2015). Urban residents' perceptions of birds in the neighborhood. *The Condor*, 117(2), 192–202.

Beninde, J., Delaney, T. W., Gonzalez, G., & Shaffer, H. B. (2023). Harnessing iNaturalist to quantify hotspots of urban biodiversity. *Frontiers in Ecology and Evolution*, 11, 983371.

Boakes, E. H., Gliozzo, G., Seymour, V., Harvey, M., Smith, C., Roy, D. B., & Haklay, M. (2016). Patterns of contribution to citizen science biodiversity projects. *Scientific Reports*, 6, 33051.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge. *BioScience*, 59(11), 977–984.

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science*, 25(1), 2–16.

Bowser, A., Cooper, C., De Sherbinin, A., Wiggins, A., Brenton, P., Chuang, T. R., … Meloche, M. (2020). Still in need of norms: The state of the data in citizen science. *Citizen Science: Theory and Practice*, 5(1).

Burgess, H. K., DeBey, L. B., Froehlich, H. E., Schmidt, N., Theobald, E. J., Ettinger, A. K., … Parrish, J. K. (2017). The science of citizen science. *Biological Conservation*, 208, 113–120.

Calaza-Martínez, P., & Cariñanos, P. (2025). Green infrastructure in Spain. In *Planning Rural Landscapes* (Routledge).

Callaghan, C. T., Bino, G., Major, R. E., Martin, J. M., Lyons, M. B., & Kingsford, R. T. (2019). Bird diversity hotspots. *Landscape Ecology*, 34(6), 1231–1246.

City Nature Challenge. (2024). *Cities around the world collaborate to share observations of nature*. https://www.citynaturechallenge.org/

Conrad, C. C., & Hilchey, K. G. (2011). Community-based environmental monitoring. *Environmental Monitoring and Assessment*, 176(1), 273–291.

Deguines, N., Julliard, R., de Flores, M., & Fontaine, C. (2012). Flower visitor whereabouts. *PLOS ONE*, 7(9), e45822.

Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen science as an ecological research tool. *Annual Review of Ecology, Evolution, and Systematics*, 41(1), 149–172.

ECSA (European Citizen Science Association). (2020). *Ten principles of citizen science.* https://www.ecsa.ngo/10-principles/

Elmqvist, T., Setälä, H., Handel, S. N., van der Ploeg, S., Aronson, J., Blignaut, J. N., … de Groot, R. (2015). Restoring ecosystem services. *Current Opinion in Environmental Sustainability*, 14, 101–108.

Follett, R., & Strezov, V. (2015). Analysis of citizen science research. *PLOS ONE*, 10(11), e0143687.

Goddard, M. A., Dougill, A. J., & Benton, T. G. (2010). Scaling up from gardens. *Trends in Ecology & Evolution*, 25(2), 90–98.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Ecology of cities. *Science*, 319(5864), 756–760.

Haklay, M. (2012). VGI overview. In *Crowdsourcing Geographic Knowledge*, 105–122.

Hecker, S., Bonney, R., Haklay, M., Hölker, F., Hofer, H., Goebel, C., … Bonn, A. (2018). Innovation in citizen science. *Citizen Science: Theory and Practice*, 3(1), 4.

Hochachka, W. M., Fink, D., Hutchinson, R. A., Sheldon, D., Wong, W. K., & Kelling, S. (2012). Data-intensive science. *Trends in Ecology & Evolution*, 27(2), 130–137.

ICLEI Europe. (2021). *Urban Nature Atlas*. https://iclei-europe.org/topics/biodiversity-and-nature-based-solutions/

Isaac, N. J., van Strien, A. J., August, T. A., de Zeeuw, M. P., & Roy, D. B. (2014). Statistics for citizen science. *Methods in Ecology and Evolution*, 5(10), 1052–1060.

iNaturalist. (2025, June 17). *We've reached 250 million verifiable observations!* https://www.inaturalist.org/blog/113107-we-ve-reached-250-million-verifiable-observations

Johnston, A., Hochachka, W. M., Strimas-Mackey, M. E., Ruiz Gutierrez, V., Robinson, O. J., Miller, E. T., … Fink, D. (2021). Analytical guidelines for community science data. *Diversity and Distributions*, 27(7), 1265–1277.

Jordan, R. C., Ballard, H. L., & Phillips, T. B. (2012). Evaluating citizen-science learning outcomes. *Frontiers in Ecology and the Environment*, 10(6), 307–309.

Kennedy, C. M., Oakleaf, J. R., Theobald, D. M., Baruch-Mordo, S., & Kiesecker, J. (2019). Managing the middle. *Global Change Biology*, 25(3), 811–826.

Kobori, H., Dickinson, J. L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., … Miller-Rushing, A. J. (2016). New approach to advance ecology and education. *Ecological Research*, 31(1), 1–19.

Kullenberg, C., & Kasperowski, D. (2016). What is citizen science? *PLOS ONE*, 11(1), e0147152.

La Sorte, F. A., Lepczyk, C. A., Burnett, J. L., Hurlbert, A. H., Tingley, M. W., & Zuckerberg, B. (2018). Big data ornithology. *The Condor*, 120(2), 414–426.

Levrel, H., Fontaine, B., Henry, P. Y., Jiguet, F., Julliard, R., Kerbiriou, C., & Couvet, D. (2010). Balancing investments in biodiversity monitoring. *Ecological Economics*, 69(7), 1580–1586.

López-Guillén, E., Herrera, I., Bensid, B., Gómez-Bellver, C., Ibáñez, N., Jiménez-Mejías, P., … López-Pujol, J. (2024). Using iNaturalist in plant research. *Diversity*, 16(1), 42.

Mason, B. M., Mesaglio, T., Barratt Heitmann, J., Chandler, M., Chowdhury, S., Gorta, S. B. Z., … Callaghan, C. T. (2025). iNaturalist accelerates biodiversity research. *BioScience*, biaf104.

McKinney, M. L. (2008). Effects of urbanization on species richness. *Urban Ecosystems*, 11(2), 161–176.

Meeus, S., Silva-Rocha, I., Adriaens, T., Brown, P. M., Chartosia, N., Claramunt-López, B., … Groom, Q. J. (2023). Multiple outcomes of a bioblitz. *BioScience*, 73(3), 168–181.

Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology & Evolution*, 20(8), 430–434.

Miller-Rushing, A., Primack, R., & Bonney, R. (2012). History of public participation. *Frontiers in Ecology and the Environment*, 10(6), 285–290.

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., & Crowston, K. (2012). Future of citizen science. *Frontiers in Ecology and the Environment*, 15(8), 298–304.

Niemelä, J. (2014). Ecology of urban green spaces. *Landscape and Urban Planning*, 125, 298–303.

Palma, E., Mata, L., Cohen, K., Evans, D., Gandy, B., Gaskell, N., … Hahs, A. K. (2024). City Nature Challenge. *BioScience*, 74(4), 290–299.

Pandya, R. E. (2012). Engaging diverse communities. *Frontiers in Ecology and the Environment*, 10(6), 314–317.

Pettibone, L., Vohland, K., & Ziegler, D. (2017). Interdisciplinary diversity of citizen science. *PLOS ONE*, 12(6), e0178778.

Pocock, M. J., Roy, H. E., August, T., Kuria, A., Barasa, F., Bett, J., … Trevelyan, R. (2019). Developing the global potential of citizen science. *Journal of Applied Ecology*, 56(2), 274–281.

Pocock, M. J., Tweddle, J. C., Savage, J., Robinson, L. D., & Roy, H. E. (2017). Diversity and evolution of citizen science. *PLOS ONE*, 12(4), e0172579.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., … Bonney, R. (2012). Public participation in scientific research: A framework for deliberate design. *Ecology and Society*, 17(2).

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, 24(9), 467–471.

Soga, M., & Gaston, K. J. (2016). Extinction of experience. *Frontiers in Ecology and the Environment*, 14(2), 94–101.

Sullivan, B. L., Aycrigg, J. L., Barry, J. H., Bonney, R. E., Bruns, N., Cooper, C. B., … Kelling, S. (2014). The eBird enterprise. *Biological Conservation*, 169, 31–40.

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E., … Parrish, J. K. (2015). Citizen science for biodiversity research. *Biological Conservation*, 181, 236–244.

Toomey, A. H., & Domroese, M. C. (2013). Citizen science and conservation attitudes. *Human Ecology Review*, 50–62.

Troudet, J., Grandcolas, P., Blin, A., Vignes-Lebbe, R., & Legendre, F. (2017). Taxonomic bias in biodiversity data. *Scientific Reports*, 7, 9132.

Turrini, T., Dörler, D., Richter, A., Heigl, F., & Bonn, A. (2018). Threefold potential of environmental citizen science. *Biological Conservation*, 225, 176–186.

UNEP (United Nations Environment Programme). (2022). *Global Biodiversity Outlook 6*. https://www.unep.org/resources/global-environment-outlook-6

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. https://sdgs.un.org/2030agenda

United Nations. (2019). *World Urbanization Prospects: The 2018 Revision – Highlights*. https://population.un.org/wup/assets/WUP2018-Highlights.pdf

van der Jagt, A. P., Szaraz, L. R., Delshammar, T., Cvejić, R., Santos, A., Goodness, J., & Buijs, A. (2017). Governance of communal urban gardens. *Environmental Research*, 159, 264–275.

Van Horn, G., Mac Aodha, O., Song, Y., Cui, Y., Sun, C., Shepard, A., … Belongie, S. (2018). The iNaturalist species classification dataset. *CVPR Proceedings*, 8769–8778.

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., … Mons, B. (2016). The FAIR guiding principles. *Scientific Data*, 3, 160018.

Wyborn, C., Datta, A., Montana, J., Ryan, M., Leith, P., Chaffin, B., … Van Kerkhoff, L. (2019). Co-producing sustainability. *Annual Review of Environment and Resources*, 44(1), 319–346.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

An Investigation into the Potential of Artificial Intelligence Applications in Low Earth Orbit Satellite Systems for Urban Planning Applications

Elif Eda TAKGİL [1*]

ORCID 1: 0003-2102-8398
[1]Research Assistant, Düzce University, Faculty of Engineering, Department of Electrical and Electronic Engineering, Düzce-Türkiye
elifedatakgil@duzce.edu.tr **(**Responsible Author)

Ali ÇALHAN [2]

ORCID 2: 0002-5798-3103
[2]Prof. Dr., Düzce University, Faculty of Engineering, Department of Computer Engineering, Düzce-Türkiye
alicalhan@duzce.edu.tr

Murtaza CİCİOĞLU [3]

ORCID 3: 0002-5657-7402
[3]Assoc. Prof. Dr., Bursa Uludağ University, Faculty of Engineering, Department of Computer Engineering, Bursa-Türkiye
murtazacicioglu@uludag.edu.tr

Abstract

Low Earth Orbit (LEO) satellites play a critical role in enabling global communications and remote sensing technologies. Positioned at altitudes ranging from approximately 200 to 2000 kilometres, these satellites can provide high-speed data transmission with low latency due to their proximity to Earth. The high-resolution image processing capabilities of LEO satellites and the wide coverage area of the LEO constellation are rapidly increasing their use in spatial analysis of cities, infrastructure planning, remote sensing applications such as agriculture and natural disaster management, and scientific research. The increasing complex requirements of these satellites have made the integration of artificial intelligence (AI)-based methods into LEO satellite systems inevitable. AI algorithms can process image and sensor data from satellites to detect disasters such as fires, floods and air pollution at an early stage, optimise the energy performance of buildings, and develop sustainable design strategies by modelling the environmental impacts of cities. Convolutional neural networks (CNN) are widely used to monitor environmental factors such as air pollution, forest fires, and humidity levels in satellite images. Deep Reinforcement Learning (DRL) algorithms provide efficient solutions for tasks such as the deployment of aerial vehicles and the management of communication resources in post-disaster areas, even under conditions of limited energy and bandwidth. Furthermore, Federated Learning (FL) techniques enable the training of global AI models in collaboration with ground stations while maintaining satellite data security. In addition, generative artificial intelligence methods automatically detect patterns in satellite data, enabling faster and more accurate environmental analysis. Consequently, it is anticipated that AI-integrated LEO satellite systems have the potential to become a fundamental component of decision support mechanisms in smart city planning, sustainable architecture applications, and comprehensive urban design processes by advancing data collection and analysis capabilities. This study has made a unique contribution to the literature by addressing the effects of AI integration with LEO satellite systems at the urban planning and architecture scale, and has provided a framework to guide future research.

Keywords: Artificial intelligence, LEO satellites, space technologies, urban planning applications

1. Introduction

LEO satellites play a critical role in global communications and remote sensing technologies today. Positioned at altitudes of 200–2000 km, these satellites can provide low latency and high-speed data transmission due to their proximity to Earth. LEO satellite constellations are effectively used in remote sensing applications such as spatial analysis of cities, infrastructure

planning, agriculture, and natural disaster management, as well as in scientific research, thanks to their high-resolution imaging capabilities and wide coverage areas (Candoğan, 2024). However, the increasing data volume and complex mission requirements of these satellites limit the data processing capacity of traditional methods, thus necessitating the integration of AI-based methods. AI algorithms can extract information quickly and accurately by automating data filtering, classification, and pattern recognition processes (Kazanskiy et al., 2025). Furthermore, Deep Learning (DL) and reinforcement learning algorithms play a critical role in real-time analysis and predictions for applications such as disaster detection, air pollution monitoring, and emergency response (Boroujeni et al., 2024). AI also enables the development of decision support mechanisms in urban planning and sustainable architecture applications; for example, it offers scalable and accurate solutions for tasks such as urban heat island analysis or energy consumption optimisation (Furuya et al., 2023).

The primary objective of this study is to examine the contributions of AI integration to urban planning and sustainable architecture applications in light of the increasing data volume and complex mission requirements of LEO satellite systems. The study refers to work carried out in the field of urban planning applications using algorithms such as CNN, DRL, FL, and Generative AI, leveraging the high-resolution imaging and wide coverage capabilities of LEO satellites. The aim is to contribute to the development of AI-based decision support systems in applications such as disaster management, environmental monitoring, and sustainable urban design. In this context, the study aims to reveal the contributions of AI integration with LEO satellites to data collection, analysis, and urban design processes. Furthermore, the study aims to present a unique framework to the literature by revealing the interdisciplinary potential of the integration of AI and LEO satellite systems and to guide future research.

2. Materials and Methods

The methodological framework followed in this study is based on a comprehensive analysis of the literature on the integration of LEO satellite systems and AI algorithms. Findings from the literature review indicate that the integration of LEO satellite systems and AI is used in a wide variety of areas in the context of urban planning and sustainability (SatNow, 2025). In this context, the analysed studies are broadly grouped under the headings of urban environment monitoring, disaster management, infrastructure planning and optimisation, energy efficiency, and agricultural-rural applications. These themes cover a wide range, from urban heat island and air pollution analysis to the assessment of environmental factors such as flood risk, green space monitoring, and land use change; and from building energy performance and transport density to the optimisation of smart city infrastructure. Furthermore, the combined use of high-resolution images provided by LEO satellite data and AI-based models in disaster early warning, damage assessment, and reconstruction processes significantly enhances the accuracy and effectiveness of decision support systems (Doshi et al., 2018). In this context, the literature reveals that LEO-AI integration offers strategic contributions not only in data collection but also in critical areas such as urban sustainability, carbon footprint analysis, and environmental resilience. Furthermore, it demonstrates that LEO-AI integration not only improves data collection processes but also provides important contributions in critical areas such as urban sustainability, carbon footprint reduction, and increased environmental resilience (Jain, 2025).

3. Findings and Discussion

This section presents an analysis of the current literature on the integration of LEO satellite systems with AI-based methods (Table 1). The studies reviewed indicate that FL, DRL, image

processing, and edge computing-based approaches are particularly prominent in this rapidly developing field between 2022 and 2025. The research reveals that LEO satellites have become a powerful tool for transformation not only in global communication infrastructures but also in urban-focused applications such as smart city planning, disaster management, environmental monitoring, and urban sustainability. It has been determined that FL and DRL-based models, in particular, enable privacy-focused and low-latency processing of sensor data at the city scale, while deep learning-based image inference approaches allow for high-accuracy analysis of urban morphology, building density, traffic patterns, and green space distribution. In this context, LEO-AI integration is seen to offer new opportunities in data-driven decision support systems, resource optimisation, and real-time environmental monitoring in urban management.

Table 1. Current Literature Studies

Year	Brief Description
2025	This study highlights that global coverage and high-resolution measurements provided by Earth observation satellites such as Terra, Aqua, Sentinel-5P, and TEMPO enable the identification of air pollutant sources and the implementation of more effective air quality strategies (Kuttippurath & Patel, 2025).
2025	This study examines the role of LEO satellites in monitoring climate change and tracking its effects in critical areas such as air pollution, atmospheric humidity, and forest fires. It also highlights how AI integration accelerates the collection and analysis of satellite data, enabling a more efficient and advanced climate monitoring process (Jain, 2025).
2025	This study has facilitated the rapid development of LEO satellites in the fields of communication, navigation, and remote sensing by reducing satellite payloads and lowering launch costs, thereby creating significant opportunities in urban planning and urban management applications. This article examines the development of LEO satellite communication payloads and the challenges encountered, highlighting opportunities and future research directions in areas such as smart city applications, urban transport management, and environmental monitoring (Hui et al., 2025).
2025	This study examines the use of LEO satellites (Starlink) and cellular internet networks for Internet of Things (IoT) Smart Farming applications in agricultural areas in Indonesia. Experimental results reveal that both networks performed well in terms of overall service quality, but the LEO network exhibited lower performance than the cellular network in terms of latency, particularly in rainy weather. (Ramadhani et al., 2025)
2025	This study summarises the use and applications of satellite data in air quality and related health assessments. It also highlights advances over the past 15 years, providing guidance for future applications. (Holloway et al., 2025)
2025	This study examines in detail the role of satellite IoT in developing smart city infrastructure and services, its architecture, applications, and the challenges encountered. (Shahi et al., 2025)
2024	This study examines the applications of AI-supported unmanned aerial vehicle (UAV) systems in pre-fire, active and post-fire management processes, summarising the contributions of remote sensing, ML and DL techniques to fire classification, detection and monitoring tasks (Haeri Boroujeni et al., 2024).
2024	This study proposes the integrated use of machine learning and physical and socio-demographic data to mitigate urban heat island (UHI) effects in hot and arid cities such as San Antonio, Texas. The results provide practical strategies for different urban areas, such as increasing green spaces, reducing impervious surfaces, and improving building design, thereby guiding policymakers and urban planners towards sustainable and equitable UHI management (Syeda, Castillo Villar, & Alaeddini, 2024).
2023	This study proposes the integration of LEO satellites and multiple aerial vehicles to provide rescue services in post-disaster areas. The proposed genetic algorithm approach ensures the fair and efficient

	deployment of aerial vehicles and the optimisation of communication performance with limited battery and bandwidth resources (Mohamed, Hashima, Hatano, & Khallaf, 2023).
2022	This study suggests that machine learning models, combined with large-scale image and sensor data collected by LEO satellites, could be used to solve global problems such as real-time disaster management. Due to data download and model training limitations, the model training time can be reduced by 1-7 days by collaborating between satellites and ground stations using the FL framework they named FedSpace. (So et al., 2022).

Based on the table compiled from the 10 academic articles examined in this study, the implications of LEO satellite and AI-based analyses in 10 thematic application areas, such as urban heat islands, disaster early warning, air pollution, water resource management, green space monitoring, building energy performance, transport density, sustainability analysis, smart infrastructure optimisation, and urban agriculture area monitoring, are evaluated below. The results obtained demonstrate that integrating LEO satellites with AI-supported decision-making mechanisms contributes significantly to the development of a data-driven, environmentally sensitive and sustainable approach in urban planning and architectural design processes.

3.1. Urban Heat Island Analysis

High-resolution thermal and optical images obtained from LEO satellites can be effectively used in urban heat island (UHI) analyses. By mapping temperature differences between satellite data and urban areas, the effects of factors such as dense construction, asphalt surfaces, and lack of green space on the urban microclimate can be determined (Wang et al., 2025; Chintalapati et al., 2025). AI algorithms can automatically classify and visualise heat intensities in different regions by processing temperature data from satellite images. This enables urban planners and architects to make data-driven decisions for energy consumption optimisation, green space placement, and sustainable urban design (Wang et al., 2025). Furthermore, DRL-based models simulate different urban design scenarios to suggest the most suitable planning strategies for minimising the heat island effect (Lozano-Cuadra et al., 2024). These methods can be used both to optimise existing urban structures and to reduce environmental impacts in new urban projects.

3.2. Disaster Early Warning

High-resolution optical and radar-based imagery provided by LEO satellites plays a critical role in the early detection of disaster processes such as forest fires, floods, landslides, and post-earthquake situation assessments. The short revisit time achieved due to these satellites' low orbital altitudes enables the observation of disaster areas within minutes, significantly reducing the coverage and access limitations of traditional ground-based monitoring networks.

In recent years, AI-based models have come to the fore in disaster detection and prediction. For example, CNN-based image classification models enable the automatic detection of fire starting points from satellite images, while Long Short-Term Memory (LSTM) and other time series prediction algorithms can predict the spread rate and direction of a disaster in a temporal dimension by correlating meteorological data, wind models, and terrain structure. The integration of these models with disaster management centres' early warning systems enables shorter response times, optimised evacuation plans, and dynamic resource allocation to emergency teams. Thus, it becomes possible not only to reduce damage after a disaster but also to increase risk management and preparedness levels before a disaster (Lozano-Cuadra et al., 2024).

3.3. Air Pollution Monitoring

LEO satellite sensors can create detailed air quality maps at city scale by monitoring the concentration of key air pollutants such as nitrogen dioxide and carbon dioxide in the troposphere with high spatial resolution. The low orbital altitude of these satellites and their short revisit times enable continuous monitoring of intraday fluctuations and seasonal changes in pollution. The data obtained not only allows for the observation of pollution levels but also contributes to the modelling of pollutant sources (e.g., traffic density, industrial facilities, meteorological transport effects). In this process, CNN-based image processing models automatically detect the spatial distribution of pollution by classifying satellite data, while regression-based and hybrid AI models can produce short- and medium-term air pollution forecasts by learning temporal trends. Thus, city administrations can shape environmental policy decisions, such as urban transport regulations, green space planning, industrial emission quotas, and emergency health alerts, in a data-driven manner. This approach enables both the protection of public health and the enhancement of long-term environmental resilience in line with the vision of sustainable urbanism (Matthiesen & Soret, 2022).

3.4. Urban Water Resources and Flood Risk Analysis

LEO satellites provide critical spatial data for identifying flood risks and water accumulation in cities, thanks to their high-resolution optical and Synthetic Aperture Radar (SAR) sensors. SAR imagery, in particular, offers uninterrupted observation during disasters, as it can detect surface water accumulation regardless of cloud cover and night-time conditions. When time-series data obtained from satellites is evaluated in conjunction with variables such as rainfall intensity, surface permeability, topography, urbanisation density, and drainage lines, it becomes possible to comprehensively model flood formation processes (Wang, 2025). In this context, CNN-based image analysis models automatically classify water accumulation and flood areas, while DRL algorithms can predict flood probability, spread direction, and severity scenarios based on dynamic environmental conditions (Tsuboi, 2019). The resulting flood risk maps provide decision support to city administrations, particularly in rapidly urbanising areas, for infrastructure planning, capacity design of stormwater drainage systems, positioning of flood prevention structures, and development of emergency response plans, contributing to the resilient and sustainable design of cities (Tsuboi, 2019).

3.5. Green Space and Vegetation Cover Monitoring

Satellite imagery serves as a crucial data source for monitoring the spatial distribution and temporal changes of urban green spaces. The high-resolution optical sensors of LEO satellite systems enable detailed classification of park areas, tree cover, grass surfaces, and other types of natural vegetation. CNN-based image classification and object-based image segmentation algorithms performed on these images can automatically detect the boundaries, density, and ecological continuity of urban green spaces (Neyns & Canters, 2022). Furthermore, the vitality, stress levels, and seasonal changes of vegetation cover can be analysed using the Normalised Difference Vegetation Index (NDVI) and similar vegetation health indices. The outputs obtained can serve as a decision support mechanism in sustainable urban planning applications such as reducing the heat island effect in cities, planning recreational areas, increasing carbon sink capacity, and creating ecological corridors. Thus, city administrations can adopt a science-based approach to the protection, development, and design of environmental rehabilitation strategies for green spaces (Neyns & Canters, 2022).

3.6. Building Energy Performance Analysis

Thermal infrared data obtained from LEO satellites play a significant role in assessing energy efficiency by analysing the surface temperature distribution of buildings in cities. Factors such as roof coverings, facade materials, insulation quality, and building density directly affect heat loss from external surfaces. These data obtained in thermal bands can be automatically processed using CNN-based image classification algorithms to detect temperature anomalies in building structures (Wang et al., 2025). This approach can contribute to energy rehabilitation studies for existing structures and guide energy-efficient and climate-responsive architectural design decisions in new urban development projects (Wang et al., 2025).

3.7. Traffic and Transport Density Forecast

High-resolution LEO satellite imagery enables the large-scale and continuous monitoring of urban traffic flow and road usage intensity. Spatial and temporal traffic data obtained from these images can be classified using CNN into vehicle density, traffic congestion zones, and road usage patterns (Wang et al., 2025). In addition, time series analyses and LSTM-based prediction models can forecast how traffic flow will change at different times of the day or during special circumstances (holiday periods, disasters, events, etc.). The Split FL architecture, which enables distributed model training on LEO satellite networks, allows traffic and mobility data to be processed locally, reducing latency while preserving data privacy (Wu & Huang, 2025; Zhang et al., 2024). Thus, decision-making processes such as urban transport planning, public transport route reorganisation, alternative route suggestions, and traffic signal optimisation can be based on scientific data. This approach provides a critical data infrastructure for urban mobility management, a fundamental component of smart city systems, contributing to both the reduction of traffic-related carbon emissions and increased time and energy efficiency in transportation (Wang et al., 2025; Wu & Huang, 2025).

3.8. Urban Sustainability and Carbon Footprint Analysis

High-resolution data obtained from LEO satellites and AI algorithms enable detailed modelling of cities' energy consumption profiles, greenhouse gas emissions, and other environmental impacts (Furuya et al., 2023). These data are analysed to cover variables such as heat loss from buildings, carbon emissions from transport, the carbon sink capacity of green spaces, and urban heat island effects (Wang et al., 2025). CNN, LSTM, and DRL-based models can process these data spatially and temporally to generate energy and environmental performance predictions, thereby enabling data-driven decision-making processes in urban planning, such as renewable energy deployment, passive design strategies, green infrastructure planning, and transport optimisation (Furuya et al., 2023). This approach can support sustainable urban design at the city scale, enabling the development of energy-efficient and environmentally friendly design solutions in architectural projects. Consequently, satellite-based AI analyses can create scientific decision support mechanisms in both the planning and implementation stages while minimising the environmental impacts of cities (Furuya et al., 2023; Wang et al., 2025).

3.9. Smart City Infrastructure Optimisation

The effective monitoring and optimisation of energy, water, and transport infrastructure is one of the fundamental requirements for sustainable and smart cities. High-resolution data obtained from LEO satellites provides critical information about the spatial distribution, usage intensity, and performance indicators of urban infrastructure (Wang et al., 2025). These data automatically analyse the condition of infrastructure components (power lines, water pipelines,

road and bridge networks) through CNN-based image processing algorithms, while DRL models optimise infrastructure usage and resource allocation by considering dynamic variables such as energy consumption, water loss and traffic flow. This process enables city administrations to make data-driven strategic decisions, such as increasing energy efficiency, managing water resources sustainably, reducing traffic congestion, and determining maintenance priorities for critical infrastructure (Furuya et al., 2023). Consequently, LEO satellite data and AI-based analyses have become an important tool for enhancing the performance of smart city infrastructure, thereby supporting the effectiveness and sustainability of urban services (Furuya et al., 2023; Wang et al., 2025).

3.10. Agriculture and Rural Areas Monitoring

Monitoring agricultural areas around cities is of strategic importance in assessing the impact of urban growth on ecosystems and food production. LEO satellites can enable the regular monitoring of indicators such as plant density, chlorophyll levels, soil moisture, and crop development stages through high-resolution multispectral imagery (Neyns & Canters, 2022). These data, combined with CNN-based image classification and plant indices such as NDVI, can be used to derive the spatial distribution of agricultural productivity (Neyns & Canters, 2022; Furuya et al., 2023). Furthermore, time series analysis can be used to predict irrigation needs, drought risk, and plant stress conditions at an early stage. This approach provides a critical data foundation for protecting agricultural areas in urban planning, controlling urban sprawl, developing food security policies, and supporting sustainable land use decisions. Thus, while maintaining the ecological balance between urban and rural areas, it becomes possible to increase local production capacity and efficiently manage environmental resources (Furuya et al., 2023; Neyns & Canters, 2022).

4. Conclusion and Recommendations

Recent research in the field of LEO satellites and AI integration has revealed that these technologies are not only critical for global communication and remote sensing, but also play a vital role in urban planning and architectural design processes. AI algorithms are effectively used in satellite image processing, data filtering, classification, and pattern recognition; they enhance decision support systems in tasks such as disaster detection, air pollution monitoring, energy optimization, and urban infrastructure planning (Furuya et al., 2023; Li et al., 2024). Particularly in applications such as urban heat island analysis, urban sustainability assessments, building energy performance optimization, and modeling the environmental impacts of urban spaces, the processing of data from LEO satellites using AI increases the accuracy and efficiency of planning and architectural design decisions (Furuya et al., 2023; (Neyns & Canters, 2022). Furthermore, AI-based methods in the orbital optimization, coverage improvement, and data transmission processes of LEO satellite constellations increase efficiency under limited energy and bandwidth conditions, providing reliable data sources for urban planning and smart architectural applications (Tsuboi, 2019; Candoğan, 2024). The integration of onboard AI and in-orbit cloud computing in small satellite missions enhances global remote sensing capabilities and supports strategic decisions in urban areas, such as sustainable design, infrastructure development, and disaster management. Consequently, findings in the literature indicate that AI integration with LEO satellites has become a fundamental component of data-driven, rapid, and effective decision-making mechanisms in urban planning and architectural applications, suggesting that future work in this field will advance toward more comprehensive and integrated solutions (Furuya et al., 2023).

Thanks and Information Note

The article complies with national and international research and publication ethics. There was no funding for this study. All authors contributed equally to the article.

References

Boroujeni, S. P. H., Razi, A., Khoshdel, S., Afghah, F., Coen, J. L., O'Neill, L., & Vamvoudakis, K. G. (2024). A comprehensive survey of research towards AI-enabled unmanned aerial systems in pre-, active-, and post-wildfire management. *Information Fusion, 108*, 102369. https://doi.org/10.1016/j.inffus.2024.102369

Candoğan, A. (2024). Türkiye'de LEO uydu sistemlerinin elektronik haberleşme sektörüne etkisi. *Türk Telekomünikasyon Dergisi, 18*(2), 77–94.

Chintalapati, B., Precht, A., Hanra, S., Laufer, R., Liwicki, M., & Eickhoff, J. (2025). *Opportunities and challenges of on-board AI-based image recognition for small satellite Earth observation missions*. Advances in Space Research, **75**(9), 6734–6751. https://doi.org/10.1016/j.asr.2024.03.053

Dwivedi, A. K., Chougrani, H., Chaudhari, S., Varshney, N., & Chatzinotas, S. (2024). *Efficient Transmission Scheme for LEO Satellite-Based NB-IoT: A Data-Driven Perspective* (arXiv preprint arXiv:2406.14107). https://doi.org/10.48550/arXiv.2406.14107

Doshi, J., Basu, S., & Pang, G. (2018). From satellite imagery to disaster insights. *arXiv preprint arXiv:1812.07033.* https://arxiv.org/abs/1812.07033

Furuya, M. T. G., Furuya, D. E. G., Dutra de Oliveira, L. Y., da Silva, P. A., Cicerelli, R. E., Gonçalves, W. N., … & Ramos, A. P. M. (2023). A machine learning approach for mapping surface urban heat island using environmental and socioeconomic variables: A case study in a medium-sized Brazilian city. *Environmental Earth Science*s, 82, 325. https://doi.org/10.1007/s12665-023-11017-8

Haeri Boroujeni, S. P., Razi, A., Khoshdel, S., Afghah, F., Coen, J. L., O'Neill, L., Fule, P., Watts, A., Kokolakis, N. M. T. & Vamvoudakis, K. G. (2024). A comprehensive survey of research towards AI-enabled unmanned aerial systems in pre-, active-, and post-wildfire management. *Information Fusion, 108,* 102369. https://doi.org/10.1016/j.inffus.2024.102369

Holloway, T., Bratburd, J. R., Fiore, A. M., Kerr, G. H., & Mao, J. (2025). Satellite data to support air quality assessment and management. *Journal of the Air & Waste Management Association*, 75(6), 429-463. https://doi.org/10.1080/10962247.2025.2484153

Hui, M., Zhai, S., Wang, D., Hui, T., Wang, W., Du, P., & Gong, F. (2025). A review of leo-satellite communication payloads for integrated communication, navigation, and remote sensing: Opportunities, challenges, future directions. *IEEE Internet of Things Journal, 12*(12), 18954-18992. https://doi.org/10.1109/JIOT.2025.3553942

Jain, D. (2025). AI-driven climate solutions: Leveraging LEO satellites for sustainability. *Research Archive of Rising Scholars.* https://doi.org/10.58445/rars.1814

Kazanskiy, N., Khabibullin, R., Nikonorov, A., & Khonina, S. (2025). A comprehensive review of remote sensing and artificial intelligence integration: Advances, applications, and challenges. *Sensors*, *25*(19), 5965. https://doi.org/10.3390/s25195965

Kuttippurath, J. & Patel, V. K. (2025). *Chapter 21 – Advances in Earth Observation Satellites for global air quality monitoring*. In Sustainable Development Perspectives in Earth Observation (pp. 361-381). Elsevier. https://doi.org/10.1016/B978-0-443-14072-3.00021-6

Lozano-Cuadra, F., Garcia, J., & Torres, M. (2024). Continual DRL for decentralized satellite routing. *arXiv preprint arXiv:2405.12308.*

Matthiesen, B., & Soret, B. (2022). Federated learning in satellite constellations. *IEEE Network.*

Mohamed, E. M., Hashima, S., Hatano, K. & Khallaf, H. S. (2023). LEO-Assisted Aerial Deployment in Post-Disaster Scenarios Using a Combinatorial Bandit and Genetic Algorithmic Approach. *Electronics*, 12(24), 4964. https://doi.org/10.3390/electronics12244964

Neyns, R. & Canters, F. (2022). Mapping of Urban Vegetation with High-Resolution Remote Sensing*:* A Review. *Remote Sensing*, 14(4), 1031. https://doi.org/10.3390/rs14041031

Ramadhani, E. H., Enriko, I. K. A., Alamsyah, A. T., Nuha, M. A. U., & Puspita Sari, E. L. I. (2025). *Comparative analysis of QoS between LEO satellite and cellular Internet networks for IoT smart farming*.

Shahi, A., Gupta, A., & Chawla, S. K. (2025). *Satellite IoT in smart cities: Architecture, applications and challenges*. In *AIP Conference Proceedings* (Vol. 3261, Article 090001). AIP Publishing. https://doi.org/10.1063/5.0258775

So, J., Hsieh, K., Arzani, B., Noghabi, S., Avestimehr, S., & Chandra, R. (2022). *FedSpace: An Efficient Federated Learning Framework at Satellites and Ground Stations* (arXiv preprint arXiv:2202.01267). https://doi.org/10.48550/arXiv.2202.01267

Syeda, A. Q., Castillo-Villar, K. K., & Alaeddini, A. (2024). *Sustainable urban heat island mitigation through machine learning: Integrating physical and social determinants for evidence-based urban policy*. *Sustainability*, *16*(5), 4362. https://doi.org/10.3390/su16054362

Tsuboi, Y. (2019, December). *Development of a CubeSat Constellation for Magnetospheric and Upper Atmospheric Remote Sensing* [Abstract NS-H33B-14]. In *AGU Fall Meeting Abstracts*. https://ui.adsabs.harvard.edu/abs/2019AGUFMNH33B..14T

Wang, B., Fang, Y., Huang, D., Lu, Z., & Lv, J. (2025). *A lightweight and adaptive image inference strategy for Earth observation on LEO satellites*. Remote Sensing, 17(7), 1175. https://doi.org/10.3390/rs17071175

Wu, W., & Huang, X. (2025). Split-LEO: Efficient AI model training over LEO satellite networks. *Science China Information Sciences*, *68*(2), 4523–1. https://doi.org/10.1007/s11432-024-4523-1

Zhang, Y., Lin, Z., Chen, Z., Fang, Z., Zhu, W., Chen, X., Zhao, J., & Gao, Y. (2024). *SatFed: A resource-efficient LEO satellite-assisted heterogeneous federated learning framework* (arXiv preprint arXiv:2409.13503). https://doi.org/10.48550/arXiv.2409.13503

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Acoustic Identity in Cultural Landscapes: Local Sounds, Memories, and Spatial Attachment

Sıla GÜNAÇAN ODABAŞI[1*]

ORCID 1: 0000-0002-7501-5851
[1]Res. Asst., Istanbul Medipol University, Faculty of Fine Arts, Design & Architecture, Department of Urban Design & Landscape Architecture, Istanbul-Türkiye
sila.gunacan@medipol.edu.tr **(**Responsible Author)

Ebru ERBAŞ GÜRLER[2]

ORCID 2: 0000-0002-3095-6594
[2]Assoc. Prof., Istanbul Technical University, Faculty of Architecture, Department of Landscape Architecture, Istanbul- Türkiye
erbaseb@itu.edu.tr

Abstract

Cultural landscapes are multidimensional environmental constructs that acquire identity not only through their visual and spatial characteristics but also through their sensory layers. Among these layers, sound emerges as a powerful element in the experience and remembrance of place, occupying a distinctive position in relation to collective memory, spatial belonging, and the production of identity. Sound functions as a medium that carries cultural memory across a broad spectrum—from everyday life practices to nature, from religious rituals to social interactions—thereby reinforcing the meanings that societies attribute to place. Local sounds are regarded as unique components of place identity; when intertwined with memories extending from the past to the present, they strengthen the sense of belonging that communities develop toward their environments. The murmur of a historic bazaar, the everyday sounds of a public square, the call emanating from a religious structure, or the natural sounds of coastal areas together produce a distinctive layer of acoustic identity that differentiates one landscape from another. Acoustic identity, integrated with everyday practices, cultural rituals, and the natural environment, evokes both individual and collective memories, ensuring the continuity of the emotional bond established with the cultural landscape. Consequently, it becomes evident that the sense of attachment and belonging to a place is constructed not solely through visual indicators but also through a multisensory experience mediated by sound. In this context, understanding how the concept of acoustic identity is formed within cultural landscapes and which components shape the perceptual integrity of the landscape emerges as a fundamental research question. This study aims to explore the formation of acoustic identity in cultural landscapes through a literature-based examination encompassing theoretical approaches, comparative examples, and experiential dimensions. Furthermore, it discusses how acoustic identity can be preserved from the perspective of intangible cultural heritage and how it can be integrated into design and planning processes.

Keywords: Acoustic identity, cultural landscape, sensory experience, intangible heritage, spatial attachment

1. Introduction

In general terms, sound is the propagation of vibrations in an environment as waves, the human brain interpreting these waves as meaningful sound, and establishing a sensory and existential relationship with space as a social, environmental, and identity-related element (Rossing, 2007; Zwicker & Fastl, 2007; Schafer, 1977; Ingold, 2007). When considered in its cultural dimension, sound is defined as a form of expression of a living relationship established with the environment as a result of the convergence of natural (wind, birds, water, etc.) and cultural (language, religion, music, humans, industry, etc.) values. In this sense, sound produces an existential bond that describes the sensory interaction established with space (Ingold, 2007). Sound clarifies its role in the emotional, ritual, and spatial meaning production of society through this bond (Feld, 2012). This bond, nourished by social dynamics, emphasizes the

understanding of sound as the 'flow of the environment' and the continuity of the sensory experience (Ingold, 2007).

As a cultural landscape element, sound represents a perceptible reflection of human activities, social relationships, and environmental processes, and with this characteristic, it is accepted as both a natural and cultural element (Schafer, 1977; Pijanowski et al., 2011; Ingold, 2007). From this perspective, sound exists not only as a physical component of the cultural landscape, but also as a social, historical, and sensory layer. Furthermore, sound contributes cultural meaning as part of the social element while constructing the identity and memory of a place. Therefore, it is undeniable that sound is:

• the spatial archive of memory,

• an indicator of identity,

• a vehicle for sensory experience (Schafer, 1977).

Therefore, as a cultural landscape element, sound is a conceptual key that determines not only how a space looks, but also how it is felt and remembered. With this feature, sound removes the concept of cultural landscape from visual centrality, directs us to read space experientially and multisensorily, and deepens social memory, identity, and belonging relationships with its acoustic dimension (Rodaway, 1994).

• removes it from visual centrality,

• directs us to read space experientially and multisensorily,

• deepens social memory, identity, and belonging relationships with its acoustic dimension (Rodaway, 1994).

The meaning of sound in the cultural landscape becomes visible and legible through certain acoustic subcomponents. These components are background sounds, signal sounds, and vocal cultural signs or sound signs. Background sounds mostly include sounds that are perceived more sensually than visually, such as wind, rustling leaves, birds chirping, the rhythmic sound of raindrops, traffic noise, and the distant sound of construction machinery. Signal sounds, as the name suggests, are sounds that exist to convey a message, attract attention, or carry/transmit information. These include the call to prayer, school bells, the shouts at the market, and the vibrational sound of the subway or train coming from afar. The last subcomponent, also known as cultural sound markers, refers to sounds that are culturally specific to a place. In other words, it defines the sounds that form the sound memory of a city and are engraved in its cultural landscape identity. These are sounds that give a sense of belonging to the place, such as ferry whistles, the buzz of the market, the seaside, neighborhood sounds, festival music, etc. This final component is particularly considered in detail when determining the acoustic identity of a cultural landscape (Labelle, 2010).

All subcomponents produce a cultural memory and sense of belonging, creating an 'acoustic identity'. When the sound characteristics of a place change, its identity and, consequently, its social memory also transform (Labelle, 2010). Therefore, sound shifts the understanding of the cultural landscape from the visual to the auditory. This ensures that the space is approached not as a visual form but as a lived environment.

Acoustic identity is the unique set of sound patterns that form over time within a space or cultural community, creating a sense of belonging (Schafer, 1977; Labelle, 2010; Cerwén,

2017). Based on this definition, the acoustic identity of a landscape is explained as a multi-sensory experience, not just a visual one, as a dynamic layer of this experience that changes over time, as a combination of natural sounds such as wind, water, and animal sounds, and cultural sounds such as speech, music, industrial noise, and rituals resulting from human activities. To elaborate further, the acoustic identity of the landscape is formed by the convergence of different conceptual layers. The first is the physical layer. This layer determines the reverberation and propagation of sound through the physical elements of the landscape, such as geographical structure, topography, materials, and vegetation (Truax, 2001). Another layer, the cultural layer, shapes human-generated sounds such as local language, rituals, and transportation sounds for the purpose of producing social belonging and memory (Labelle, 2010; Feld, 1996). The sensory or perceptual layer, on the other hand, concerns how individuals within a society perceive sounds, what meanings they assign to these sounds, and the psychoacoustic dimension of the identity created. Furthermore, this layer is not just about 'the sounds that are there', but how they are felt (Ingold, 2007). Although these layers are considered separately, they are interconnected at a certain point and enable the concept of acoustic identity to be evaluated in terms of its dimensions.

2. Materials and Methods

This study examines the formation of acoustic identity within the context of cultural landscapes. Within this scope, a literature-based research method has been adopted, incorporating theoretical approaches, comparative examples, and experiential dimensions related to the subject. Furthermore, the study includes applications demonstrating how acoustic identity is addressed in cultural landscapes from the perspective of intangible cultural heritage.

3. Findings and Discussion

Sound manifests itself in various forms in cultural landscape studies and in the creation of the perceptual integrity of the landscape. Some of these forms are particularly influential in guiding current studies. In this context, sound can serve as an urban reading tool or take the form of acoustic mapping that reveals the sound layers of a space. Furthermore, sound can be used as a design input in these studies or integrated into participatory research and social memory studies. The place of the concept of sound in the perceptual integrity of the landscape and its form in cultural landscape studies are explained in more detail with the examples below. For example, sound walks are used as an urban reading tool. In a study conducted by Öner (2021), users' perception of space was investigated through soundscape experiences in sound walks conducted specifically in Kadıköy Square (Figure 1).

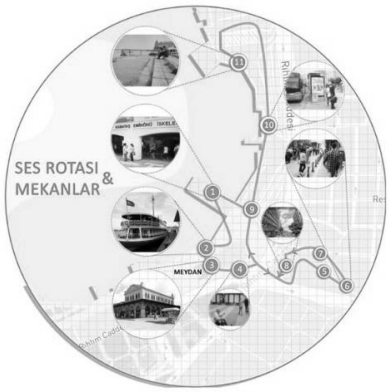


Figure 1. Sound walk route and stops (Öner, 2021)

A similar study was conducted by Sun et al. (2023) in an urban park. In this study, the soundscape perceived by participants was evaluated according to different walking routes defined within the park boundaries (Figure 2).

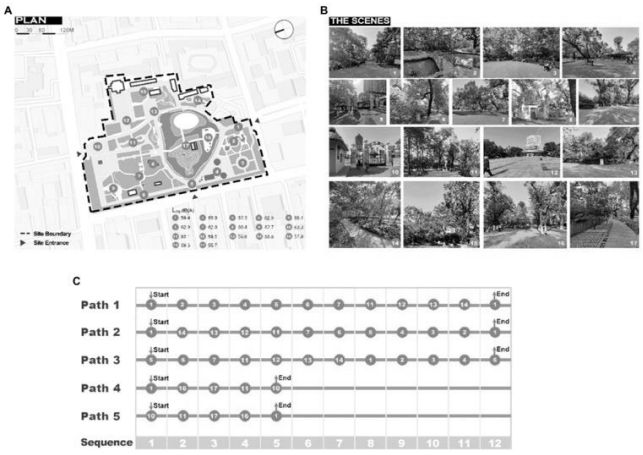


Figure 2. Park boundaries and walking routes (Sun et al., 2023)

Another form of sound within the perceptual integrity of the landscape is acoustic mapping, which aims to document the sonic layers of a space. Between 2010 and 2012, a TÜBİTAK-supported study produced sound maps for five different parks by conducting sound pressure level measurements, surveys and observational studies (Akpınar et al., 2010–2012).

Sound can also be considered as a design input within a cultural landscape; aspects such as acoustic comfort, reverberation, directionality, and areas of silence are defined within this context. In a study by Özçevik (2016), the concept of the auditory landscape is addressed conceptually and discussed in the context of acoustic comfort, offering suggestions on what kind of input sound can be in design work. Furthermore, social memory is revealed and clarified through participatory research such as sound diaries or recordings. In this way, sound creates a layer of auditory meaning in a cultural landscape, forming the identity of the space.

These studies are not merely about visible physical forms, but rather a holistic understanding that derives meaning from the sensory, historical and social relationships people establish with a space. In this context, sound exists as a constantly functioning component of this holistic understanding. Therefore, sound-focused research and design strategies are also considered important tools for revealing, strengthening and sustaining the semantic integrity of the landscape in the public experience.

Sound-focused strategies have been grouped and explained under five categories:

• Site-specific sound analyses and soundwalks

• Sound installations and speaker architecture

• Control/masking with acoustic materials and topography (Buitenschot Park)

• Integration of ecological sound science / soundscape ecology (monitoring biological sound recordings in conservation projects and tracking restoration success using sound data – the work of Bernie Krause is the most prominent reference example)

• Social/cultural participation and identification of cultural sound markers (Sound-memory studies conducted with local communities determine which sounds should be preserved and emphasised.)

In addition to all this, sensory landscapes, which include acoustic ecology explaining the relationship between sound and the environment, social memory defined as an individual and collective memory spatial archive, and sensory-acoustic mapping, are accepted as interpretations of sound in the cultural landscape.

In short, acoustic identity characterises the unique sound signature of a place or community and is formed by the convergence of ecological, cultural and sensory layers. Therefore, in cultural landscape studies, sound should be considered not as a complement to visual identity, but as a defining dimension. Within this scope, key studies that emphasise acoustic identity on a global scale and in the cultural landscape have been cited as examples.

The first of these is the work titled Audio Walks & The Forty-Part Motet, created by Janet Cardiff in 2001. It is a work in which sound recordings, pre-designed by the artist within an urban space, are conveyed to the listener in relation to the location. This work features audio walks and sound installations utilising multiple speakers distributed throughout the space. Furthermore, it enables the user to re-experience the space by walking through it. This work combines monumental and spatial orientation with sound, transporting the landscape experience into a temporal and narrative dimension (Figure 3). The fundamental logic of the work is to blur the boundaries between reality and virtuality by creating a layer between the listener's physical movement, immediate spatial experience, and sound recordings. The aim here is to manipulate ambient sounds to superimpose urban memory, lost narratives, and individual stories, thereby re-layering reality.



Figure 3. Sound installation in the workplace (Cardiff, 2001)
(https://cardiffmiller.com/installations/the-forty-part-motet/)

A similar work, entitled Sound Sculptures, was carried out by Fontana (1990). It deals with the spatial reorganisation or reinterpretation of real-time or recorded sounds from sources such as bridges, water/industrial infrastructure, described as urban elements, in the form of sound sculptures. It makes the sounds of the city aesthetically and contextually audible and conveys

the acoustic data of the cultural landscape to the other side through art (Figure 4). According to the artist, a sculpture is not merely a physical object. The acoustic potential of the space, surface vibrations, environmental sound flows, and human movement within the space are conveyed through a sculptural experience. The work emphasises the fluidity of sound, reinterpreting the concept of sculpture acoustically. In other words, the acoustic identity of the space is the sculpture itself. As the viewer moves through the space, the 'sculpture' shifts and is reproduced through sound.

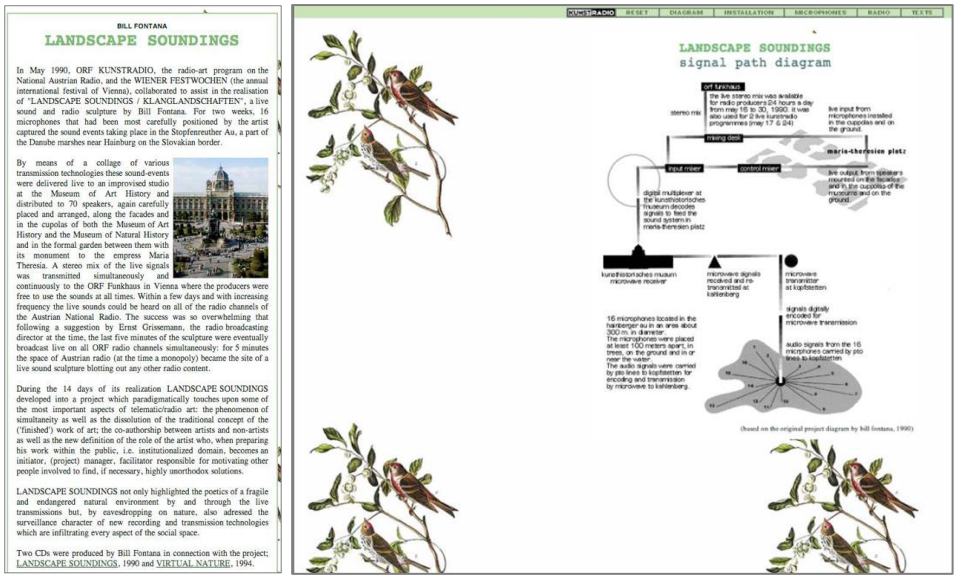


Figure 4. Exhibition catalogue describing the work content and signal path diagram (Fontana, 1990) (https://www.resoundings.info/landscape-soundings)

Another study conducted by Kubisch (2003) under the name Electrical Walks (EM field soundwalks) with numerous stakeholder cities on a global scale focuses on acoustic mapping. This study is actually known as a series of site-specific sound walks. Participants wear specially developed magnetic induction headphones to walk around the city and hear invisible but constantly present electromagnetic fields such as metro networks, security cameras, Wi-Fi signals, ATMs, and billboards (Figure 5). In other words, it is an auditory walking project in which electromagnetic fields are converted into sound data. The main objective of the study is to create an acoustic map of the city's digital, technical and infrastructure systems, while also making invisible electromagnetic energy audible, thereby creating a new urban awareness.

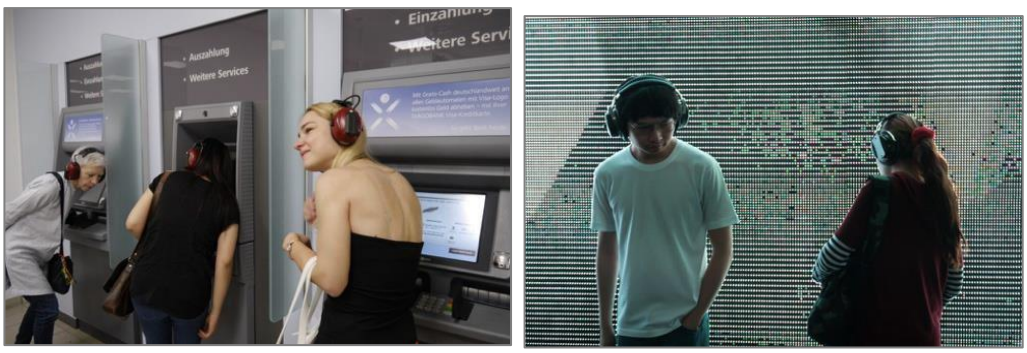


Figure 5. Participants' auditory experience of the electromagnetic field in front of the ATM and advertising board (Kubisch, 2003) (https://christinakubisch.de/electrical-walks)

Unlike the examples mentioned, another work, also known as a cultural sound sculpture, was constructed in Burnley, England, in 2006. It takes its name from both its tree-like appearance and the melodic, ringing, humming sounds it produces when the wind blows. The work is described as a 'Singing-Ringing Tree'. It is actually designed as a wind sound sculpture that produces sound by interacting with the wind (Figure 6). The work is located on a hill overlooking the rural landscape, in a position visible from the city centre. Therefore, it is perceived both as a visual city image and an acoustic landmark. The work is based on the idea of making the auditory character of urban and rural areas audible through a single structure and turning it into a symbolic structure that blends in with the landscape. It is an important work in terms of materialising the sound of the wind and revealing natural flows as an auditory layer of the landscape. Furthermore, within the sculpture, the wind functions as both a design input and an energy source, as well as a sound generator. Consequently, the boundary between the landscape and the structure dissolves, and the wind activates the work.



Figure 6. The singing-ringing tree (cultural sound symbol) (Burnley, İngiltere) (https://en.wikipedia.org/wiki/Singing_Ringing_Tree%2C_Burnley)

A similar work is also referred to as a cultural sound sign. Known as the Cobar Sound Chapel and carried out in Australia, the work is a permanent installation room that combines architecture and sound composition (Figure 7). The work offers both a visual and auditory experience with its concrete walls, sky-facing window, and interior volume, illustrating the mutual interaction between landscape and sound. Some of the sound processes in the work also feature approaches generated by artificial intelligence.

The structure, which is the subject of the work, is not just a concert venue, but is described as a 'sound chapel' where architecture and music come together to materialise sound. Therefore, the work conveys the natural and cultural landscape of a town as an auditory layer. In this context, the work provides local cultural depth.

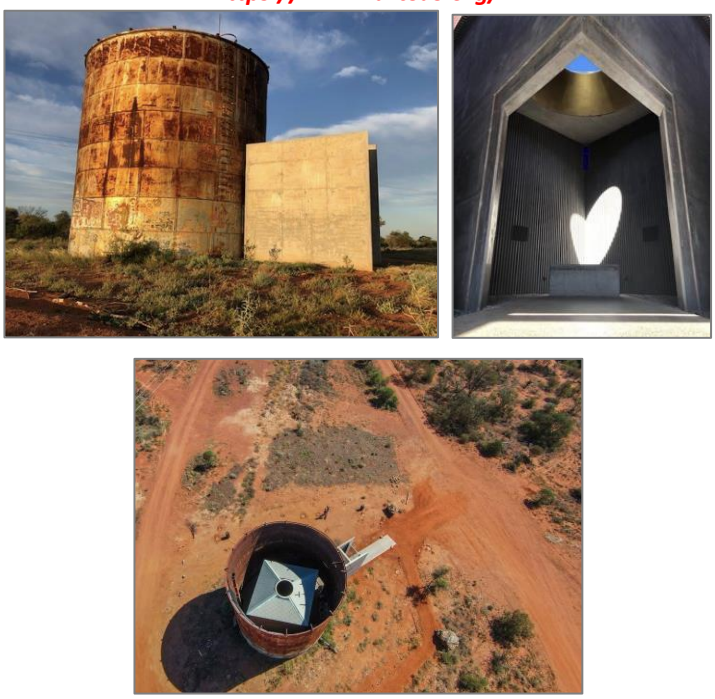


Figure 7. Cobar Sound Chapel (cultural sound landmark) (Australia)
(https://en.wikipedia.org/wiki/Cobar_Sound_Chapel)

The Soundscape Park, designed by West8 in 2011, is larger in scale than other projects and was conceived with a direct urban focus. Based on the principle of concretising the integration of sound into design in terms of acoustic identity and cultural landscape, the project is described as one of the best sound-focused design projects on an urban scale. This urban park is public in nature, an open-air sound and image park based on the principle of 'the socialisation of sound', created with the integration of the New World Symphony Orchestra (Figure 8). The park not only creates a physical green space but also an acoustic landscape area that combines space and sound. The work contains both spatial and symbolic meanings that will nourish the cultural identity of the area in which it is located. In this context, the work refers to the concept of multisensory perception through acoustic identity by bringing together street life, culture and nature as part of the urban public space.

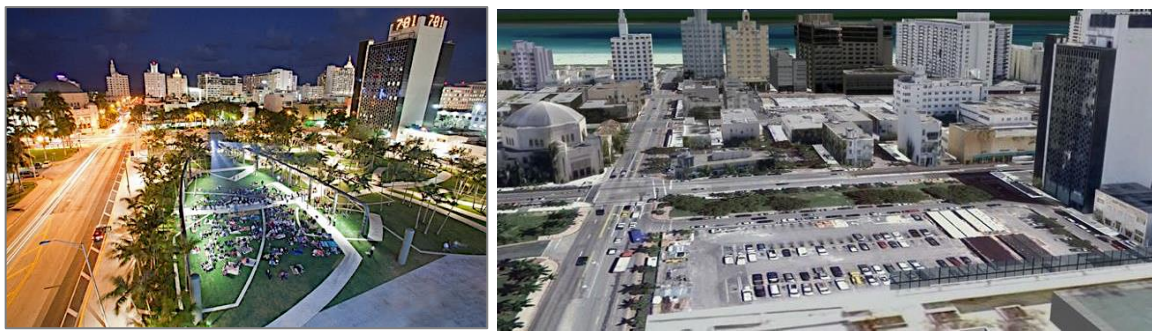


Figure 8. SoundScape Park (left-current and right-before design) (Miami)
(https://www.landscapeperformance.org/case-study-briefs/soundscape-park)

The final example is an acoustic identity study known as the Paris Sound Atlas. The study documents the city's acoustic identity by recording and archiving its sounds. It takes the form

of a digital soundscape library created from the sounds of local cafés, restaurants, squares and parks (Figure 9). It thus reveals the city's auditory landscape. The sound maps prepared as part of the study invite the local population to contribute, enabling the emergence of a practice of listening to, discovering and reimagining the city. The audio recording and mapping of regional languages is a powerful tool for preserving cultural diversity in the study area. In this context, sound maps visualise both noise sources and the city's acoustic identity, creating ecological awareness.



Figure 9. Paris Sound Effects Library website cover photo (https://atlassoundlibrary.com/downloads/paris-sound-effects/)

Conclusion and Recommendations

The concept of cultural landscape has long been approached and incorporated into studies primarily through visual and formal dimensions. However, recent studies have revealed that landscapes are not only ‘seen’ but also ‘heard’ and ‘experienced’ environments (Ingold, 2007; Labelle, 2010). In this context, the concept of ‘acoustic identity’ emerges as a new way of reading that brings together the cultural, ecological and sensory components of a place.

Particularly when examining studies conducted since the second half of the twentieth century, sound has been evaluated within the framework of concepts such as acoustic environment, environmental awareness, silence, and noise balance. In such studies, the concept in question has been regarded as an ‘environmental value that must be protected’ However, this situation has changed since the beginning of the twenty-first century. With the contributions of many researchers, sound has been redefined as an active element in the production of cultural identity, social memory and belonging, and has been the subject of studies. This approach has ensured that acoustic identity is accepted not only as a physical environmental phenomenon but also as a form of cultural representation.

In general, current studies are pioneering the integration of auditory landscapes into design and conservation processes by making the acoustic character of cities visible through documentation (Cerwen, 2017). These studies emphasise that sound can be treated as a ‘plannable environmental and cultural layer’, contributing to the aesthetic, psychological and social experiences of public spaces.

However, significant gaps in the literature are also noteworthy. As most studies are conducted in Western-centric cities, the effects on acoustic identity in terms of local and cultural diversity

are not sufficiently researched. Similarly, the auditory identity of non-urban areas such as rural landscapes, industrial areas, and ecological corridors is often overlooked. Furthermore, there is limited research on the integration of acoustic identity studies into more nuanced perceptual layers such as sensory thresholds, gender, and socio-economic differences.

In future scenarios, it is crucial that acoustic identity-based studies progress with an interdisciplinary approach that recognises them not merely as an environmental element, but as a tool for cultural production, spatial belonging, and forms of social interaction. Comprehensive research combining acoustic ecology and digital mapping methods, particularly within the discipline of landscape architecture, will enable both more accurate documentation of acoustic identity and the creative incorporation of sound into design processes.

Ultimately, the concept of 'acoustic identity' highlights the multisensory nature of the cultural landscape, reminding us that sound must be repositioned as cultural data within the disciplines of design and planning. In this context, any new work undertaken holds significant potential for both the preservation of auditory heritage and the sensory redefinition of spatial identity.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

References

Akpınar, N., Kaymaz, I., Büyükşahin Sunal, A., Turan, E. F., & Belkayalı, N. (2010–2012). Kent parklarında işitsel peyzaj (soundscape) algısı ve kullanıcı tercihlerinin yaşam kalitesi kapsamında değerlendirilmesi: Ankara örneği (TÜBİTAK Projesi No. 110Y186). AVESİS.

Cerwén, G. (2017). Urban soundscapes: A quasi-experiment in landscape architecture. *Landscape Research*, 42(4).

Feld, S. (1996). Waterfalls of Song: An Acoustemology of Place Resounding in Bosavi, Papua New Guinea.

Ingold, T. (2007). The Perception of the Environment: Essays on Livelihood, Dwelling and Skill. Routledge.

Labelle, B. (2010). Acoustic Territories: Sound Culture and Everyday Life. Continuum.

Öner, O. (2021). Ses Algısı Çalışmalarından Kentsel Planlamaya: Kadıköy Akustik.

Özçevik, A. (2016). *İşitsel peyzaj (soundscape) kavramı ile kentsel akustik konforun irdelenmesinde yeni bir yaklaşım* (Doktora tezi, Yıldız Teknik Üniversitesi). Yıldız Teknik Üniversitesi Akademik Arşivi.

Pijanowski, B.C., Farina, A., Gage, S.H. et al., (2011). What is soundscape ecology? An introduction and overview of an emerging new science. *Landscape Ecol*. 26, 1213–1232. https://doi.org/10.1007/s10980-011-9600-8.

Rodaway, P. (1994). Sensuous Geographies: Body, Sense and Place. Routledge.

Rossing, T. D. (2008). The Science of Sound. California: Addison-Wesley Publishing Company.

Schafer, R. M. (1977). The Tuning of the World. Knopf.

Sun, C., Meng, Q., Yang, D., & Wu, Y. (2023). Soundwalk path affecting soundscape assessment in urban parks. *Frontiers in Psychology*, Volume 13-2022. https://doi.org/10.3389/fpsyg.2022.1096952.

Truax, B. (2001). Acoustic Communication. Ablex.

Zwicker, E., & Fastl, H. (2007). Psycho-acoustics: Facts and Models. Springer.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Open-Green Spaces within the Framework of Türkiye's Climate Law

Demet DEMİROĞLU [1]

ORCID 1: 0000-0002-3934-5319
[1] Prof. Dr., Kilis 7 Aralık University, Faculty of Agriculture, Department of Horticulture, Kilis- Türkiye
ddemiroglu@kilis.edu.tr

Aybike Ayfer KARADAĞ [2*]

ORCID 2: 0000-0002-7726-8756
[2] Prof. Dr., Düzce University, Faculty of Forestry, Department of Landscape Architecture, Düzce-Türkiye
ayferkaradag@duzce.edu.tr (Responsible Author)

Abstract

Urban areas are both major contributors to and highly vulnerable to climate change. The 2025 Turkish Climate Law (No. 7552) establishes a legal framework for national climate mitigation and adaptation policies, indirectly highlighting the strategic role of urban open and green spaces. Although the law does not explicitly define "urban green areas," it emphasizes concepts such as carbon sinks, sustainable management, green growth, just transition, and climate justice, which collectively support the ecological, social, and economic value of these spaces. This study employs qualitative content analysis of the Climate Law alongside national planning legislation, including the Zoning Law (No. 3194) and the Spatial Plans Regulation, to evaluate the law's implications for urban green infrastructure. Findings indicate that green areas, including parks, urban forests, green corridors, and green roofs, serve as multifunctional urban systems that provide carbon sequestration, heat island mitigation, ecosystem services, and social benefits. The law's just transition and climate justice provisions reinforce the importance of accessibility, equitable distribution, and prioritization for vulnerable populations, integrating social inclusivity into urban climate strategies. However, the analysis reveals a limited direct legal integration between the Climate Law and existing spatial planning regulations, rendering its impact primarily guiding rather than binding. To fully realize the law's objectives, local governments must proactively incorporate urban green infrastructure into municipal plans, climate action strategies, and development projects. Strengthening this integration would enhance Türkiye's ability to achieve net-zero emissions while simultaneously improving urban resilience, social equity, and quality of life.

Keywords: Türkiye's Climate Law, urban green spaces, urban landscapes.

Introduction

Cities today function both as principal drivers of climate change and as spatial units most adversely affected by its impacts. Factors such as increasing population density, fossil fuel consumption, rising energy demand, and the expansion of impervious surfaces elevate greenhouse gas emissions in urban areas and disrupt local climate systems, thereby intensifying the urban heat island effect (Gill et al., 2007; IPCC, 2022). This process directly affects not only the ecological balance but also the social, economic, and public health dimensions of urban life (Carter et al., 2015). In particular, rising global temperatures, the increasing frequency of extreme weather events, and the depletion of water resources weaken the resilience capacity of urban ecosystems (Bowler et al., 2010; Báthoryné Nagy, 2024).

In this context, urban open and green spaces emerge as critical ecological components for climate change adaptation and mitigation. By providing multifunctional ecosystem services-such as carbon sequestration, stormwater retention, air quality improvement, and the conservation of biodiversity-these areas enhance the climate resilience of cities (Nowak et al., 2013; Corgo et al., 2024). Research demonstrates that urban forests, park systems, green roofs, and permeable surfaces regulate microclimates by reducing the urban heat island effect,

lowering energy demand, and increasing carbon storage capacity (Elmqvist et al., 2015; Wamsler et al., 2016; Seidu et al., 2025; Sheng et al., 2025). Additionally, when evaluated within the framework of nature-based solutions, green infrastructure planning is regarded as one of the fundamental instruments for sustainable adaptation in urban areas (Kabisch et al., 2017; Raymond et al., 2017).

In Türkiye, the Climate Law (No. 7552), which entered into force in 2025, represents a significant milestone in establishing a comprehensive national legal framework for combating climate change. The law incorporates principles aimed at strengthening ecosystem-based approaches, increasing carbon sink capacity, promoting the sustainable management of natural resources, and institutionalizing climate adaptation policies (Official Gazette, 2025). Within this scope, open and green spaces are regarded as strategic components due to their carbon storage potential, their role in reducing the urban heat island effect, their contribution to the continuity of ecosystem services, and their importance for biodiversity conservation (Khalili et al., 2024).

The aim of this study is to examine the explicit and implicit references to urban open and green spaces within the framework of the Türkiye Climate Law and to evaluate the institutional and spatial interactions of these areas with the law's goals and strategies. The study also provides assessments of how green infrastructure planning, nature-based solutions, and urban ecosystem management can be more effectively integrated into legal and institutional frameworks in order to enhance the law's effectiveness. In doing so, it offers a perspective that supports ecological sustainability and the development of climate-responsive urbanization policies.

Materials and Methods

This study aims to reveal possible events in the planning and design of light green modules presented by the Climate Law No. 7552, adopted on 9/7/2025. The primary material of the research consists of the text of the Law as published in the Official Gazette. By analyzing the Law's objectives, principles, and implementation provisions, direct and indirect references related to green spaces and ecological planning were identified. Additionally, national policy documents such as the Zoning Law No. 3194 (1985) (Official Gazette, 1985) and the Regulation on Spatial Plans (2014) (Official Gazette, 2014) were reviewed as supporting sources. The study employs documentary analysis and qualitative content analysis methods (Bowen, 2009). The texts were examined with the focus on the keywords "climate adaptation", "green infrastructure", "nature-based approach" and "ecosystem services". The findings were then compared with existing planning legislation to interpret the potential implications of the Climate Law for green space management.

Findings and Discussion

The Türkiye Climate Law (No. 7552) is a fundamental regulation that codifies the country's net-zero emissions target and establishes a legal framework for climate change mitigation and adaptation policies (Official Gazette, 2025). Although the law does not explicitly use the term 'urban open-green space,' it provides a supportive framework for the ecological, economic, and social value of such areas through concepts such as 'sink areas,' 'sustainable management,' 'green growth,' 'climate adaptation,' and 'climate justice.' Examining the provisions that indirectly reference these areas offers strategic insights for local governments and urban planners:

Article 1 – Purpose: Article 1 of the Law aims to address climate change in line with the vision of green growth and the national net-zero emissions targets. This provision offers a strategic framework for urban open and green spaces. Parks, urban forests, green belts, and ecological corridors directly contribute to carbon sequestration, the mitigation of the urban heat island effect, and the maintenance of ecosystem services (Bowler et al., 2010; Khalili et al., 2024). Although Article 1 does not legally define the presence of open and green spaces, it situates them within climate policy, thereby providing guidance at the higher policy level.

Article 2 – Definitions (Mitigation and Sink Areas): Article 2 of the Law specifies, within the scope of mitigation, the protection, enhancement, and improvement of sink areas. In this context, urban green spaces—such as parks, green roofs, and afforested corridors—function as carbon sink areas. This provision offers legal support for making green spaces a mandatory component of climate action plans developed by local governments (Bolund & Hunhammar, 1999; Costanza et al., 2017).

Article 2 – Definitions (Just Transition and Climate Justice): When considered together, the definitions of just transition and climate justice in Article 2 of the Law indicate that climate policies should be grounded not only in environmental sustainability but also in principles of social equity, economic transformation, and spatial justice. These two concepts provide a holistic framework for the planning of urban open and green spaces. Urban green areas function as multifunctional urban systems that embody both the socio-economic objectives of just transition and the spatial requirements of climate justice. The principle of just transition envisions a shift toward a low-carbon and green economy that includes, rather than excludes, vulnerable groups (women, children, the elderly, persons with disabilities, and low-income communities) (McCauley & Heffron, 2018). In this context, urban open and green spaces are not only tools for environmental improvement but also spaces where social benefits—such as employment generation, social cohesion, and enhanced public welfare—are realized (Newell & Mulvaney, 2013). Green infrastructure investments—such as park rehabilitation, urban afforestation, and ecological corridor projects—simultaneously support climate adaptation and social inclusivity, thereby strengthening the spatial dimension of just transition (IPCC, 2022).

Meanwhile, the principle of climate justice aims to ensure that environmental risks caused by climate change, as well as the solutions developed to address these risks, are distributed equitably across societal groups. Within this framework, the accessibility and spatial distribution of urban open and green spaces are of critical importance. Inequities in access to green areas represent a visible form of environmental and social injustice and increase the climatic vulnerability of cities (Kabisch & Haase, 2014; Anguelovski et al., 2020). Conversely, balanced and equitably planned green infrastructure systems reduce climate disparities among urban residents by mitigating the urban heat island effect and distributing ecosystem services fairly (Wolch et al., 2014; Shi et al., 2016). The approach reflected in the definitions of just transition and climate justice in Article 2 establishes a foundation for a climate response that is not only technical but also socially equitable and comprehensive.

Article 6 – Sustainable Management of Sink Areas: This article provides a critical provision for the sustainable management of sink areas established outside of forests, thereby strengthening the legal status of urban open spaces. Urban forests, recreational green areas, and green belts acquire the function of sink areas under this article, creating an obligation for local governments to manage these areas sustainably. Consequently, Article 6 ensures the protection of urban

ecological infrastructure and its management in alignment with climate targets (Wamsler et al., 2016; An & Dedekorkut-Howes, 2025).

Article 7 – Integration in Plans, Programs, and Strategies: Article 7 of the Türkiye Climate Law (No. 7552) stipulates that institutions and organizations must consider the vision of green growth and net-zero emission targets in the development of their plans, programs, and strategies. At the urban scale, this article functions as a policy directive requiring that green space planning be integrated with principles of carbon balance and landscape ecology. Although the term 'plan' is general and does not explicitly refer to binding spatial plans under the Zoning Law or the Regulation on Spatial Plans, the content of the article offers broader potential for integration between urban open and green spaces and planning processes. Accordingly, this provision provides a significant framework for strategic guidance and planning coherence regarding urban open and green spaces:

- *Integration of Urban Green Infrastructure into Planning Documents:* Article 7 mandates that climate objectives be considered in plans and strategies developed at both national and local levels. This approach emphasizes that urban open spaces should be regarded not only for their aesthetic or recreational values but also as elements of ecological infrastructure due to their climate-related functions, including carbon sequestration, biodiversity conservation, and mitigation of the urban heat island effect (Gill et al., 2007; Khalili et al., 2024).
- *Functional Integration of Green Spaces:* Article 7 promotes the integration of green spaces with urban ecosystem services. In this context, planning parks and groves in relation to population density, air quality, and water management, as well as incorporating green roofs, vertical gardens, and ecological corridors into the planning process, aligns with the green growth vision envisaged by the article (Raymond et al., 2017; Sheng et al., 2025).
- *Planning and Adaptation Obligation:* Although the phrase "shall be considered" does not carry direct binding authority, it exerts a strong guiding influence. This places a responsibility on local governments to integrate urban open and green spaces into planning decisions in accordance with climate adaptation strategies, carbon reduction targets, and principles of ecological resilience (Wamsler et al., 2016; An & Dedekorkut-Howes, 2025).
- *Spatial Planning Perspective and the Role of Local Governments:* While Article 7 does not explicitly reference master or implementation plans, it can be interpreted as a guiding principle in terms of urban and landscape planning. The article encourages municipalities to take initiative in strategic planning and decision-making processes, develop projects that increase the quantity of urban open spaces, design green infrastructure based on ecological planning principles, and transform the urban fabric in alignment with climate objectives (Sevinçli, 2025).

Articles 9 and 10 – Climate Adaptation Planning and Local Governments: These articles establish the responsibility of local governments to develop climate adaptation plans. Municipalities can devise strategies to increase the quantity of urban green spaces, mitigate the urban heat island effect, and strengthen carbon sink networks. These provisions position urban open and green spaces as the physical and functional infrastructure of climate action at the local level (Raymond et al., 2017; Sheng et al., 2025). This regulation provides a guiding framework for integrating urban open and green spaces into climate adaptation policies through spatial planning instruments and contributes to the development of an ecological planning vision at the local level.

When examining the integration between the Law and the country's spatial planning legislation, the following observations can be made:

The concept of 'plans, programs, and strategies' in Article 7 stipulates that institutions and organizations must take into account the vision of green growth and net-zero emission targets in the policy documents they prepare. However, this provision does not establish a direct connection with the Zoning Law No. 3194, the Regulation on Spatial Plans, or municipalities' master and implementation zoning plans. Therefore, the effect of Article 7 remains primarily advisory and guiding, without binding authority over local zoning processes, planning decisions, or implementation practices (Sevinçli, 2025). This situation provides local governments with broad discretion in planning and managing urban open and green spaces in alignment with climate policies. Indeed, legal and institutional analyses of urban green infrastructure and nature-based solutions in Türkiye support this observation. Tuğaç (2023) emphasizes that urban infrastructure policies do not demonstrate full coherence at the legislative and implementation levels, and that local green infrastructure practices are not entirely aligned with existing legislation. Within this framework, while Article 7 of the Climate Law provides significant strategic guidance, it highlights the need to strengthen institutional and legal mechanisms for its integration into the spatial planning system.

Similarly, Article 6 regulates the 'sustainable management of sink areas established outside forests.' This provision allows elements such as urban forests, green belts, and recreational green spaces to be recognized as carbon sink areas. However, this article does not provide explicit or detailed guidance for mandating the identification of such sink areas in local zoning or master/implementation plans, nor does it link them directly to planning decisions. Consequently, the systematic integration of green spaces into planning processes largely depends on the capacity and implementation willingness of local governments at the regional level.

The effectiveness of climate legislation relies on addressing green infrastructure plans and nature-based solutions in an integrated manner through legal and institutional mechanisms. As frequently emphasized in the literature, the success of climate policies largely depends on the effective integration of these elements into local governments' spatial planning processes. Such integration not only supports environmental sustainability but also forms the foundation for a holistic planning approach that enhances urban climate resilience, strengthens ecosystem services, and supports carbon reduction targets (Benedict & McMahon, 2006; Kabisch et al., 2017; Raymond et al., 2017; Demiroğlu et al., 2019; Khalili et al., 2024; Li & Carter, 2025).

When the study's findings are evaluated holistically, it can be concluded that the law provides a framework supporting the importance of urban open and green spaces in climate change mitigation and adaptation policies. However, this framework is primarily guiding and strategic rather than establishing a direct and binding integration with spatial planning processes. Therefore, the effective reflection of provisions regarding urban open and green spaces in planning decisions largely depends on local governments' technical and administrative capacity, municipal council decisions, and the scope of implementation regulations. This indicates that the local applicability of the policy objectives set forth by the law is closely linked to the interaction between institutional capacity, planning practice, and administrative will.

Conclusion and Recommendations

In conclusion, although Türkiye Climate Law (No. 7552) does not explicitly define urban open and green spaces, it indirectly underscores their strategic importance for climate change mitigation and adaptation policies. Through concepts such as 'just transition,' 'climate justice,' 'sink areas,' and 'green growth,' the law addresses the ecological, social, and economic functions of urban open and green spaces from a holistic perspective. Nevertheless, the lack of direct integration with existing spatial planning legislation (i.e., Zoning Law No. 3194 and the Regulation on Spatial Plans) limits the full realization of this potential in practice.

This indicates that the law's influence on urban planning processes remains primarily guiding rather than binding, serving as a strategic framework rather than a legal mandate. Within this context, local governments are expected to voluntarily integrate the principles and objectives defined in the Climate Law into planning documents. In particular, reflecting the carbon sequestration capacity, ecosystem services, and social justice dimensions of urban open and green spaces in municipal climate action plans, environmental plans, and master zoning plans constitutes a critical step toward achieving the law's objectives.

In this regard, defining urban green infrastructure as a functional component within planning documents would enhance the implementability of climate objectives while contributing to the promotion of spatial justice. Furthermore, in line with the principles of just transition and climate justice, prioritizing the accessibility, equitable distribution, and planning of green spaces for vulnerable groups provides a policy framework that supports social inclusivity.

In conclusion, the Türkiye Climate Law positions urban open and green spaces as a key instrument of climate policy; however, realizing this potential requires stronger integration with spatial planning legislation and implementation-oriented sub-regulations. Ensuring such integration would not only facilitate the achievement of Türkiye's net-zero emissions targets but also simultaneously strengthen the ecological resilience, social equity, and overall quality of life in urban areas.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

An, S., & Dedekorkut-Howes, A. (2025). A Review of Adaptation Strategies to Increased Urban Temperatures and Heat Island Effect. *Discover Cities*, 2(1), 1-21.

Anguelovski, I., Connolly, J. J., Masip, L., & Pearsall, H. (2018). Assessing green gentrification in historically disenfranchised neighborhoods: a longitudinal and spatial analysis of Barcelona. *Urban Geography*, *39*(3), 458-491.

Báthoryné Nagy, I. R. (2024). *Review of the Role of Urban Green Infrastructure on Climate Resiliency: A Focus on Heat Mitigation Modelling Scenario on the Microclimate and Building Scale.*Urban Science*, 8(4), 220.

Benedict, M. A., & McMahon, E. T. (2012). Green infrastructure: linking landscapes and communities. Island press.

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics*, 29(2), 293-301.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2), 27–40.

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, 97(3), 147–155.

Carter, J. G., Cavan, G., Connelly, A., Guy, S., Handley, J., & Kazmierczak, A. (2015). Climate change and the city: Building capacity for urban adaptation. Progress in Planning, 95, 1–66.

Corgo, J., Cruz, S. S., & Conceição, P. (2024). Nature-based solutions in spatial planning and policies for climate change adaptation: A literature review. *Ambio*, 53(11), 1599-1617.

Costanza, R., De Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., ... & Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go?*Ecosystem Services*, 28, 1-16.

Demiroğlu, D., Karadağ, A. A., & Cengiz, A. E. (2019). Türkiye'de yeşil alt yapı sisteminin uygulanabilirliği üzerine bir değerlendirme. *Peyzaj*, *1*(2), 12-21.

Elmqvist, T., Setälä, H., Handel, S. N., van der Ploeg, S., Aronson, J., Blignaut, J. N., ... & de Groot, R. (2015). Benefits of restoring ecosystem services in urban areas. Current opinion in environmental sustainability, 14, 101-108.

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. *Built Environment*, 33(1), 115–133.

Intergovernmental Panel on Climate Change (IPCC). (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the IPCC. Cambridge University Press.

Kabisch, N., & Haase, D. (2014). Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and urban planning*, 122, 129-139.

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice. *Springer Nature*.

Khalili, S., Kumar, P., & Jones, L. (2024). Evaluating the benefits of urban green infrastructure: Methods, indicators, and gaps. *Heliyon*,10(19).

Li, L., & Carter, J. (2025). Exploring the relationship between urban green infrastructure connectivity, size and multifunctionality: a systematic review. *Landscape Ecology*, 40(3), 61.

McCauley, D., & Heffron, R. (2018). Just transition: Integrating climate, energy and environmental justice. *Energy policy*, 119, 1-7.

Newell, P., & Mulvaney, D. (2013). The political economy of the 'just transition'. *The Geographical Journal*, 179 (2), 132-140.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*, 178, 229–236.

Official Gazette (1985, May 9). İmar Kanunu (Kanun No.3194). Sayı: 18749. Access Address (15.10.2025): https://www.resmigazete.gov.tr/

Official Gazette (2014, June 14). Mekânsal Planlar Yapım Yönetmeliği. Sayı: 29030. Access Address (15.10.2025): https://www.resmigazete.gov.tr/

Official Gazette (2025, July 9). Türkiye İklim Kanunu (Kanun No. 7552). Sayı: 32951. Access Address (15.10.2025): https://www.resmigazete.gov.tr/

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., ... & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy*, 77, 15–24.

Seidu, S., Chan, D. W., Edwards, D. J., & Owusu-Manu, D. G. (2025). A systematic review of green infrastructure and ecosystem-based technologies for climate resilience: development trends, research outlook and future projections. Environmental Research Letters.

Sevinçli, B. G. (2025) Türkiye'nin 7552 Sayılı İklim Kanunu: Kentler ile Yerel Yönetimlerin Rolü ve Sorumlulukları Üzerine Akademik Bir Değerlendirme. *Türkiye Siyaset Bilimi Dergisi*, 8(2), 129-142.

Sheng, L. S., Hao, Y. Y., Zhou, S. Q., Tan, B., Yuan, Q., Xu, D. F., & Zhao, B. (2025). Nature-based Solutions (NbS) in China: implementation and practice modes. *Environmental Research Communications*, 7(5), 051002.

Shi, L., Chu, E., Anguelovski, I., Aylett, A., Debats, J., Goh, K., ... & VanDeveer, S. D. (2016). Roadmap towards justice in urban climate adaptation research. *Nature Climate Change*, *6*(2), 131-137.

Tuğaç, Ç. (2023). Evaluation of urban infrastructure policies in Türkiye for climate resilience and adaptation. *Sustainable and Resilient Infrastructure*, *8*(sup1), 190-202.

Wamsler, C., Luederitz, C., & Brink, E. (2014). Local levers for change: Mainstreaming ecosystem-based adaptation into municipal planning to foster sustainability transitions. *Global Environmental Change*, 29, 189-201.

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban planning*, *125*, 234-244.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Legal Vulnerability of Ecological Assets in The Post-Disaster Period in Türkiye

Aybike Ayfer KARADAĞ [1*]

ORCID 1: 0000-0002-7726-8756
[2] Prof. Dr., Düzce University, Faculty of Forestry, Department of Landscape Architecture, Düzce-Türkiye
ayferkaradag@duzce.edu.tr (Responsible Author)

Demet DEMİROĞLU [2]

ORCID 2: 0000-0002-3934-5319
[1] Prof. Dr., Kilis 7 Aralık University, Faculty of Agriculture, Department of Horticulture, Kilis- Türkiye
ddemiroglu@kilis.edu.tr

Abstract

The extraordinary speed and efficiency of the "reconstruction" processes prioritized following disasters pose a serious threat to the legal framework safeguarding Türkiye's most valuable natural assets. This study focuses on the intersection of Natural Resource and Environmental Protection Laws (including the Soil Conservation and Land Use Law, Forest Law, Pasture Law, Coastal Law, National Parks Law, and Environmental Law) and Disaster Management and Spatial Planning Laws (specifically the Law on the Transformation of Areas under Disaster Risk and the Law on Measures and Aid to be Provided Due to Disasters Affecting Public Life). Our primary objective is to thoroughly examine, from a landscape architecture perspective, how concepts such as "public interest", "urgency", "exception" and "reserve area" intensify the pressure on ecological assets and create new legal vulnerabilities by rendering conservation law dysfunctional. The findings reveal that the post-disaster legal effect is primarily shaped by the principles of "centralization, exception, and urgency". Based on these findings, recommendations have been developed to mitigate legal fragility.

Keywords: Legal vulnerabilities, law in ecological protection, protection of natural assets, Türkiye.

1. Introduction

Natural and anthropogenic disasters constitute an ancient reality that the modern world is constantly tested by and which inflicts profound wounds. Each year, geological tensions accumulating beneath the Earth's seemingly unshakeable crust are unleashed through major earthquakes. Simultaneously, meteorological storms accelerated by climate change lead to floods and droughts, threatening ecosystems and the livelihoods of billions of people. These devastating events do not merely result in immediate loss of life and hundreds of billions of dollars in economic ruin; they also collapse healthcare systems, deepen social inequalities, and displace millions, ultimately evolving into chronic social crises that severely test the limits of human resilience. The true impact of disasters lies beyond the collapsed buildings, leaving behind a global legacy of instability and uncertainty that effectively holds the development potential of future generations hostage.

A disaster is the general term given to the consequences of events that cause large-scale physical, social, economic, cultural, and environmental damage to a society and significantly disrupt the flow of daily life. Such events create a crisis so profound that the affected region is incapable of coping with its own local facilities and resources. Therefore, disasters are defined as situations requiring a specialized crisis management approach and external support (Kadıoğlu, 2011). Disasters are generally categorized into three main groups based on their causes: Natural disasters (natural events such as earthquakes, floods, avalanches, tornadoes, and volcanic eruptions), Technological disasters (those resulting from human-made system failures such as nuclear or chemical accidents and dam failures), and Human-Caused disasters

(large-scale crises stemming from direct human actions or negligence, such as social unrest, major building collapses, or acid rain) (Kadıoğlu, 2008).

Global disaster data for 2023, when compared to the 2003-2022 period averages, reveals significant dynamic shifts in the frequency and impact area of natural disasters. In terms of frequency of occurrence, floods, storms, and earthquakes were the most prevalent disaster types. However, a noticeable increase in the number of storm events (from 104 to 139) and earthquake events (from 27 to 32) during this period suggests that atmospheric and tectonic risks pose a growing global threat. Parallel to this increase, the dramatic rise in fatalities observed across earthquake, storm, and flood categories indicates an increase in the average lethality of disasters. Specifically, the rise in earthquake deaths from 35,124 to 62,451 and in storm deaths from 10,017 to 14,668 underscores the critical importance of robust risk reduction and early warning systems.

In terms of the number of people affected, there was a significant decrease compared to the previous period for those impacted by floods (from 74.6 million to 32.4 million) and droughts (from 57.1 million to 21.8 million). This reduction might be attributed to the partial success of adaptation strategies implemented against climate variability or a change in the geographical distribution of events. However, the surge in the number of people affected by earthquakes from 5.6 million to 20.2 million during the same period suggests that major tectonic events in 2023 were concentrated in highly populated or infrastructurally vulnerable regions.

The examination of economic losses confirms the increasing global economic risk, as costs rose across all storm, earthquake, and drought disaster types. The increase in storm-related losses from $95.6 billion to $100.8 billion, earthquake losses from $39.9 billion to $51.9 billion, and drought losses from $9.6 billion to $22.1 billion demonstrates that the interactions between urbanization, asset concentration, and the climate crisis are heightening the pressure on the insurance and reinsurance sectors. The concentration of the most affected populations in 2023 in countries such as Indonesia, India, and Türkiye highlights the high vulnerability of these regions to specific disaster types. The fact that 18.8 million people in Indonesia were affected by drought, 10.2 million people in India by floods, and 9.2 million people in Türkiye by earthquakes proves the necessity of specialized national disaster risk management strategies based on regional hazard profiles (hydro-meteorological or geological) (Senir, 2024).

An examination of disaster events occurring in Türkiye between 1900 and 2022 reveals that disaster frequency varies by year. The highest number of disasters during this period was recorded between 1996-2008 and 2008-2020, followed by the 1984-1996 period. The total number of disasters (1900-2022) was 376, of which 206 were natural in origin and 170 were technological. This data clearly demonstrates that Türkiye confronts a wide and complex spectrum of risks (Usta, 2023). According to published statistics, a total of 29,503 events occurred in Türkiye in 2024, including 8,058 natural disasters, 3,976 human/technology-related incidents, and 17,469 other events (such as being trapped, lost, etc.). When 205 natural disasters that occurred in Türkiye between 1900 and 2021 were examined, it was determined that a total of 97,086 people lost their lives and 9,787,122 people were directly affected as a result of these catastrophes (Şahan, 2024).

2. Materials and Methods

This study aims to reveal the legal vulnerabilities arising from the interaction between the Natural Resources and Environmental Protection Laws-which include the "*Law on Soil*

Conservation and Land Use (No. 5403), Forestry Law (No. 6831), Pasture Law (No. 4342), Coastal Law (No. 3621), National Parks Law (No. 2873), and Environmental Law (No. 2872)"- and the Disaster Management and Spatial Planning Laws-which include the "Law on the Transformation of Areas Under Disaster Risk (No. 6306) and the Law on Measures and Aid to be Taken Due to Disasters Affecting Public Life (No. 7269)".

All legal texts subjected to examination were downloaded from the database of the T.R. Presidency Legislation Information System (www.mevzuat.gov.tr). To ensure the currency of the analysis, all texts were included in the dataset in their latest updated versions effective as of 14.11.2025.

The research employed a qualitative content analysis method. From a landscape architecture perspective, a deductive approach was used to examine key concepts-such as "public interest", "urgency", "urgent expropriation", "exception", and "risky/reserve area"-that increase pressure on ecological assets/natural resources, thereby weakening conservation efforts and creating legal vulnerability. The resulting findings were interpreted through comparison against the backdrop of ecological sensitivities.

3. Finding

The protection objectives of the laws evaluated within the scope of the study are given below.

- Soil Conservation and Land Use Law: The primary objective of this Law is the protection and enhancement of soil. It also aims to determine the procedures and principles for the classification of agricultural lands, the designation of their minimum and financially sufficient sizes, the prevention of their subdivision, and their planned use in accordance with the principle of environmentally-prioritized sustainable development (Soil Conservation and Land Use Law, 2005).

- Forest Law: The fundamental purpose of the Forest Law is to ensure the continuity of forest assets within the borders of the Republic of Türkiye. In line with this purpose, the Law establishes the principles for the conservation, improvement, and sustainable management of forests (Forest Law, 1956).

- Pasture Law: The objective of the Pasture Law is to ensure the identification, delimitation, and subsequent allocation of all grazing areas (pastures, summer pastures, wintering grounds, meadows, and rangelands) designated by various laws or traditionally used, assigning them to the relevant village or municipality. Furthermore, the Law regulates the proper use of these areas, their improvement to enhance productivity, continuous supervision, conservation, and, when necessary, the procedures for changing their designated use (Pasture Law, 1998).

- Coastal Law: The Coastal Law aims to preserve the natural and cultural characteristics of the coasts of seas, lakes, and rivers, along with their connected coastal strips, and to determine the principles for the use of these areas in a manner that allows the public to benefit freely, while observing the public interest (Coastal Law, 1990).

- National Parks Law: The purpose of the National Parks Law is to establish the principles that ensure the identification of globally and nationally significant nature conservation areas (such as national parks, nature parks, nature monuments, and nature protection areas) in Türkiye, their preservation without alteration of their unique characteristics, and their development and management.

- Environmental Law: The Environmental Law aims to ensure the protection of the environment, which is the common heritage of all living beings, in line with the principles of sustainable environment and development. This legal regulation also covers the procedures for managing hazardous and debris waste generated, especially after major disasters, without causing harm to the environment (Environmental Law, 1983).

The objectives of the laws examined under the basis of disaster management and spatial planning that impact conservation processes are presented below:

- Law on the Transformation of Areas under Disaster Risk: The objective of this Law is to determine the principles for transformation, liquidation, and renewal processes to create safe and healthy living spaces in compliance with scientific and technical standards, both in regions posing a disaster risk and in areas outside these regions containing risky structures (Law on the Transformation of Areas under Disaster Risk, 2012).

- Law on Measures to be Taken and Aid to be Provided Due to Disasters Affecting Public Life: This Law provides the necessary legal basis for all processes carried out immediately following a disaster, including emergency response, rescue operations, temporary and permanent sheltering, and the overall re-establishment of life (Law on Measures to be Taken and Aid to be Provided Due to Disasters Affecting Public Life, 1959).

When the relevant laws were analyzed through qualitative content analysis based on the provisions concerning “public interest”, “urgency”, “urgent expropriation”, “exception clauses”, and “risky/reserve area”, the mechanisms introduced by the disaster laws were found to erode conservation law under three main themes. The post-disaster legal impact has been primarily shaped by "centralization, exception, and urgency.

a) Centralization (Central Authority Use in Disaster Laws): Centralization manifests as the transfer of planning authority from local governments directly to the central administration, consequently weakening local control mechanisms.

- Transfer of Planning Authority to the Central Administration: Post-disaster reconstruction laws largely consolidate the power of implementation within the central administration (specifically, the Ministry of Environment, Urbanization and Climate Change). This effectively transfers the authority granted by the Metropolitan Municipality Law and the Municipality Law to the central authority.
- Weakening of Local Control: Centralization removes the planning process for ecologically significant assets such as forests, agricultural lands, and pastures from the jurisdiction and control of institutions responsible for their protection (such as the General Directorate of Forestry, the Ministry of Agriculture and Forestry, etc.). Instead, this authority is shifted to the central administration, resulting in a weakening of local oversight.

The consolidation of planning and site selection decisions within the central administration weakens the institutional resistance and local control mechanisms established by laws protecting forests, agriculture, pastures, and coasts. This consequently increases the risk that the principle of protecting ecological assets will be overlooked.

b) Exception (Exemptions to Ecological Protection Provisions): The term “Ecological Protection” serves as the core pillar of legal texts, promising to carry nature, forests, agricultural lands, and coasts into the future. However, a closer examination of the legal provisions that safeguard Türkiye’s most critical natural assets reveals a dangerous opening behind this rigid shield of protection-a door that threatens the integrity of ecosystems and is often justified by

powerful reasons like “public interest” and “urgency”: The Exceptions. The situations that lead to exceptions in the conservation process are detailed below.

- Forest Law Additional Article 13 (2012): This provision introduces an exception to the fundamental conservation principle of forests, based on disaster and social need. It allows the use of forested areas, first in urban centers and their immediate surroundings, and subsequently for temporary sheltering. At this point, the provision permits the introduction of infrastructure services, thereby enabling structural changes. This authority is exercised by the General Directorate of Forestry (OGM) or other administrations (local or central) deemed appropriate by the central administration. This situation creates pressure for permanent construction and devastation on forest ecosystems, justified by “public interest” and “urgency” grounds.

- Soil Conservation and Land Use Law, Article 13(b): The clause concerning the "need for temporary settlement areas arising after a natural disaster" is an exception provision that bypasses the strict conservation rules on the most productive agricultural lands by prioritizing public interest and disaster urgency. It permits these lands to be rapidly opened up for development. Although applications for such projects are reviewed by the relevant Provincial Soil Conservation Boards, the final and most critical decision-making authority rests with the Ministry of Agriculture and Forestry.

- Pasture Law, Article 14(g): The clause concerning the “need for settlement areas in natural disaster zones” can prioritize the urgent post-disaster settlement requirement over the primary intended use of pastures, which is livestock farming. The relevant article allows the purpose of use of pasture-qualified lands to be changed for the establishment of new settlements, whether permanent or temporary.

- Coastal Law: The Law (including Articles 1, 2, 5, 6, and 7) provides a legal framework and basis for the utilization and planning of coasts, and for carrying out all types of structural activities such as infilling, ports, piers, and fishing shelters, despite the Law’s fundamental conservation provisions. These activities are usually legitimized by obtaining a “public interest” decision. In this context, Article 1 establishes the basic principle regarding public interest, Article 2 dictates the conditions of use, Article 5 functions as the door to exceptions, and Articles 6 and 7 establish the planning effect.

- National Parks Law: Due to its core philosophy prioritizing conservation, this Law has a more restricted structure compared to others regarding exceptions that permit construction based on “public interest” or disaster. Any measure taken in park areas to prevent the potential consequences of disasters must comply with the park's main management plan. The priority here is the conservation of the natural ecosystem as much as human safety. However, the centralized structure and indirect provisions of the law can be associated with these concepts.

- Environmental Law: Within the Environmental Law, “public interest” represents a superior principle embodying the right to a healthy and clean environment. “Disaster” is a critical area of application where the inspection authority of this Law intersects with other disaster laws, specifically in the fields of post-disaster environmental risk management and pollution control.

Disaster laws create a normative conflict by introducing exceptional provisions against special protection laws that prohibit the misuse of ecological assets. Disaster laws pose the risk of forested areas being declared “Reserve Construction Areas”; agricultural lands being subject to exceptional provisions and opened to development due to their need for settlement and infrastructure; pastures being rapidly relegated to development status due to the overriding

public interest; and coastal areas being breached through the exception mechanism in infrastructure and reconstruction projects.

c) Urgency (Acceleration of Legal Processes): The inherently rapid pace of post-disaster reconstruction processes often results in the bypassing of detailed scientific procedures required by environmental conservation laws. This is because the accelerated procedures for the prompt identification of risky structures under the Law on the Transformation of Areas under Disaster Risk and the fast-tracked planning and implementation processes mandated by the Law on Measures to be Taken and Aid to be Provided Due to Disasters Affecting Public Life concentrate the decision-making mechanism around the concepts of "public interest" and “urgency” rather than scientific data.

The principle of "urgency" functions as a tool to accelerate and bypass legal processes, planning, and environmental assessments that would normally be lengthy. Urgency drives the process through urgent expropriation and the shortening of legal timelines, as disaster situations necessitate immediate measures and rapid implementation.

In contrast, conservation laws such as the Soil Conservation and Land Use Law, the Forest Law, and others, mandate long-term, scientifically-based study and assessment processes. Consequently, the urgency embedded in disaster laws renders the scientific planning, impact assessment, and detailed permitting processes envisaged by conservation laws impossible to implement. This situation legally weakens the protection of ecological assets. Furthermore, it either makes the application of processes like Environmental Impact Assessment (EIA) impossible or superficial. Accelerated administrative actions (such as the declaration of a risky area/reserve building area, and zoning plan changes) narrow the periods for objection and litigation or increase the risk of rendering judicial review ineffective by implementing decisions directly.

As a result, the scientific and legal control mechanisms vital for the conservation of ecological assets are rendered ineffective when confronted with the principle of urgency.

4. Conclusion and Recommendations

The mechanisms of centralization, exception, and urgency introduced by post-disaster reconstruction laws (particularly the Law on the Transformation of Areas under Disaster Risk) carry the risk of rendering inoperative the absolute protection provisions within laws safeguarding the legal status of ecological assets. This situation demonstrates a tendency for the post-disaster goal of “safe reconstruction” to override the principle of “ecological sustainability”, thereby creating a serious area of legal vulnerability for Türkiye's ecological assets.

The ecological vulnerabilities are particularly concentrated in the following areas:

- Planning Authority: Transfer of power to the central administration and the weakening of local oversight.
- Ecological Allocation: Changes in the use designation of forest, agricultural, and pasture lands, and their opening up to development.
- Coastal Areas: Pressure for construction and development.
- Legal Processes: Bypassing of environmental assessment procedures and restriction of judicial review.

To address these legal vulnerabilities, recommendations are presented under three main themes, aimed at increasing the legal protection of ecological assets while maintaining the speed and efficiency of post-disaster processes:

Strengthening Local Oversight Against Centralization

- Authority Sharing and Coordination: In planning processes such as the declaration of Reserve and Risky Areas, mandatory approval and oversight by local governments and relevant expert institutions (Forestry, Agriculture, Waterworks) should be required, in addition to the central administration's authority. This measure will increase institutional resistance.

- Ecological Constraint Report: Before any post-disaster zoning plan changes, the submission of a report containing the area's ecological asset inventory and carrying capacity, approved by local governments and professional chambers, must be made mandatory. This will render scientific data binding for legal decisions.

- Ecological Disaster Management Unit: An interdisciplinary unit should be established within the relevant Ministry to monitor and oversee the long-term ecological impacts of post-disaster demolition and reconstruction processes.

Limiting Exception Clauses

- Categorical Conservation Priority: The special protection provisions of the Soil, Forest, Pasture, and Coastal Laws must be regulated to hold priority over disaster laws within the hierarchy of norms. Barriers against the use of highly protected areas, even as a "last resort", should be increased by mandating the selection of ecologically less sensitive areas for settlement location.

- Expansion of Absolute Protection Rule: The principle of "absolutely unsuitable" designation, currently applied to Drinking-Water Supply Basins, should be extended to the core protection zones of Absolute Agricultural Lands, Forest Ecotopes, and Pastures/Wintering Grounds.

- Transparency and Compensation (Ecological Offset): The use of exception clauses must be publicly disclosed with scientific and socio-economic justifications. A condition should be imposed requiring the mandatory rehabilitation of an equivalent area at least twice the size of the destroyed ecological asset, or the declaration of a new protected area.

Subordinating Urgency to Legal Safeguards

- Accelerated Ecological Impact Assessment (AEIA): Instead of completely bypassing EIA processes due to post-disaster urgency, a brief, legally binding procedure that reviews fundamental ecological risks must be made mandatory.

- Enhancing Judicial Review: The swift and effective use of the injunction authority in lawsuits filed against post-disaster decisions must be ensured. Specialized administrative courts should be designated to guarantee the technical and rapid processing of judicial reviews.

- Ecological Constraint in Urgent Expropriation: The authority for urgent expropriation must be limited to prevent arbitrary use in first-priority protected ecological assets (Absolute Agriculture, Forest, Water Basins).

This comprehensive set of recommendations will ensure that ecological assets are brought under a comprehensive protection mechanism and their legal safeguards are enhanced, all while preserving the speed and efficiency required by post-disaster reconstruction.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

5. Resources

Afet Riski Altındaki Alanların Dönüştürülmesi Hakkında Kanun (Kanun No. 6306). (2012). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.6306.pdf] (14.11.2025)

Çevre Kanunu (Kanun No. 2872). (1983). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.2872.pdf] (14.11.2025)

Kadıoğlu, M. (2008). Bütünleşik afet yönetiminin temel ilkeleri. M. K. Özdamar (Ed.), *Afet zararlarını azaltmanın temel ilkeleri* içinde. JICA Türkiye Ofisi Yayını. (Not: Kitap bölümü için sayfa aralığı eklenmelidir.)

Kadıoğlu, M. (2011). *Afet yönetimi: Beklenilmeyeni beklemek, en kötüsünü yönetmek*. T.C. Marmara Belediyeler Birliği Yayını.

Kıyı Kanunu (Kanun No. 3621). (1990). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.3621.pdf] (14.11.2025)

Mera Kanunu (Kanun No. 4342). (1998). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.4342.pdf] (14.11.2025)

Milli Parklar Kanunu (Kanun No. 2873). (1983). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.2873.pdf] (14.11.2025)

Orman Kanunu (Kanun No. 6831). (1956). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.3.6831.pdf] (14.11.2025)

Senir, G. (2025). 2000–2024 Arası Em-Dat verilerine göre Türkiye ve Dünya'da doğal afetlerin karşılaştırmalı analizi. *Tarsus Üniversitesi Uygulamalı Bilimler Fakültesi Dergisi*, *5*(2), 91-105.

Şahan, C. (2024). Türkiye özelinde doğa kaynaklı afetlere yönelik bir araştırma. *Ordu Üniversitesi Sosyal Bilimler Enstitüsü Sosyal Bilimler Araştırmaları Dergisi, 14*(2), 414-428.

Toprak Koruma ve Arazi Kullanımı Kanunu (Kanun No. 5403). (2005). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address : https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5403.pdf] (14.11.2025)

Umumi Hayata Müessir Afetler Dolayısıyla Alınacak Tedbirlerle Yapılacak Yardımlara Dair Kanun (Kanun No. 7269). (1959). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. [Access Address: https://www.mevzuat.gov.tr/MevzuatMetin/1.3.7269.pdf] (14.11.2025)

Usta, G. (2023). Dünya'da meydana gelen afetlerin istatistiksel olarak analizi (1900-2022). *Gümüşhane Üniversitesi Sosyal Bilimler Dergisi*, *14*(1), 172-186.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Leadership, Communication, and Cognitive Skills as Drivers of Project Performance: Prioritizing Soft Skills in the Construction Industry

Greg Odee IKWE [1]*

ORCID 1: 0009-0006-6296-2266
[1]Bingham University, Faculty of Environmental Science, Department of Quantity Surveying
ikwegreg@gmail.com (Responsible Author)

Abstract

Project success depends not only on technical proficiency but also on a project manager's ability to mobilize people, coordinate diverse teams, and navigate uncertainty across the project life cycle. Although soft skills are increasingly recognized as essential competencies for project delivery, their phase-specific relevance remains insufficiently explored in construction research, particularly in developing countries. This study identifies the soft skills that most significantly influence project outcomes and determines how their importance varies across project phases. Drawing on data from 276 Nigerian construction practitioners and a two-round Delphi ranking exercise involving 11 senior experts, the study evaluates the prioritization of soft skills for initiation, planning, execution, and closure phases. Findings indicate that leadership and communication are indispensable during project initiation, fostering clarity, trust, and stakeholder alignment. Teamwork emerged as the dominant skill during execution due to high collaboration demands. Cognitive skills—though relatively underdeveloped among practitioners—were identified as the most critical for planning, scheduling, resource allocation, and risk management. Interpersonal and motivational skills, while positively rated, played mainly supportive roles. The study proposes a soft skill–life cycle alignment framework designed to guide training and competency development in the construction industry. The findings emphasize the transformative potential of strengthening soft skills to improve project outcomes, especially in developing contexts where human-related performance gaps persist.

Keywords: Leadership, communication, cognitive skills, project life cycle, construction project management

Introduction

Construction project management involves the integration of human, financial, and material resources to achieve project objectives under constraints of time, cost, and quality. Despite improvements in professional standards and digital technologies, the construction sector in developing economies continues to experience underperformance—manifesting as delays, cost overruns, quality deficiencies, and stakeholder dissatisfaction (Aibinu & Jagboro, 2002; Olaniran, 2015).

These recurring issues demonstrate that technical skills alone are inadequate for addressing dynamic project complexities. Soft skills—such as leadership, communication, teamwork, interpersonal competence, and cognitive reasoning—have gained increasing recognition as fundamental to project success. Because construction projects are highly collaborative, human-centered, and uncertainty-prone, the ability of project leaders to engage, influence, and coordinate people is crucial.

Despite this recognition, the literature provides limited empirical insight into how the importance of soft skills shifts across different project phases. This study addresses this gap by examining phase-specific soft skill needs for construction project success in Nigeria.

2.0 Literature Review

Soft skills comprise non-technical competencies enabling effective communication, leadership, team collaboration, problem-solving, and adaptability (Robles, 2012). In construction, they complement technical skills and enhance managerial effectiveness (Crawford, 2005).

2.1 Soft Skills in Construction Management

- **Leadership** facilitates shared vision, team alignment, and strategic guidance (Müller & Turner, 2010).
- **Communication** ensures information clarity, stakeholder engagement, and conflict reduction.
- **Cognitive skills** enable analytical thinking, decision-making, and risk evaluation—critical for planning.
- **Teamwork** drives coordination and productivity in multidisciplinary project environments.

2.2 Soft Skills and the Project Life Cycle

The project life cycle comprises initiation, planning, execution, and closure.

- **Initiation:** Leadership and communication are vital for establishing direction.
- **Planning:** Cognitive skills underpin problem-solving, scheduling, and resource allocation.
- **Execution:** Teamwork and communication support coordination and task interdependence.
- **Closure:** Interpersonal and communication skills facilitate handover, documentation, and evaluation.

Despite their importance, there is little empirical evidence on which skills matter most at each stage—particularly in developing construction industries. This study provides such evidence.

3. Methodology

3.1 Survey of Practitioners

A quantitative survey was administered using structured questionnaires:

- 360 questionnaires distributed
- 276 valid responses used for analysis (76.6% response rate)
- Respondents: project managers, engineers, architects, quantity surveyors, site supervisors

Competencies assessed using a 5-point Likert scale included:

1. Leadership
2. Communication
3. Teamwork
4. Interpersonal skills

5. Motivational skills
6. Cognitive skills
7. Conflict management

3.2 Delphi Expert Ranking

A Delphi panel comprising 11 senior construction professionals participated in two iterative rounds to:

- Rank soft skills by importance per project phase
- Reach consensus using ≥80% agreement threshold

3.3 Data Analysis

- Descriptive statistics
- Mean scores
- Correlation analysis (Pearson's r)
- Consensus tracking for Delphi responses

4. Results

4.1 Practitioner Soft Skill Proficiency

Table 1. Mean scores of soft skills among practitioners

Soft Skill	Mean Score	Interpretation
Leadership	4.32	High proficiency
Communication	4.28	High proficiency
Teamwork	4.19	Good proficiency
Interpersonal Skills	4.12	Good proficiency
Motivational Skills	4.03	Good proficiency
Cognitive Skills	3.76	Moderate proficiency
Conflict Management	3.68	Moderate proficiency

Practitioners recorded strong interpersonal attributes but comparatively lower cognitive competencies.

4.2 Phase-Specific Soft Skill Prioritization (Delphi Results)

Table 2. Soft Skills by Project Phase (Ranked by Experts)

Project Phase	Most Important Skill	2nd Most Important	3rd Most Important
Initiation	Leadership	Communication	Interpersonal skills
Planning	Cognitive skills	Leadership	Communication
Execution	Teamwork	Communication	Motivational skills
Closure	Communication	Interpersonal skills	Leadership

4.3 Correlation Between Soft Skills and Project Success

Table 3. Correlation Analysis Results

Soft Skill	Correlation with Project Success (r)
Leadership	0.69
Communication	0.66
Teamwork	0.64
Cognitive Skills	0.73
Interpersonal Skills	0.58
Motivational Skills	0.54

All correlations were statistically significant at **$p < 0.01$.**

5. Discussion

The results demonstrate that soft skills are not uniformly critical across project phases; instead, their importance is contingent on project demands.

Leadership & Communication

These skills dominate early project phases, ensuring:

- Clear objectives
- Stakeholder alignment
- Risk-awareness initiation

This supports findings by Clarke (2010) that emotional and leadership competencies drive early-stage clarity.

Cognitive Skills

Strongly correlated with project success ($r = 0.73$), cognitive skills:

- Support analytical decision-making
- Strengthen planning accuracy
- Reduce risk exposure

The moderate proficiency reported indicates a gap requiring targeted training.

Teamwork

Teamwork is most vital during execution due to:

- High coordination
- Multidisciplinary collaboration
- Task interdependence

Communication in Closure

Ensures:

- Clear reporting

- Smooth handover
- Stakeholder satisfaction

These findings align with the argument that communication influences overall project perception.

6. Conclusion

This study confirms that leadership, communication, teamwork, and cognitive skills significantly influence project performance, with their relative importance shifting across the project life cycle. Leadership and communication dominate initiation; cognitive skills drive planning; teamwork is most influential during execution; and communication is essential for closure.

Recommendations:

1. Develop phase-specific soft skill training programs.
2. Integrate soft skills into professional certification requirements.
3. Improve cognitive skill development in university curricula.
4. Use soft skill assessments in recruitment and project assignment.
5. Strengthen CPD initiatives focusing on leadership, communication, and teamwork.

Thanks and Information Note

The article complies with national and international research and publication ethics. This study complies with all national and international standards for research and publication ethics. Ethics Committee approval was not required, as the research involved non-sensitive questionnaire responses from adult professionals and did not include any personal or medical data. The author expresses sincere appreciation to the construction practitioners and expert panelists who participated in the survey and Delphi exercises. Their insights and professional contributions were instrumental to the success of this study. No external funding, grants, or financial sponsorship were received for this research. The study was conducted independently without influence from any organization or commercial entity. The author declares no conflict of interest. All contributions to the article were made by the sole author:

Author Contribution: Conceptualization, data collection, analysis, interpretation, and manuscript preparation: Greg Odee Ikwe (100%)

References

Aibinu, A. A., & Jagboro, G. O. (2002). The effects of construction delays on project delivery. *International Journal of Project Management*, 20(8), 593–599.

Clarke, N. (2010). Emotional intelligence and project manager competence. *Project Management Journal*, 41(2), 5–20.

Crawford, L. (2005). Senior management perceptions of project management competence. *International Journal of Project Management*, 23(1), 7–16.

Goleman, D. (1998). Working with Emotional Intelligence. Bantam Books.

Müller, R., & Turner, J. R. (2010). Leadership competency profiles of successful project managers. *International Journal of Project Management*, 28(5), 437–448.

Olaniran, O. J. (2015). Cost and time overruns in Nigerian projects. *African Journal of Applied Research,* 7(1), 173–180.

PMI (2021). Talent Triangle: Power Skills for Project Professionals.

Robles, M. M. (2012). Top 10 soft skills needed in today's workplace. *Business Communication Quarterly,* 75(4), 453–465.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

AI Tools in Architectural Design: Transforming Creativity, Efficiency, and Sustainability

Abhigyan GANGULY[1]

[1] Dept. of CSE-AI, Brainware University, Kolkata, India
adg.cseai@brainwareuniversity.ac.in

Sandipan BISWAS [2]

[2] Dept. of CSE-AI, Brainware University, Kolkata, India

Shivnath GHOSH [3]

[3] Dept. of CSE-AI, Brainware University, Kolkata, India

Nitai PAITYA [4]

[4] Amity University, Kolkata, India

Abstract

Artificial Intelligence (AI) has emerged as a transformative technology across industries, and architecture is no exception. The integration of AI tools in architectural design processes has redefined how architects conceptualize, simulate, and optimize the built environment. This paper reviews the evolution, applications, and challenges of AI in architectural design, emphasizing generative modeling, Building Information Modeling (BIM), environmental performance analysis, and smart construction workflows. It explores how machine learning (ML), deep learning (DL), and generative design algorithms enhance creativity, accelerate decision-making, and improve energy efficiency. Furthermore, it discusses the key software tools enabling this transformation—such as Autodesk Revit, Spacemaker AI, Finch 3D, Midjourney, and ClimateStudio—and examines the limitations and future trajectory of AI-driven architectural practice.

Keywords: *AI, ML, BIM, design, architecture*

I. Introduction

Architectural design has traditionally combined artistic intuition with engineering precision. However, the growing complexity of urban environments, sustainability requirements, and computational advancements have driven a shift toward data-informed and automated design processes. Artificial Intelligence (AI), encompassing techniques such as machine learning, deep learning, and generative algorithms, now plays a central role in optimizing design workflows [1], [2].

AI assists architects not only in visualizing conceptual ideas but also in simulating material performance, energy efficiency, and user behavior. Unlike conventional Computer-Aided Design (CAD) tools, AI systems can learn from data, recognize patterns, and propose alternative solutions based on defined objectives and constraints. This capability allows architects to explore a vast design space, reduce manual effort, and generate innovative, performance-driven outcomes [3].

The following sections examine the operational frameworks of AI in architecture, focusing on generative design, BIM automation, sustainability modeling, and construction optimization. The discussion integrates conceptual understanding with references to specific AI tools currently reshaping professional practice.

II. AI-Driven Design Workflow

The AI-driven architectural workflow can be divided into four primary phases: **concept generation, design optimization, environmental simulation,** and **construction management**.

1. **Concept Generation:** Generative design algorithms—powered by reinforcement learning and genetic optimization—enable the creation of multiple design alternatives based on input parameters such as site geometry, budget, daylight access, and spatial efficiency [4]. Autodesk's Generative Design and Spacemaker AI exemplify this approach, allowing architects to rapidly evaluate thousands of spatial configurations [5].

2. **Design Optimization:** Once preliminary concepts are established, AI tools refine geometry, materials, and spatial layouts through multi-objective optimization. Finch 3D, for example, adapts building forms in real time as parameters change, maintaining spatial logic while improving structural efficiency [6].

3. **Environmental Simulation:** Machine learning algorithms predict environmental performance, including daylight availability, solar gain, and ventilation efficiency. Tools such as ClimateStudio and Sefaira employ AI to automate thermal simulations and energy-use predictions, enabling sustainable design decisions at early stages [7].

4. **Construction and Lifecycle Management:** During execution, AI-powered systems like Buildots and nPlan use computer vision and predictive analytics to track construction progress, identify delays, and forecast risks [8]. Integration with BIM platforms allows real-time synchronization of physical and digital environments, creating a continuous feedback loop throughout the building lifecycle.

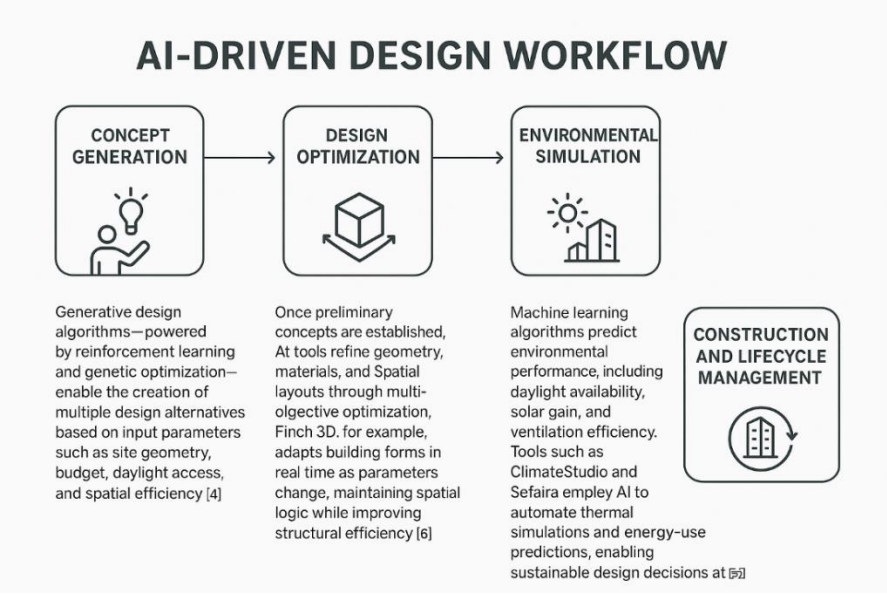


Fig. 1. AI-Driven Design Workflow

III. Key AI Tools and Techniques

AI in architecture operates through several computational paradigms—each addressing specific challenges across the design and construction continuum.

1. **Generative Design:** Generative design combines evolutionary algorithms with ML to create design options that optimize for performance metrics. Autodesk Generative Design and

Hypar allow users to specify constraints (e.g., daylight, energy use) and produce form alternatives evaluated through fitness functions [9].

2. **Machine Learning and Data Analytics:** ML models analyze historical data to identify design correlations and predict outcomes. In BIM, predictive ML tools automate clash detection, cost estimation, and scheduling. Revit's Dynamo scripts and Rhino's Grasshopper plugins increasingly incorporate ML modules for real-time analysis [10].

3. **Deep Learning and Visualization:** Deep learning models, particularly Convolutional Neural Networks (CNNs), enhance visual rendering and spatial recognition. Platforms like NVIDIA Omniverse and D5 Render utilize AI to produce photorealistic imagery faster than traditional rendering engines [11].

4. **AI-Enhanced Visualization Tools:** Midjourney, Stable Diffusion, and Runway ML facilitate conceptual visualization through text-to-image synthesis, bridging early-stage ideation and client communication [12].

5. **BIM and Digital Twin Integration:** AI-integrated BIM platforms generate predictive digital twins that simulate building performance in real time. These systems enhance facility management by predicting maintenance schedules and resource demands [13].

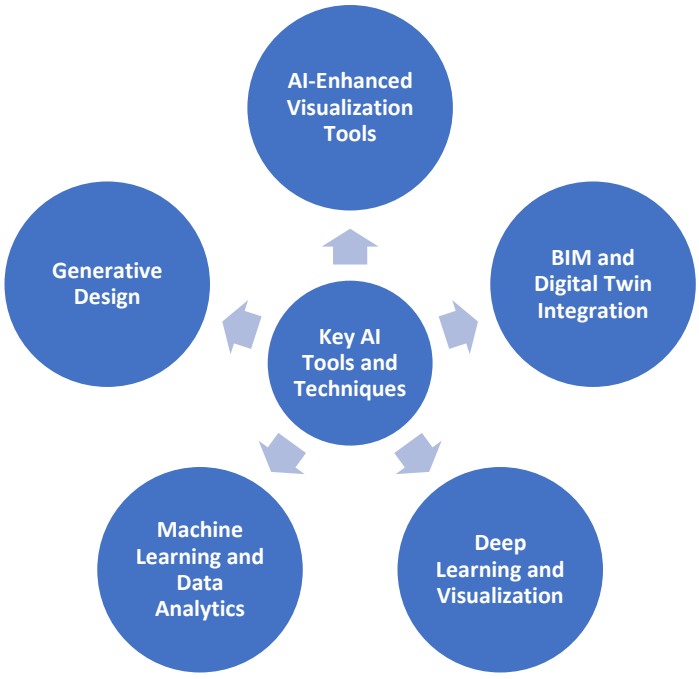


Fig 2. Key AI Tools and Techniques

IV. AI for Sustainability and Smart Design

Sustainability has become a defining priority in architectural practice, and AI is instrumental in achieving performance-driven environmental outcomes.

1. **Energy Optimization:** AI models assess the impact of orientation, shading, and façade materials on energy consumption. Tools like Cove.Tool and ClimateStudio use ML algorithms to optimize envelope design for passive heating and cooling [14].

2. **Material and Structural Efficiency:** Deep generative models are used to identify lightweight, high-strength material combinations. Reinforcement learning frameworks adapt material selection dynamically to minimize embodied carbon [15].

3. **Urban-Scale Applications:** At city scales, AI-driven simulation models predict microclimate effects, optimize traffic flow, and assess renewable energy potential. Spacemaker AI and Sidewalk Labs apply multi-agent systems to evaluate urban density and pedestrian comfort [16].

4. **Integration with Smart Cities and IoT:** AI-enhanced buildings can interface with Internet of Things (IoT) systems to monitor energy consumption, air quality, and occupancy patterns. Predictive analytics supports adaptive systems that optimize performance autonomously [17].

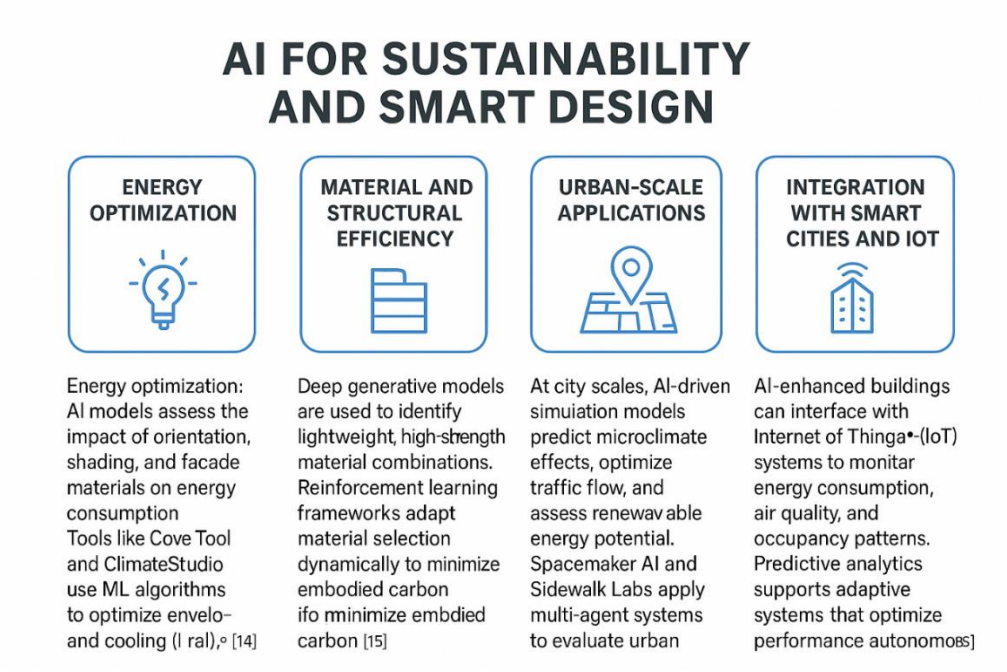


Fig 3. AI for Sustainability and Smart Design

V. Challenges and Limitations

Despite its transformative potential, the integration of AI into architecture faces several challenges:

- **Data Scarcity:** Architectural datasets are often small and proprietary, limiting model training and generalization [18].
- **Black-box Nature:** Deep models lack interpretability, raising ethical and accountability issues in design decisions [19].
- **Standardization and Compatibility:** Interoperability between AI tools and BIM platforms remains limited [20].
- **Overreliance on Automation:** Excessive algorithmic control may constrain human creativity, necessitating careful balance between automation and authorship [21].

- **Resource Intensity:** High computational costs and limited AI literacy in architecture firms pose barriers to widespread adoption [22].

VI. Future Directions

The next generation of AI-driven architectural design will prioritize **explainability, hybrid modeling, and autonomous optimization**.

- **Physics-Informed Machine Learning:** Combining AI with physical simulation models will yield hybrid systems capable of producing accurate, generalizable results with minimal data [23].
- **Explainable AI (XAI):** Transparent models will allow architects to understand how algorithms make design decisions, reinforcing trust and ethical accountability [24].
- **Self-Driving Design Systems:** Integration of AI with robotic fabrication and 3D printing could lead to self-evolving design-construction ecosystems [25].
- **Cloud-Based Collaboration:** AI-driven cloud platforms will enhance multidisciplinary collaboration across design, engineering, and construction domains [26].

VII. Conclusion

AI tools have fundamentally reshaped architectural practice, shifting the focus from manual drafting to intelligent, performance-driven design exploration. By combining data analytics, generative algorithms, and predictive modeling, AI empowers architects to create sustainable, efficient, and contextually adaptive environments. Although challenges in data standardization, interpretability, and resource management persist, the trajectory of AI in architecture is clear: a future of collaborative intelligence, where human creativity and machine computation converge to redefine the built environment.

Refereneces

1. Kallayil A, Patadiya J, Kandasubramanian B, Adamtsevich A, Kchaou M, Aldawood FK (2025) Adaptive Smart Materials in Architecture: Enhancing Durability and Sustainability in Modern Construction. ACS Omega

2.Nagy D et al (2017) Project discover: An application of generative design for architectural space planning. In Proceedings of the Symposium on Simulation for Architecture and Urban Design

3.Kudless A (2023) Hierarchies of bias in artificial intelligence architecture: collective, computational, and cognitive. Int J Architectural Comput 21(2):256–279

4.del Campo M, Manninger S, AI AND THE MORPHOLOGY OF THE CITY AI'S, DYNAMIC POWER IN SHAPING THE (2024). The Routledge Companion to Smart Design Thinking in Architecture & Urbanism for a Sustainable, Living Planet,: p. 86

5.Płoszaj-Mazurek M, Ryńska E, Grochulska-Salak M (2020) Methods to optimize carbon footprint of buildings in regenerative architectural design with the use of machine learning, convolutional neural network, and parametric design. Energies 13(20):5289

6.Valls F et al (2018) Urban data and urban design: A data mining approach to architecture education. Telematics Inform 35(4):1039–1052

7.Rumbarger J, Vitullo R (2003) Architectural graphic standards for residential construction: the architect's and builder's guide to design, planning, and construction details, vol 4. Wiley

8.Abreu S (2019) Automated architecture design for deep neural networks. ArXiv Preprint ArXiv:190810714

9.Ilvitskaya S, Prihodko V (2018) Innovative technologies in the field of topography, land management, territorial planning, construction and architecture. in IOP Conference Series: Materials Science and Engineering. IOP Publishing

10.Alyami M (2022) An approach to enhancing energy performance in residential buildings in hot climate regions: the case of Saudi Arabia. University of Nottingham

11.Asif M (2016) Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. Renew Sustain Energy Rev 55:1267–1273

12.Alnaser AA, Maxi M, Elmousalami H (2024) AI-Powered digital twins and internet of things for smart cities and sustainable Building environment. Appl Sci 14(24):12056

13.Kutty AA et al (2020) A system thinking approach for harmonizing smart and sustainable City initiatives with united nations sustainable development goals. Sustain Dev 28(5):1347–1365

14.Okeke FO (2021) Analysing the role of architects in achieving the sustainable cities goal by 2030. University-Led Knowledge and Innovation for Sustainable Development. Edited by F. A Anyogu, CA Eme, J. A Ogbodo published by Boldscholar Research Ltd. Abuja, Nigeria.:104– 12

15.Xu X, Mumford T, Zou PX (2021) Life-cycle Building information modelling (BIM) engaged framework for improving Building energy performance. Energy Build 231:110496

16.Lee J et al (2023) Simplified methods for generative design that combine evaluation techniques for automated conceptual Building design. Appl Sci 13(23):12856

17.Bölek B, Tutal O, Özbaşaran H (2023) A systematic review on artificial intelligence applications in architecture. J Des Resil Archit Plann 4(1):91–104

18.Meeran A, AI and, Architecture (2021) Image-Based machine learning for Early-Stage design conceptualisation. Singapore University of Technology and Design Singapore

19.Borglund C (2022) Artificial Intelligence in Architecture and its Impact on Design Creativity: A Study on how Artificial Intelligence Affect Creativity in the Design Process

20.Hunde BR, Woldeyohannes AD (2022) Future prospects of computer-aided design (CAD)–A review from the perspective of artificial intelligence (AI), extended reality, and 3D printing. Results Eng 14:100478

21.Newton D (2019) Generative deep learning in architectural design. Technology| Archit + Des 3(2):176–189

22. Allam Z, Dhunny ZA (2019) On big data, artificial intelligence and smart cities. Cities 89:80–91

23. Morales EF, Escalante HJ (2022) A brief introduction to supervised, unsupervised, and reinforcement learning. Biosignal processing and classification using computational learning and intelligence. Elsevier, pp 111–129

24. Berčič T, Bohanec M, Ažman L, Momirski (2024) Integrating multi-criteria decision models in smart urban planning: A case study of architectural and urban design competitions. Smart Cities 7(2):786–805

25. Arranz-Paraíso S, Arranz-Paraíso D (2024) Artificial Intelligence, Virtual Reality, and Augmented Reality to Enhance Visual Quality and Accessibility in Sustainable Built Environments. InDesign Strategies for Efficient and Sustainable Building Facilities. IGI Global, pp 179–199

26. Winfield AF, Jirotka M (2018) Ethical governance is essential to Building trust in robotics and artificial intelligence systems. Philosophical Trans Royal Soc A: Math Phys Eng Sci 376(2133):20180085

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Quantitative Effects of Soft Skills on Project Success: Evidence from Construction Practitioners in Nigeria

Greg Odee IKWE [1]*

ORCID 1: 0009-0006-6296-2266
[1]Bingham University Karu-Naarawa Nigeria, Faculty of Environmental Science, Department of Quantity Surveying
ikwegreg@gmail.com (Responsible Author)

Abstract

The construction industry continues to face cost overruns, project delays, rework, and client dissatisfaction, particularly in developing countries such as Nigeria. While technical skills remain essential, research increasingly highlights the critical role of soft skills—communication, leadership, teamwork, cognitive ability, interpersonal competence, and motivation—in achieving project success. However, empirical evidence on their quantitative contribution to project outcomes remains limited in developing contexts. This study examines the extent to which Nigerian construction practitioners possess soft skills and evaluates the impact of these competencies on project performance. A structured questionnaire survey was administered to 360 practitioners across different organizations, yielding 276 valid responses (76.6% response rate). In addition, a two-round Delphi exercise involving 11 project management experts was conducted to reach consensus on the most essential soft skills for effective project delivery. Data were analyzed using descriptive statistics, Mean Item Scores (MIS), ANOVA, and Pearson's correlation techniques. Results reveal that practitioners scored highest in interpersonal and motivational skills but significantly lower in cognitive abilities such as analytical reasoning and decision-making. Delphi ranking identified leadership, communication, and teamwork as the three most essential competencies throughout the project life cycle. Correlation analysis revealed a strong, positive, statistically significant relationship between soft skills and project success ($r = 0.67$, $p < 0.01$). Cognitive skills showed the strongest individual correlation with project outcomes ($r = 0.74$). The study concludes that soft skills are fundamental—not supplementary—to construction project success. It recommends integrating soft-skill capacity-building into professional development, accreditation programs, and organizational training frameworks.

Keywords: Soft skills, project success, leadership, communication, construction management, Nigeria

1. Introduction

Project success has traditionally been assessed using parameters such as cost, time, quality, and stakeholder satisfaction. Despite advancements in construction technology and project management tools, Nigerian construction projects continue to experience cost overruns, delays, and poor client satisfaction (Aibinu & Jagboro, 2002; Olaniran, 2015). These persistent challenges demonstrate the inadequacy of relying solely on technical competencies.

Soft skills—leadership, communication, teamwork, interpersonal skills, motivation, and cognitive abilities—have emerged as essential drivers of project performance. They influence team coordination, decision-making, conflict resolution, planning efficiency, and stakeholder engagement. However, their uptake and prioritization in Nigeria remain underreported. This study provides empirical evidence on soft skills and their direct contribution to project success among Nigerian construction professionals.

2. Literature Review

Soft skills refer to interpersonal, behavioural, and cognitive attributes that enable effective human interactions. According to PMI (2021), soft skills now constitute the *Power Skills* of modern project managers.

Key literature insights include:

- Leadership and communication are the most consistent predictors of project success (Crawford, 2005; Müller & Turner, 2010).
- Emotional intelligence, a component of soft skills, enhances team relationships and increases project success (Clarke, 2010; Rezvani et al., 2016).
- Cognitive skills, particularly analytical reasoning, have been linked with improved planning and execution quality.

In Nigeria, practitioners' emphasis remains largely on technical competencies, creating a skills gap in communication, leadership, and decision-making (Ameh & Odusami, 2010). This study contributes by quantifying this gap and establishing the importance of soft skills statistically.

3. Methodology

A quantitative survey design complemented with Delphi expert analysis was employed.

3.1 Questionnaire Survey

- 360 questionnaires distributed
- 276 valid responses (76.6% response rate)
- Respondents included: project managers, architects, engineers, quantity surveyors, and site supervisors
- Soft skills assessed using a 5-point Likert scale (1 = Very Low to 5 = Very High)

Seven soft skill categories were measured:

1. Leadership
2. Communication
3. Teamwork
4. Interpersonal skills
5. Motivational skills
6. Cognitive skills
7. Conflict management

3.2 Delphi Expert Survey

- 11 senior project management experts
- Two rounds of ranking
- Consensus threshold = 80% agreement
- Objective: prioritize soft skills based on importance to project success

3.3 Data Analysis

- Mean Item Score (MIS)
- Descriptive statistics
- ANOVA
- Pearson's correlation (significance level: $p < 0.01$)

4. Results

4.1 Mean Item Score (MIS) for Soft Skills

Table 1 presents the ranking of soft skills based on MIS:

Table 1: Mean Item Scores (MIS) for Soft Skills

Soft Skill	Mean Score	Rank
Leadership	4.31	1
Communication	4.26	2
Teamwork	4.18	3
Interpersonal Skills	4.11	4
Motivational Skills	4.05	5
Cognitive Skills	3.78	6
Conflict Management	3.64	7

Practitioners scored highest in leadership and communication but lowest in cognitive and conflict management skills.

4.2 Correlation Between Soft Skills and Project Success

Key correlation outcomes:

- Overall soft skills ↔ project success: $r = 0.67$ ($p < 0.01$)
- Cognitive skills showed the strongest individual correlation: $r = 0.74$
- Leadership correlated strongly with stakeholder satisfaction: $r = 0.69$

This demonstrates that practitioners with stronger soft skills consistently deliver better-performing projects.

4.3 Delphi Expert Ranking

Experts identified the following top soft skills:

Rank	**Soft Skill**
1	Leadership
2	Communication
3	Teamwork
4	Cognitive Skills
5	Interpersonal Skills
6	Motivational Skills
7	Conflict Management

5. Discussion

The results reinforce global findings that leadership and communication shape early project activities such as planning, team formation, and stakeholder engagement. The low cognitive skill rating among practitioners indicates gaps in analytical reasoning and decision-making capacity—a critical weakness in managing complex construction environments.

The strong correlation between cognitive skills and project outcomes highlights their importance in scheduling, cost estimation, risk management, and technical decision-making. The findings suggest that while practitioners exhibit strong interpersonal skills, they lack the analytical depth required for modern construction project management.

6. Conclusion

The study provides strong empirical evidence that soft skills significantly influence construction project success in Nigeria. Leadership, communication, and teamwork emerged as universally essential across project phases, while cognitive skills are the strongest statistical predictor of project performance.

Recommendations:

1. Integrate soft-skills training into professional licensing requirements.
2. Embed soft skills in university construction management curricula.
3. Develop organizational training focused on cognitive and decision-making skills.
4. Use soft-skill competency criteria during project manager recruitment.
5. Encourage CPD programmes focusing on interpersonal and leadership competencies.

Thanks and Information Note

The article complies with national and international research and publication ethics. This study complies with all national and international standards for research and publication ethics. Ethics Committee approval was not required, as the research involved non-sensitive questionnaire responses from adult professionals and did not include any personal or medical data. The author expresses sincere appreciation to the construction practitioners and expert panelists who participated in the survey and Delphi exercises. Their insights and professional contributions were instrumental to the success of this study. No external funding, grants, or financial sponsorship were received for this research. The study was conducted independently without influence from any organization or commercial entity. The author declares no conflict of interest. All contributions to the article were made by the sole author: Author Contribution: *Conceptualization, data collection, analysis, interpretation, and manuscript preparation:* Greg Odee Ikwe (100%)

References

Aibinu, A. A., & Jagboro, G. O. (2002). The effects of construction delays on project delivery in the Nigerian construction industry. *International Journal of Project Management,* 20(8), 593–599.

Ameh, O. J., & Odusami, K. T. (2010). Professionals' ambivalence toward ethics in the Nigerian construction industry. *Journal of Professional Issues in Engineering Education and Practice,* 136(1), 9–16.

Clarke, N. (2010). Emotional intelligence and transformational leadership in project managers. *Project Management Journa*l, 41(2), 5–20.

Crawford, L. (2005). Senior management perceptions of project management competence. *International Journal of Project Management,* 23(1), 7–16.

Müller, R., & Turner, J. R. (2010). Leadership competency profiles of successful project managers. *International Journal of Project Management*, 28(5), 437–448.

PMI (2021). Talent Triangle: Power Skills for Project Management Professionals. Project Management Institute.

Rezvani, A., Chang, A., Wiewiora, A., Ashkanasy, N. M., Jordan, P. J., & Zolin, R. (2016). Manager emotional intelligence and project success. *International Journal of Project Management*, 34(7), 1112–1122.

Robles, M. M. (2012). Executive perceptions of top workplace soft skills. *Business Communication Quarterly*, 75(4), 453–465.

Turner, J. R., & Müller, R. (2006). Choosing appropriate project managers. Project Management Institute.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Development of Roman Bath Architecture in the Light of the Sebastopolis Roman Bath

Akın TEMÜR[1]*

ORCID 1: 0000-0001-9777-5256
[1] Assoc. Prof. Dr., Ondokuz Mayıs University, Faculty of Humanities and Social Sciences, Department of Archaeology, Samsun-Türkiye
*akintemur@yahoo.com **(**Responsible Author)

Abstract

Baths, which are among the significant institutions of Roman social life, constitute one of the fundamental building blocks of the Roman bathing tradition. In the Roman world, baths were not merely places for washing; they were also socializing venues that transcended bathing, positioned at the center of community life, and transformed into symbols of urban living. Unlike other nations, they were not exclusive locations for the elite but took on the identity of structures that benefited all segments of society. The Roman bath in Sebastopolis must have played a crucial role in shaping the social life of this city. The excavation of the Roman bath in Sebastopolis is among the strongest evidence of this. This study evaluates the architectural elements obtained from excavations conducted to date, identifies the components based on the findings, and attempts to propose a historical context using existing Roman bath terminology. Although the ongoing nature of the excavation and the fact that the structure was repurposed for different uses at various periods complicate its dating, the architectural layout has been analyzed in light of similar structures, revealing the innovations it contributed to Roman bath architecture.

Keywords: Black Sea, Tokat, Sulusaray, Sebastopolis, Roman Bath architecture

1. Introduction

The ancient city of Sebastopolis is located within the boundaries of today's Sulusaray district, 69 km south of Tokat province in Türkiye's Central Black Sea Region (Le Guen & Rémy, 2010). Research on the city, which dates back to the 19th century, is primarily based on the observations of travelers (Uyanık, 2023). One of these researchers, Damon, noted in his observations from the 1870s that the city contained significant ancient and Byzantine ruins, well-constructed walls, and foundations of one of the largest churches in Asia Minor to the southeast of the village. He also mentioned the presence of a Byzantine bridge to the east of the village, a Roman bridge made of volcanic stones that connects the shores of Skylax (Figure 1), massive public buildings, and an Early Christian Church with a dome decorated with golden mosaics, located about two thousand paces from the village (Amandry & Remy, 1998; Le Guen & Remy, 2010).



Figure 1. Roman Bridge over Skylax (Çekerek River)

Additionally, he suggested that there must have been an amphitheater or stadium for gladiatorial contests, as well as several temples visible on coins, indicating that the identified Roman and Early Christian remains in Sulusaray and surrounding villages reflect a high population density during Antiquity. He emphasized the city's strategic importance due to its location at a junction connecting the west-east road from Tavium in Galatia to Sebaste and then to Armenia, along with a route linking Central Anatolia to the Black Sea port of Amisos (present-day Samsun) (Cumont & Cumont, 1906; Mitford, 1966; Mitford, 1991; Amandry & Remy, 1998; Le Guen & Remy, 2010).

The Cumont brothers, who visited Sulusaray during their travels in the Black Sea region, indicated that the city began to mint coins during the Traianus period and that Hadrian visited the city in AD 124. They noted that during this period, various structures were built, including a stadium for gladiatorial contests, a portico, a gymnasium, temples, and many more (Cumont & Cumont, 1906). Magie, who conducted research on the city in the 1950s, suggested that contrary to the Cumont brothers, Hadrian may have visited the city in AD 129 and indicated that during this time, the “Hadrian Priesthood” was established in the city, with a portico built in his honor (Magie, 1950; Akşar, 2019).

Epigraphical and numismatic studies conducted in the region provide more information about the socio-economic and cultural structure of the city. It is believed that Herakles was venerated in Sebastopolis, as depicted on coins, and that there may have been a temple and a monumental cult statue dedicated to him in at least two sacred areas (Waddington et al., 1925; Amandry & Remy, 1998; Le Guen & Remy, 2010). Furthermore, it is thought that there were altars dedicated to Asklepios and Apollo for the thermal waters used in modern baths (Cumont & Cumont, 1906; Le Guen & Remy, 2010), and a dedication inscription to Zeus Pylaios suggests the existence of cults related to these gods (Cumont & Cumont, 1906; Mitford, 1991; Le Guen & Remy, 2010; Ful, 2025). In addition to these gods, it is known that Hadrian visited the city during his travels in Anatolia and that an imperial cult was established in Sebastopolis in his honor (Anderson, 1900; 1903; Amandry & Remy, 1998; Le Guen & Remy, 2010). It can be inferred that there was a highly populated community living in prosperity under the influence of Greco-Roman culture, as evidenced by the sending of a statue of Hadrian by the city's ambassadors during the opening of the Olympic Games in Athens and the fact that some of its citizens received "Roman Citizenship" (Le Guen & Remy, 2010).

Inscriptions from the Byzantine period indicate that there was a considerable Christian population in the city before AD 325, and during the Justinian period, the city was connected to the episcopate of Sebasteia. It is known that a bishop affiliated with the Sebasteia Metropolis resided in the city. Although not much is known about the city after the 9th century, tombstones belonging to Jews found in the area suggest that a Jewish population coexisted with Christians in the city (Cumont & Cumont, 1906; Amandry & Remy, 1998). After the Battle of Manzikert, it is known that a small Turkish village named Sulusaray was established over the ancient city, which is still present today.

2. Excavation Activities in the City

The first excavation activities in the city were carried out by the Tokat Museum between 1987 and 1990 as a rescue excavation (Özcan, 1991; 1992). At that time, it was unclear to which structures the excavated areas belonged, leading to these areas being labeled as "Area 1 and Area 2." In subsequent evaluations, these areas were identified as a bath and a church structure (for church studies, see Temür & Gültekin-Genç, 2023; Temür, 2023a; Temür, 2023b; Temür

et al., 2023). Excavations conducted in the area designated as "Area 3," located to the east of the district, revealed large stone blocks that were interpreted as part of a city wall. During excavation work in the south and southwest of the district, a significant amount of pottery from the Hittite and Phrygian periods was discovered in the area termed "Area 4." These findings indicate that part of the ancient city was built on a mound that dates back to the Hittite and Phrygian periods. In "Area 7," located within the borders of Ilıcak Village, approximately 2 km west of the ancient city, excavations revealed a mosaic-floored structure with an apse, featuring floral and geometric motifs dating to the Late Roman/Early Byzantine period, which had been damaged by treasure hunters (Özcan, 1991). The existing remains suggest that the ancient city of Sebastopolis spread over at least 2 km². Based on the presence of thermal waters still in use today, it has been concluded that the structure may have been an Asklepion. Following the rescue excavations conducted by the Tokat Museum, excavation activities resumed in 2010 after a 20-year hiatus; however, these lasted only for one season (Kohl et al., 2012). After a two-year break, excavations recommenced in 2013 and concluded in 2018. Excavations began again in 2021 and are still ongoing.

3. Roman Bath

One of the public structures from the Roman Period in Sebastopolis, the Roman Bath is located in the city center. The excavations carried out in the Roman Bath date back to 1987 (Özcan, 1991). During the rescue excavations conducted by the Tokat Museum between 1987 and 1990, only a small portion of the structure was uncovered, and its exact function could not be determined, leading to its registration as "Excavation Area 1" and its description as a "Columned Structure." Excavations during these years uncovered marble floor tiles, water channels, rubble stone walls, and column bases within the structure.



Figure 2. Roman Baths and Byzantine Church

In 1989, work intensified on the southern side of the building, where it was believed that materials possibly related to the roof—composed of stones and bricks—were found, indicating that the flooring and water channels extended beneath the fill soil. Although the excavation team hypothesized that this structure could be a bath based on drainage channels and a stone

basin, it was also suggested that it might belong to a much larger structure due to the columns aligned in the same direction.

In 1990, while the structure was still described as "Excavation Area 1," efforts were made to remove the fill soil measuring up to 5 meters, resulting in the discovery of stacked bricks on the ground, leading to further speculation that it could be a bath, although a definitive conclusion could not be reached (Özcan, 1992).



Figure 3-4. The Latest Situation of the Roman Baths Before the 2010 Excavations

After a 20-year hiatus, excavations resumed in 2010, during which the areas filled with soil over time were cleaned, revealing the hypocaust system. The praefurnium located at the center of the southern wall of the structure was identified, and it was concluded that the uncovered areas represented the frigidarium, tepidarium, and caldarium sections of a large Roman Bath, although only a small part had been excavated to date (Kohl et al., 2012).



Figure 5-6. The Roman Baths After the 2010 Excavations

After a two-year break, excavations in 2013 were resumed by another team. They focused on understanding the function of the praefurnium located in the center of the octagonal room identified as the caldarium (Figure 7). During leveling work, a significant quantity of ceramic shards dating to the Late Roman and Early Byzantine periods and many roof tile fragments thought to belong to the superstructure were found. Additionally, during these excavations, walls made of large cut stone blocks and mortar rubble stones extending east-west were discovered. Ongoing work revealed the arched rear facade of the praefurnium constructed from double rows of bricks. Excavations in the south of the bath shifted eastward due to the presence of modern houses, leading to work starting on the eastern side of the caldarium, where it was concluded that the area represented an alveus, characterized by walls made partially of bricks. The work resulted in the complete excavation and unveiling of the caldarium (Ful et al., 2014).



Figure 7. 2013 Excavation of the Roman Baths, Caldarium

The focus of the 2014 investigations was to determine the function of the hypocaust system, unveiled in the previous season (Figure 8). Excavations conducted to the east and north of the bath revealed late-period fire and lime layers. Further investigations on the east side of the caldarium, adjacent to the alveus revealed in the 2013 excavation season, concluded that this area was also heated by an octagonal hypocaust system, similar to that found in the caldarium. Although no portions of the bath were uncovered in the northern excavations, coins from the Byzantine period and rubble stone wall remnants from the late period were discovered (Ful et al., 2016).



Figure 8. 2014 Excavation of the Roman Baths, Hypocaust System

In 2015, investigations were conducted on the eastern section of the bath to understand the function of the octagonal area containing the brick supports of the hypocaust system, which had been partially revealed in previous seasons. Work was also carried out in the frigidarium to the west and in areas connected to the waste water channel (Figure 9).

During this excavation, a second praefurnium with a brick arch was uncovered within the octagonal structure. In the section immediately behind this area, remnants of a wall made of cut stone blocks defining the southeastern corner of the bath were also found. The coins from the Byzantine period indicated that the structure had been used in different periods (Şengül et al., 2017).



Figure 9. Roman Bath 2015 Excavation, Frigidarium

The 2016 excavation season primarily took place along the western side of the bath. During these excavations, both Roman-period pottery and Byzantine-era coins, weighing stones, and numerous roof tile fragments were found. The entrance door along the wall that forms the western boundary of the bath was later found to have been blocked with rubble stones, suggesting that the structure had been used for different functions in different periods. The

leveling work conducted in the northwest yielded ceramic finds dated to the Iron Age, indicating that earlier remains may exist beneath the structure (Ful et al., 2018).

In 2017, excavations were conducted in the eastern and northern sections of the bath. In efforts to reveal the palestra section, which was supposed to be located to the north of the bath, remnants of Byzantine and Ottoman coins and bone artifacts were found during the northern section's excavations (Figure 10). In the eastern section, work was done at a site believed to have corresponded to the city wall based on boreholes previously conducted by the Tokat Museum in the 1980s, where a surface paved with irregular stones whose function could not be completely identified was found. However, no identifiable findings related to the palestra were noted in the northern excavations.

Nevertheless, in that area, structures composed of square or rectangular rooms were uncovered, which were thought to have been used as shops or small workshops during the Byzantine period. This indicates that the bath lost its function in the later period and underwent a second phase of use for various purposes (Ful et al., 2019).



Figure 10. Roman Bath 2017 Excavation, Palestra

In the 2018 season, excavations focused primarily on the wall of cut stones defining the eastern boundary of the bath, with the aim of determining how far the stone-paved surface extended in the north-south direction. During excavations in areas showing remnants of modern housing, it was determined that the stone-paved surface continued in a north-south orientation. In both this area and in work on the southern side of the bath, ceramics, glass, weights, and coins from the Byzantine period were found. The discovery of an Ottoman coin during the excavation also underscored the irregular stratigraphy of the area. As a result, it was concluded that, considering the size of the city, this bath represents just one of the baths located within Sebastopolis (Ful, 2018)(Figure 11).



Figure 11. The Condition of the Roman Baths After the 2018 Excavations

In 2018, the excavations of the Roman Bath were paused, and in 2021 another team resumed the work. During this period, the primary objective was to uncover the eastern section of the bath. The excavations revealed the continuation of the foundations belonging to modern houses that had been demolished following expropriations. Following the removal of these foundations, Roman-period red-slipped and Byzantine-period green-yellow slipped pottery fragments, along with numerous roof tile fragments, were found within the fill soil (Figure 12).



Figure 12. Roman Bath 2021-2023 Excavation Columned Street (Road)

Subsequently, sections of the wall made of rubble stones that delineated the eastern side of the bath were also uncovered. In the area where the stone-paved surface was revealed during the 2017 excavation season, cleaning, leveling, and excavation work began, uncovering the stone-paved surface believed to have been used as a road or street (Temür et al., 2024; Temür et al., 2025).

4. Conclusion and Recommendations

The sections and dimensions of the Sebastopolis Bath represent a singular example of Roman bath architecture in Anatolia. The presence of modern buildings over the excavated areas and the issues with expropriations resulted in a slow progress of excavation and occasional halts in the work. The process, which began with rescue excavations by the Tokat Museum in 1987, has seen the structure excavated for a prolonged period by different teams using varying methods. The incomplete state of the excavations, along with the additions made during different periods for varying purposes, presents another challenge. The involvement of various teams, alongside brief excavation periods and long interruptions, poses significant problems for the excavation overall. These ongoing processes complicate the dating of the structure and lead to differing chronological proposals. However, considering the architectural plan and the Greco-Roman style that merges Hellenistic and Italic elements, it can be asserted that the bath was likely constructed in the 2nd century CE and was utilized for various functions up until the late Byzantine period. Establishing a definitive date and accurately identifying the phases experienced by the bath will only be possible once all sections buried under modern structures have been uncovered.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Akşar, A. (2019). *İmparator Hadrianus'un Anadolu Gezileri*, Üniversite Yayınevi, Samsun.

Amandry, M. & Rémy, B. (1998). Pontica II, Les Monnaies de L'atelier de Sebastopolis du Pont, *Varia Anatolica X*, Institut français d'études anatoliennes Georges Dumézil, İstanbul.

Anderson, J. G. C. (1900). Pontica, *JHS* 20, 1900, 151-158.

Anderson, J. G. C. (1903). John George Clark, A Journey of Exploration in Pontus: *Studia Pontica I*, H. Lamertin, Bruxelles.

Cumont, F. & Cumont, E. (1906). Voyage D'Exploration Archéologique Dans Le Pont et La Petite Arménie: *Studia Pontica II*, H. Lamertin, Bruxelles.

Ful, Ş. D., Tekin, M., Hanoğlu, C., Akın, E. S., Susam, T. & Yaprak, S. (2014). Sebastopolis Antik Kenti 2013 Yılı Kazı Çalışmaları, *36. Kazı Sonuçları Toplantısı*, Cilt 1, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 475-491.

Ful, Ş. D., Tekin, M., Hanoğlu, C., Akın, E. S., Susam, T. & Hanoğlu, C. (2016). Sebastopolis Antik Kenti 2014 Yılı Kazı Çalışmaları, *37. Kazı Sonuçları Toplantısı*, Cilt 1, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 379-390

Ful, Ş. D., Tekin, M., Hanoğlu, C., Akın, E. S., Susam, T. & Hanoğlu, C. (2017). 2015 Yılı Sebastopolis Antik Kenti Kazı ve Restorasyon Çalışmaları, *38. Kazı Sonuçları Toplantısı*, Cilt 2, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 315-331.

Ful, Ş. D., Tekin, M., Hanoğlu, C. & Akın, E. S. (2018). 2016 Yılı Sebastopolis Antik Kenti Kazı Çalışmaları, *39. Kazı Sonuçları Toplantısı*, Cilt 2, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 165-174.

Ful, Ş. D., Tekin, M., Hanoğlu, C. & Akın, E. S. (2019). 2017 Yılı Sebastopolis Antik Kenti Kazı Çalışmaları, *40. Kazı Sonuçları Toplantısı*, Cilt 2, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 553-564.

Ful, Ş. D. (2019). The Ancient City of Sebastopolis in the Light of Archaeological Data and Inscriptions, *Settlements and Necropoleis of the Black Sea its Hinterland in Antiquity*, Tsetskhladze G. R. & Atasoy, S. (ed.), Archaeopress, Oxford, 208-213.

Ful, Ş. D. (2025). Epigrafik, Nümizmatik ve Arkeolojik veriler ışığında Tokat'ta Zeus Kültü, *Karadeniz İncelemeleri Dergisi*, 19/38, 67-90.

Le Guen, B. & Remy, B. (2010). La Cite De Sebastopolis Du Pont, *Anatolia Antiqua* XVIII, 97-107.

Kohl, M., Matoğlu, M. & Alkan, A. (2012). Tokat-Sulusaray/Sebastopolis: Temizlik Çalışmaları ve Ziyaretçiler İçin Bir Gezi Güzergâhı Oluşturulmasında İlk Adımlar, *33. Kazı Sonuçları Toplantısı*, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 559-567.

Magie, D. (1950). *Roman Rule in Asia Minor. To the End of the Third Century After Christ*, Vol. I: Text. Princeton University Press, Princeton.

Mitford, T. B. (1966). The God Pylon in Eastern Pontus, *Byzantion*, 36, 471-485.

Mitford, T. B. (1991). Inscriptions Ponticae-Sebastopolis", *ZPE*, 87, 181-243.

Özcan, B. (1991). Sulusaray-Sebastopolis Antik Kenti, *I. Müze Kurtarma Kazıları Semineri*, 261-307.

Özcan, B. (1992). Sulusaray-1990 Kurtarma Kazısı, *II. Müze Kurtarma Kazıları Semineri*, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 167-200.

Ramsay, W. M. (1960). *Anadolu'nun Tarihi Coğrafyası*, Pektaş, M. (trans.) Milli Eğitim Yayınevi, İstanbul.

Temür A., Yeniay, G., Çakır, N. & Torun, S. (2023). Sebastopolis Antik Kenti 2021 Yılı Kazı ve Restorasyon Çalışmaları, *42. Uluslararası Kazı, Araştırma ve Arkeometri Sempozyumu*, 23-27 Mayıs 2022, Denizli, 1. Cilt, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 71-82

Temür, A. & Gültekin-Genç, İ. (2023). Sebastopolis Excavations and Observations on the Byzantine Church, *JAHA*, Vol. 10, No 3, 146-161.

Temür, A. (2023a). Sebastopolis/Herakleiopolis (Tokat/Sulusaray) Kazı Çalışmaları ve Erken Dönem Bizans Kilisesi Üzerine Bir Değerlendirme, *Türkiye Cumhuriyeti'nin Kuruluşunun 100. Yılı Anısına Danişmendli Havzasında Tarih ve Kültür Tokat*, Demir, A., Dönder & Erdem, Y. H. (ed.), Kömen Yayınları, Konya, 3-15.

Temür, A. (2023b). Sulusaray-Sebastopolis Kazılarının Dünü, Bugünü ve Yarını, *5. Tokat Sempozyumu* 14-16 Ekim 2022, Bildiriler Kitabı Cilt IV, Yılmaz, Ç. (ed.), İstanbul, 227-237.

Temür, A., Gültekin-Genç, İ., Bilge, E. & Susam, T. (2024). Sebastopolis Antik Kenti 2022 Yılı Kazı ve Restorasyon Çalışmaları, *43. Uluslararası Kazı, Araştırma ve Arkeometri Sempozyumu*, Cilt 1, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 53-64.

Temür, A. & Gültekin-Genç, İ. (2025). Sebastopolis Antik Kenti 2023 Yılı Kazı ve Restorasyon Çalışmaları, *44. Uluslararası Kazı, Araştırma ve Arkeometri Sempozyumu*, Kültür ve Turizm Bakanlığı Yayınları, Ankara, 51-62.

Uyanık, H. (2023). Cizvit Misyonerlerin Tokat'ta Yapmış Olduğu Arkeolojik Çalışmalar Üzerine Bir Değerlendirme", *Danişmendli Havzasında Tarih ve Kültür Tokat*, Demir, A., Dönder, Y. & Erdem, H. (ed.) Konya, 17-33.

Waddington, W. H., Babelon, E. & Reinach, T. (1925). *Recueil général des monnaies grecques d'Asie Mineure*, T. I, Fasc. 1, Pont et Paphlagonie, Académie des Inscriptions et Belles-Lettres, Paris.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Utilization of Restorative Design Features in The Design Proposal for Resort Centre in Abuja, Nigeria

Ahmed T. KASIM [1*]

[1] Department of Architecture, Federal University of Technology Minna
kasimxahmed@gmail.com **(**Responsible Author)

Abubakar D. ISAH [2]

[2] Department of Architecture, Federal University of Technology Minna

Abstract

In today's fast-paced world, where stress and mental fatigue are increasingly common, restorative environmental design has become crucial in shaping resort spaces that promote psychological recovery and connection to nature. This study investigates the influence of biophilic interventions and spatial configuration on restorative experience within Nigerian resort environments. The research adopts a quantitative methodology, drawing on responses from a varied cohort of resort users reached through multiple digital platforms. Data were analysed using descriptive and inferential statistical methods, including correlation, multiple regression, and exploratory factor analysis (EFA) using PCA with Varimax rotation to examine relationships among Restorative Principles Evaluation (RPE), Biophilic Interventions (BIRE), and Prospect–Refuge Restorative (PRR) constructs. The results revealed strong positive correlations between RPE and both BIRE ($r = 0.763$, $p < 0.01$) and PRR ($r = 0.632$, $p < 0.01$), with BIRE exerting the greater predictive effect on restorative perception ($\beta = 0.659$, $p < 0.001$), while PRR contributed additional but smaller significance ($\beta = 0.138$, $p = 0.034$). The combined model accounted for 59% of the variance ($R^2 = 0.590$), demonstrating that natural elements such as daylight, vegetation, water features and natural materials along with spatial qualities like legibility, prospect and refuge, jointly enhance user well-being and restorative appraisal. Furthermore, demographic factors such as age and frequency of resort use moderated perceptions of restoration, highlighting the importance of user diversity in design evaluation. The study concludes that contextually grounded biophilic design, integrating both natural and spatial restorative features, is essential for fostering relaxation, comfort and psychological well-being in resort settings. It recommends that architects and designers prioritize daylight access, greenery, water features and coherent spatial organization to create environments that harmonize human experience with Nigeria's ecological and cultural context.

Keywords: Abuja, Resort Centre, biophilic design, spatial restorative

Introduction

The 21st century's rapid urbanization, digital saturation, and demanding lifestyles have intensified global levels of stress, anxiety and mental fatigue, underscoring the growing need for environments that foster genuine rest, recovery, and psychological well-being (Ventriglio et al., 2021; Magomedova and Fatima, 2025; Basu et al., 2019; Schumann et al., 2022; Pham and Sanocki, 2024). This shift has redefined the tourism and hospitality industry, as travellers increasingly seek transformative, wellness-oriented experiences that promote reconnection with nature and holistic rejuvenation (Smith and Puczkó, 2016; Zhong et al., 2021). Grounded in environmental psychology, Kaplan and Kaplan's Attention Restoration Theory (ART) and Ulrich's Stress Reduction Theory (SRT) explain how natural environments restore attention and reduce stress through cognitive and physiological mechanisms (Huang et al., 2020; Joye et al., 2018; Jimenez et al., 2021; Reese et al., 2021). These theories inform restorative and biophilic design principles, which integrate nature into architecture through direct, indirect, and spatial connections to enhance human well-being (Ryan et al., 2014; Browning et al., 2020; Brielmann et al., 2022; Lefosse et al., 2023). While such design approaches have demonstrated measurable benefits in healthcare, educational, and corporate settings, their application within hospitality particularly resort design remains limited, despite resorts' inherent potential to

transcend luxury and serve as immersive environments that actively facilitate mental and physiological restoration (Aristizabal et al., 2021; Lei et al., 2022; Akinyemi et al., 2024).

Despite the increasing demand for wellness-oriented travel, many resorts still emphasize luxury and aesthetics over restorative design strategies that support well-being and sustainability. This neglect reflects limited application of principles from Attention Restoration Theory (ART) and Stress Reduction Theory (SRT), which highlight how nature-based design can reduce stress and enhance mental health (Huang et al., 2020; Joye et al., 2018; Jimenez et al., 2021). Consequently, opportunities to create truly restorative and health-supportive environments are often missed, diminishing guest satisfaction and retention. Moreover, many designs fail to consider cultural, climatic and ecological contexts, resulting in generic and disconnected spaces. This study therefore examines how context-responsive biophilic interventions such as natural materials and symbolic connections with nature can be integrated into resort design to foster holistic restoration and sustainability. Thus, the study aimed to assess the utilization of restorative design features towards the design of resort centre in Abuja, Nigeria. This study is justified by growing evidence that restorative design features such as natural light, greenery, and water elements enhance guest well-being, reduce stress, and support sustainable hospitality practices (Lehto et al., 2019; Ifebi et al., 2024). Rooted in biophilic design principles, it emphasizes reconnection with nature to promote holistic wellness (Panagopoulos et al., 2020; Hung and Chang, 2024). By developing a framework for integrating these elements within diverse resort contexts, the research aims to enhance guest experiences while advancing environmental stewardship and sustainability (Suess et al., 2024; Ajeuyjo et al., 2025). This study examines the application of biophilic design strategies in developing a restorative resort centre tailored to Abuja's cultural and environmental context, enhancing well-being, promoting wellness tourism, and providing evidence-based insights for sustainable, health-oriented hospitality design in Nigeria and beyond (Huang et al., 2020; Joye et al., 2018).

Background Study

Restorative design has gained prominence in contemporary architecture and hospitality as a response to the global rise in wellness and experiential tourism, which emphasizes holistic health, cultural engagement, and meaningful connection with nature (Zhong et al., 2021; Dillette et al., 2021; Backman et al., 2023). Integrating biophilic principles, environmental sustainability, and user-centred spaces, restorative design enhances guest well-being, reduces stress, and fosters deeper connections with the natural environment (Purani and Kumar, 2018; Hung and Chang, 2024; Martínez et al., 2021). Resort centres, often located in serene natural settings, are uniquely suited for applying these principles, serving as ideal environments to study how architectural, landscape, and spatial elements can be optimized to promote relaxation, attention restoration, and holistic rejuvenation. As wellness tourism continues to grow, such resorts not only fulfil the demand for health-enhancing experiences but also advance sustainability and restorative design practices in hospitality (He et al., 2021; Singh et al., 2021; Sachin and Dash, 2022).

Theoretical Foundations of Restorative Environments

Attention Restoration Theory (ART) developed by Kaplan and Kaplan (1989), posits that exposure to natural environments replenishes depleted cognitive resources, forming the basis for restorative resort design (Pham and Sanocki, 2024; Tipler and Ruddell, 2025). Its four key components which are being away, extent, fascination, and compatibility guide how biophilic elements like greenery, water, and spatial coherence promote relaxation, mental recovery, and

alignment between user needs and environmental experience (Ohly et al., 2016; Zhang et al., 2021; Yusli et al., 2021; Basu et al., 2019; Marois et al., 2021).

The Perceived Restorativeness Scale (PRS), grounded in Kaplan and Kaplan's (1989) Attention Restoration Theory, assesses how individuals perceive an environment's ability to restore cognitive resources through dimensions such as being away, fascination, extent, and compatibility (Hartig et al., 1997; Ratcliffe, 2021). Widely applied across urban, workplace, and healthcare settings, PRS findings reveal that natural elements especially vegetation, water, and nature sounds all enhance restorative experiences differently, offering designers data-driven insights for creating more health-promoting environments despite cultural and perceptual limitations (Li et al., 2022; San Juan et al., 2017; Lyu et al., 2022; Yildirim et al., 2023).

Stress Reduction Theory (SRT), developed by Ulrich (1983), emphasizes humans' innate, evolution-based tendency to respond positively to unthreatening natural environments, which evoke calmness, pleasure, and reduced physiological stress indicators such as heart rate and cortisol levels (Ulrich et al., 1991; Yao et al., 2021; Geneshka et al., 2021). It highlights the rapid, often unconscious, restorative effects of nature exposure, with studies showing quicker stress recovery in natural settings than in built environments devoid of natural elements (Elsadek et al., 2019; Ulrich, 2023).

The Biophilia Hypothesis, introduced by Wilson (1984) and expanded by Kellert (1993), posits an innate human affinity for nature rooted in evolutionary adaptation, forming the foundation for biophilic design that integrates natural elements, materials, and spatial patterns to enhance well-being (Lencastre et al., 2023; Divya and Naachimuthu, 2020; Barragan et al., 2023). Building on this, Ryan et al. (2015) identified three biophilic design patterns such as Nature in the Space, Natural Analogues and Nature of the Space. For this study, the Natural Analogues category, emphasizing materials like wood and stone and biomorphic patterns, is central, as research shows such indirect nature representations effectively reduce stress, improve cognition, and enhance well-being (Peters and D'Penna, 2020; Bolten and Barbiero, 2020; Kwak and Choi, 2025).

Individual perceptions of biophilic design vary based on personal experiences, cultural background, and cognitive preferences, influencing how people connect with natural elements such as light, water, or materials (Berto et al., 2018; To and Grierson, 2024; Hung and Chang, 2022). Recognizing these subjective differences is essential for creating restorative environments that cater to diverse user needs rather than adopting a one-size-fits-all approach (Plotnikova, 2021).

In addition to ART, SRT, and Biophilia, the Prospect-Refuge Theory (Appleton, 1975) emphasizes the human preference for spaces that balance openness and protection, fostering feelings of safety and relaxation (Dosen and Ostwald, 2016; Suess et al., 2024). Similarly, Place Attachment Theory highlights the emotional and cognitive bonds individuals form with meaningful environments, enhancing identity, belonging, and well-being (Inalhan et al., 2021; Ilovan and Markuszewska, 2022). Together, these theories provide a comprehensive framework for designing resort environments that integrate natural elements, spatial harmony, and cultural connection to promote psychological restoration.

Restorative and sustainable design principles intersect through strategies that enhance both environmental performance and human well-being. Passive design approaches, sustainable

materials, and efficient water management reduce energy use, improve indoor air quality, and promote ecological balance (Grimm et al., 2023). By preserving biodiversity and fostering a connection to natural systems, sustainable resort design supports a holistic model of wellness that benefits both people and the environment (Marselle et al., 2021; Russo and Cirella, 2020).

Resort Centre Evolution, Architecture and Design

The evolution of resort architecture reflects a long-standing recognition of the restorative relationship between humans and nature. From ancient Roman baths and Greek healing sanctuaries that integrated natural elements for wellness (Brodie, 2021; Pavli et al., 2024) to Renaissance spa towns and formal gardens emphasizing beauty, contemplation, and health (UNESCO World Heritage Centre, n.d.; Sillmann et al., 2024), resorts have historically embodied environments of relaxation and renewal. The 18th and 19th centuries saw the rise of nature-oriented retreats for the leisure class, influenced by Romantic ideals celebrating the emotional and spiritual power of nature (Wedekind, 2021; Levytska, 2024). By the 20th and 21st centuries, advances in psychology and environmental science led to the intentional incorporation of restorative and biophilic design principles into resort planning (Ryan et al., 2014; Sachin and Dash, 2022). Contemporary resorts now embrace sustainability, wellness, cultural authenticity, and advanced technology to enhance well-being and connection to nature (Papallou et al., 2024; Dillette et al., 2021; Ukpabi, and Karjaluoto, 2017). These trends collectively demonstrate how resort design continues to evolve toward holistic, health-centred, and environmentally responsive spaces aligned with restorative design principles.

Designing successful resort centres requires a holistic approach that balances environmental sensitivity, functionality, and guest experience. Effective site planning and landscape integration must respect topography, climate, and ecology to enhance restorative potential (Suta et al., 2021; Baranova, and Kegeyan, 2018). Clear circulation and intuitive wayfinding reduce cognitive stress, while thoughtful programming ensures diverse amenities that promote relaxation, social interaction, and engagement with nature and culture (Jiang et al., 2022; Miller and Rafia-Tracy, 2025). The architectural journey from arrival to departure should evoke comfort, sensory delight, and emotional connection (Shahid and Paul, 2022). A strong sense of place achieved through local materials, cultural expression, and contextual design enhances authenticity and guest attachment (Smith and Ram, 2017; Cheer et al., 2022). Additionally, long-term scalability and adaptability are vital to ensure cohesive growth and sustainable operations (Deroos, 2012; Wu et al., 2017).

The Resort Industry in Nigeria

The resort industry in Nigeria is an emerging yet underdeveloped segment of the country's tourism and hospitality sector, characterized by private sector dominance, limited government participation, and growing domestic demand (Esu, 2015; Ajani and Kalu, 2017; Bassey, 2015). Nigerian resorts range from coastal and nature-based facilities to leisure, recreational and conference-oriented establishments, reflecting the nation's diverse geography and cultural richness (Uduma-Olugu and Onukwube, 2015; Mohammed, 2022; Sayyora and Diyora, 2020). The primary market comprises domestic tourists, diaspora Nigerians, and a smaller segment of international visitors (Yusuff and Aliu, 2019; Liu et al., 2019). However, challenges such as inadequate infrastructure, security issues, financing constraints, skill shortages, and inconsistent policy frameworks continue to impede growth (James and Essien, 2019; Kolawole et al., 2020; Ugwukah and Obomanu, 2020). Despite these limitations, Nigeria's abundant natural resources, cultural diversity, and expanding local market present significant

opportunities for developing eco-tourism, wellness tourism, and culturally immersive resort experiences that align with global trends in restorative and sustainable travel (Adeola and Evans, 2019; Adeola et al., 2020).

Theoretical framework

The theoretical framework of this study is rooted in Wilson's (1984) Biophilia Hypothesis and structured around Kellert et al.'s (2008**)** biophilic design framework, which emphasizes *symbolic connections with nature* through the use of natural materials, colours and biomorphic forms that stimulate emotional balance and cognitive restoration. It is further reinforced by complementary theories Attention Restoration Theory (Pham and Sanocki, 2024**),** Stress Recovery Theory (Ulrich, 2023**),** Prospect-Refuge Theory (Appleton, 1975**),** and Place Attachment Theory (Inalhan et al., 2021**)** collectively providing a comprehensive foundation for understanding how nature-inspired environments enhance psychological comfort and overall well-being.

Despite extensive evidence supporting biophilic design's restorative potential, existing studies have predominantly focused on *direct nature interactions* such as vegetation, daylight and outdoor views, while its *symbolic dimension* remains insufficiently explored, particularly within hospitality environments in the Global South. Addressing this gap, the present study investigates how resonant natural materials and forms can be strategically integrated into Nigerian resort design to serve as restorative and health-supportive features where direct engagement with nature is limited (Kellert et al., 2008; Lencastre et al., 2023).

Methodology

This study adopts a quantitative research approach to collect and statistically analyse numerical data, enabling the identification of patterns, relationships and differences among variables (Assaf and Tsionas, 2019; Andayana and Pitanatri, 2023). A cross-sectional survey design will be used to gather data at a single point in time from participants such as resort guests or architects (Punch, 2013; Nwabuko, 2024), while a correlational design will examine the strength and direction of relationships between restorative design features and user perceptions like satisfaction and perceived restorativeness (Cohen, Manion and Morrison, 2002; Gamage, 2025). This approach supports objective measurement and potential generalization of findings within the resort context. Data for this study will be collected through structured online questionnaires distributed to resort guests who have stayed at least one night, enabling efficient and standardized data gathering on perceptions of restorative design features and well-being across diverse locations (Dillman et al., 2014; Altaf et al., 2022; Andayana and Pitanatri, 2023). Utilizing online platforms such as TripAdvisor, Booking.com, TikTok, WhatsApp, Facebook, and email ensures convenience, cost efficiency, and confidentiality while addressing the logistical challenges of surveying a transient population. The questionnaire will employ validated scales to assess perceived restorativeness and evaluate the presence and quality of restorative design elements in resort environments.

The questionnaire comprises eighteen (18) questions across four structured sections combining multiple-choice and Likert-scale formats to capture comprehensive data. The first section gathers demographic information (Gifford, 2007; Creswell and Creswell, 2017), while the second measures perceived restorativeness using the Perceived Restorativeness Scale (PRS) by Hartig et al. (1997). The third section evaluates biophilic design features through a modified Biophilic Environmental Variables (BEVs) framework adapted from Asim and Shree (2019)

and Browning et al. (2015), and the fourth assesses the spatial balance of prospect and refuge in resort environments (Dosen and Ostwald, 2016; El-Metwally et al., 2021; Bornioli et al., 2023). This four-part instrument enables a systematic analysis of restorative design strategies and their relationship to perceived restorativeness in resort settings. The study targets adults aged 18 and above who have stayed at resorts for at least one night, ensuring participants possess direct experience with resort environments and design features. Individuals without such experience are excluded. A random sampling method will be used to ensure representativeness and reduce selection bias, giving each eligible participant an equal chance of selection (Creswell and Creswell, 2017; Mweshi and Sakyi, 2020). This approach strengthens the statistical validity and generalizability of the findings to the broader population of resort guests (Field, 2018; Teeroovengadum and Nunkoo, 2018).

Ethical standards were upheld by ensuring participant anonymity through an online survey that excluded personal identifiers and included an information sheet explaining the study's purpose, voluntary participation, and right to withdraw (Orb et al., 2001; Emami et al., 2019; Collis & Hussey, 2020; Kumar, 2018). Reliability and validity were reinforced through the use of university-approved sources, APA (7th edition) citation standards, and a structured questionnaire tested for internal consistency using Cronbach's alpha (Cronbach, 1951; Sekaran and Bougie, 2016). Pre-testing with academic experts and select respondents ensured clarity and alignment with established research, enhancing both methodological rigor and the validity of the study's conclusions (Malhotra and Dash, 2020; Dauda et al., 2023).

Results and Discussion

This chapter presents and analyses both quantitative and qualitative data to examine how biophilic design and spatial configuration contribute to restorative experiences within resort environments. Quantitative data were analysed using descriptive and inferential statistics, while qualitative insights provided contextual depth. A structured online questionnaire distributed via platforms such as TripAdvisor, Booking.com, WhatsApp, and Facebook yielded 235 responses, of which 227 were valid for analysis. Prior to analysis, a reliability test using Cronbach's Alpha was conducted to confirm internal consistency and the reliability of the measurement scales and the results are presented in Table 4.1 (Rak, and Wrześniowski, 2023).

Table 4.1. Reliability statistics (Source: Author's field work, 2025)

Scale	Items	Cronbach's Alpha (α)	Interpretation
Restorative Principles Evaluation (RPE)	11	0.735	Acceptable internal consistency
Biophilic Interventions & Restorative Experience (BIRE)	17	0.798	Acceptable-to-Good internal consistency (borderline good)
Prospect–Refuge Restorative (PRR)	13	0.707	Acceptable internal consistency

The Cronbach's Alpha values ranged between 0.707 and 0.798. This indicated an acceptable internal consistency across all constructs. The Biophilic Interventions scale (α = 0.798) recorded the highest reliability, followed by Restorative Principles Evaluation (α = 0.735) and Prospect–Refuge Restorative (α = 0.707). According to George and Mallery (2024), values

above 0.7 are considered satisfactory for social science research. Hence, all scales were reliable for subsequent statistical analyses.

4.2.2 Demographic Data Presentation

To understand the composition of respondents, demographic data such as age, gender, occupation, frequency of resort visits, and purpose of stay were summarized. The results are presented in Table 4.2.

Table 4.2: Demographic characteristics of respondents (Source**:** Author's field work 2025)

Variable	Category	Frequency	Percent	Valid Percent	Cumulative Percent
Age	18 – 29	54	23.8	23.8	23.8
	30 – 39	77	33.9	33.9	57.7
	40 – 49	50	22.0	22.0	79.7
	50 and above	46	20.3	20.3	100.0
Total		227	100.0	100.0	
Gender	Male	117	51.5	51.5	51.5
	Female	110	48.5	48.5	100.0
Total		227	100.0	100.0	
Occupation	Business/Corporate	58	25.6	25.6	25.6
	Government Employee	93	41.0	41.0	66.5
	Self-employed	76	33.5	33.5	100.0
Total		227	100.0	100.0	
Frequency of Resort Visits	Rarely	71	31.3	31.3	31.3
	Occasionally	115	50.7	50.7	81.9
	Frequently	41	18.1	18.1	100.0
Total		227	100.0	100.0	
Purpose of Stay	Business	62	27.3	27.3	27.3
	Leisure/Vacation	106	46.7	46.7	74.0
	Conference/Events	59	26.0	26.0	100.0
Total		227	100.0	100.0	

The results show that respondents aged 30–39 years formed the largest group (33.9%), followed by those aged 18–29 years (23.8%). The gender distribution was nearly balanced, with males representing 51.5% and females 48.5%. In terms of occupation, 41% were government employees, 33.5% were self-employed, and 25.6% worked in corporate or business organizations. Most participants (50.7%) reported visiting resorts occasionally, primarily for leisure or vacation purposes (46.7%)**,** followed by business trips (27.3%) and conference or event attendance (26.0%)**.** This demographic composition provides diverse perspectives for evaluating restorative experiences in resort environments.

Factor Analyses

Exploratory Factor Analysis (EFA) was conducted to identify the underlying dimensions of the three main constructs: Restorative Principles Evaluation (RPE), Biophilic Interventions (BIRE), and Prospect–Refuge Restorative (PRR). Principal Component Analysis (PCA) with Varimax rotation was used to determine the core factors that explain each construct.

Factor Analysis of Restorative Principles Evaluation (RPE)

Table 4.3 presents the factor analysis results for the RPE scale, showing sampling adequacy, total variance explained, and identified factors.

Table 4.3. EFA Summary for RPE (Source: Author's field work 2025)

Statistical Test / Factor Summary	Value	Interpretation
KMO Measure of Sampling Adequacy	0.748	Data adequate for factor analysis
Bartlett's Test of Sphericity	$\chi^2 = 439.258$, df = 55, $p < 0.001$	Correlation matrix appropriate
Number of Components Extracted	4	Meets Eigenvalue > 1 criterion
Cumulative Variance Explained	61.19 %	Adequate total variance
Range of Communalities	0.494 – 0.751	Acceptable shared variance
Identified Components	Being Away, Fascination, Extent, Compatibility	Consistent with theoretical model

The four extracted components align with the key restorative factors proposed by Kaplan and Kaplan (1989): Being Away, Fascination, Extent and Compatibility. Together, they explain 61.19% of the total variance, confirming the validity of the RPE scale in capturing core restorative experiences. This finding addresses the research objective, which aimed to evaluate restorative design principles and their relevance to resort environments.

Factor Analysis of Biophilic Interventions (BIRE)

The BIRE construct was tested to confirm its internal structure and relationship to biophilic design theory. Table 4.4 summarizes the factor extraction results.

Table 4.4. EFA Summary for BIRE (Source: Author's field work, 2025)

Statistical Test / Factor Summary	Value	Interpretation
KMO Measure of Sampling Adequacy	0.807	Data suitable for factor analysis
Bartlett's Test of Sphericity	$\chi^2 = 900.818$, df = 120, $p < 0.001$	Correlation matrix appropriate
Number of Components Extracted	4	Meets Eigenvalue > 1 criterion
Cumulative Variance Explained	54.62 %	Adequate total variance
Range of Communalities	0.399 – 0.764	Moderate to strong shared variance
Identified Components	Natural Light, Greenery and Vegetation, Water Features, Natural Materials and Forms	Aligned with biophilic theory

These four distinct dimensions consistent with biophilic design theory which are natural light, greenery and vegetation, water features, natural materials and forms. Together, these factors explained 54.62 % of the total variance and affirms the construct validity of biophilic interventions in resort contexts. This outcome addresses the research objective to assess the role of specific biophilic interventions.

Factor Analysis of Prospect–Refuge Restorative (PRR)

The PRR construct was analysed to explore how spatial layout and configuration influence restorative experience. Table 4.5 presents the results.

Table 4.5. EFA Summary for PRR (Source: Author's field work (2025)

Statistical Test / Factor Summary	Value	Interpretation
KMO Measure of Sampling Adequacy	0.696	Marginal but acceptable
Bartlett's Test of Sphericity	$\chi^2 = 576.807$, df = 78, $p < 0.001$	Correlation matrix appropriate
Number of Components Extracted	4	Meets Eigenvalue > 1 criterion
Cumulative Variance Explained	57.83 %	Adequate total variance
Range of Communalities	0.485 – 0.679	Moderate shared variance
Identified Components	Legibility and Prospect, Refuge and Control, Complexity and Coherence, Restorative Spatial Outcomes	Consistent with Prospect–Refuge theory

The four extracted factors, Legibility and Prospect, Refuge and Control, Complexity and Coherence, and Restorative Spatial Outcomes, represent essential qualities of environmental legibility and safety. These four factors explained 57.83% of the total variance, confirming the multidimensional nature of spatial experience in restorative design.

Correlation Analysis between Biophilic Features, Spatial Configuration and Restorative Experience

A Pearson correlation analysis was conducted to examine the relationships among Biophilic Interventions (BIRE), Prospect–Refuge spatial configuration (PRR), and Restorative Experience (RPE). The results are displayed in Table 4.6.

Table 4.6: Pearson Correlation Matrix

Variables	RPE mean	BIRE mean	PRR mean
RPE mean	1	0.763**	0.632**
BIRE mean	0.763**	1	0.748**
PRR mean	0.632**	0.748**	1

Source: Author's field work (2025)

The correlation coefficients show strong and positive relationships among all constructs. The association between RPE and BIRE (r = 0.763) is particularly strong, indicating that natural features significantly contribute to restorative experiences. The RPE–PRR relationship

(r = 0.632) shows that spatial design also plays a meaningful role. The strong correlation between BIRE and PRR (r = 0.748) further suggests that biophilic design often complements spatial qualities that enhance restoration.

Interrelationship between RPE, BIRE and PRR

The analysis revealed strong positive relationships among Restorative Experience (RPE), Biophilic Interventions (BIRE), and Prospect–Refuge (PRR), highlighting their combined role in shaping restorative perceptions within resort environments. RPE showed a robust correlation with BIRE ($r = .763$, $p < 0.01$) and a moderate correlation with PRR ($r = .632$, $p < 0.01$), indicating that both natural elements and spatial balance enhance perceived restoration. Regression results confirmed BIRE as the strongest predictor ($\beta = .659$, $p < 0.001$), while PRR contributed modestly but significantly ($\beta = .138$, $p = 0.034$). A strong interrelationship between BIRE and PRR ($r = .748$, $p < 0.01$) further suggested that resorts rich in biophilic qualities often exhibit well-structured, prospect-refuge spatial characteristics. Overall, the multiple regression model ($R^2 = 0.590$, $p < 0.001$) demonstrated that integrating biophilic and spatial strategies substantially enhances restorative experiences in resort design.

The results demonstrate that restorative experience (RPE) in resort environments is influenced by two key pathways: biophilic content—comprising daylight, vegetation, water, and natural materials and spatial configuration defined by legibility, enclosure and coherence. Reliability and factor analyses confirmed consistent dimensions across RPE, BIRE, and PRR, validating their theoretical structure. Strong positive correlations were found between RPE,

BIRE (r = 0.763), and PRR (r = 0.632), with a notable link between BIRE and PRR (r = 0.748), indicating synergistic effects between natural and spatial features. Regression analysis showed

that biophilic interventions (β = 0.659) exerted a greater influence on restoration than prospect–refuge qualities (β = 0.138), explaining 59% of the variance. These findings align with Attention Restoration Theory (Kaplan and Kaplan, 1989), Prospect–Refuge Theory (Appleton, 1975), and biophilic design principles (Kellert et al., 2008), underscoring their combined role in promoting restorative experiences.

Conclusions

This study concludes that restorative experiences in resort environments are shaped by the integration of biophilic interventions such as daylight, vegetation, water features and natural materials and spatial configuration features like legibility, prospect, refuge and coherence. The combined influence of these variables explained nearly 60% of the variance in restorative perception, confirming their joint role in enhancing mental well-being and user satisfaction. Aligning with biophilic design and restorative environment theories (Kellert et al., 2008; Kaplan and Kaplan, 1989; Appleton, 1975), the study provides an empirically validated framework (RPE, BIRE and PRR) for assessing restorative quality in hospitality design. It recommends prioritizing natural materials, balanced spatial layouts and locally responsive design approaches to strengthen human–nature connection and sustainability. Future research should incorporate physiological and post-occupancy assessments such as HRV and biometric analyses to objectively validate restorative outcomes and optimize biophilic patterns for Nigerian contexts.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

Adeola, O., & Evans, O. (2019). ICT, infrastructure, and tourism development in Africa. *Tourism Economics*, 26, 114 - 97. https://doi.org/10.1177/1354816619827712.

Adeola, O., Eigbe, O., & Muritala, O. (2020). Drivers and opportunities in Nigeria's tourism industry: Towards sustainable growth and development. *In Routledge Handbook of Tourism in Africa* (pp. 265-281). Routledge. https://doi.org/10.4324/9781351022545-23

Ajani, F., & Kalu, K. (2017). Economy diversification: a potent tool for tourism development in Nigeria. AFRREV STECH: *An International Journal of Science and Technology*, 6, 94-114.

Ajeuyjo, O. O., Ajayi, O. O., & Raufu, K. A. (2025). Exploring the role of biophilic design elements in enhancing guest well-being in resort hotels: A study from Southwestern Nigeria. *Journal of Research in Environmental and Earth Sciences*, 11(2), 1-6. https://doi.org/10.35629/2532-11020106

Akinyemi, H., Adewole, E., & Tejumaiye, A. (2024). A review of biophilic design concepts in hotel architecture. *African Journal of Environmental Sciences and Renewable Energy*, 14(1), 75-87. https://doi.org/10.62154/3aqdkf16

Andayana, I. W. Y., & Pitanatri, P. D. S. (2023). Understanding the effect of online reviews on consumer decision-making: Evidence from Alaya Resort Ubud. International Journal of Management, *Innovation & Entrepreneurial Research*, 9(2), 01-10. https://doi.org/10.18510/ijmier.2023.921

Appleton, J. (1975). *The experience of landscape*. London, England: John Wiley & Sons.

Aristizabal, S., Byun, K., Porter, P., Clements, N., Campanella, C., Li, L., Senerat, A., Nenadic, I., Ly, S., Mullan, A. F., Browning, W., Loftness, V., & Bauer, B. (2021). Biophilic office design: Exploring the impact of a multisensory approach on human well-being. *Journal of Environmental Psychology*, 77, 101682. https://doi.org/10.1016/j.jenvp.2021.101682

Assaf, A. G., & Tsionas, M. G. (2019). Quantitative research in tourism and hospitality: an agenda for best-practice recommendations. *International Journal of Contemporary Hospitality Management*, 31(7), 2776-2787. https://doi.org/10.1108/IJCHM-02-2019-0148

Backman, S. J., Huang, Y. C., Chen, C. C., Lee, H. Y., & Cheng, J. S. (2023). Engaging with restorative environments in wellness tourism. *Current Issues in Tourism*, 26(5), 789-806. https://doi.org/10.1080/13683500.2022.2039100

Baranova, A., & Kegeyan, S. (2018). Urban planning of the resort infrastructure in modern conditions. 193, 01027. https://doi.org/10.1051/matecconf/201819301027.

Barragan-Jason, G., Loreau, M., De Mazancourt, C., Singer, M., & Parmesan, C. (2023). Psychological and physical connections with nature improve both human well-being and nature conservation: A systematic review of meta-analyses. *Biological Conservation.* https://doi.org/10.1016/j.biocon.2022.109842.

Bassey, B. E. (2015). Transforming the Nigeria tourism industry through tourism entrepreneurial development. *African Journal of Business Management*, 9(15), 569-580. https://doi.org/10.5897/AJBM2015.7844

Basu, A., Duvall, J., & Kaplan, R. (2019). Attention restoration theory: Exploring the role of soft fascination and mental bandwidth. *Environment and Behavior*, 51(9-10), 1055-1081. https://doi.org/10.1177/0013916518774400

Berto, R., Barbiero, G., Barbiero, P., & Senes, G. (2018). An Individual's Connection to Nature Can Affect Perceived Restorativeness of Natural Environments. Some Observations about Biophilia. *Behavioural Sciences*, 8(3), 34. https://doi.org/10.3390/bs8030034

Bolten, B., & Barbiero, G. (2020). Biophilic Design: How to enhance physical and psychological health and wellbeing in our built environments. https://doi.org/10.13135/2384-8677/3829

Brielmann, A. A., Buras, N. H., Salingaros, N. A., & Taylor, R. P. (2022). What happens in your brain when you walk down the street? Implications of architectural proportions, biophilia, and fractal geometry for urban science. *Urban Scienc*e, 6(1), 3. https://doi.org/10.3390/urbansci6010003

Brodie, A. (2021). *The Urban Character of the Early English Seaside Resort 1700-1847*. PhD thesis University of Westminster Architecture and Cities https://doi.org/10.34737/v5606

Browning, W. D., & Ryan, C. O. (2020). Nature inside: a biophilic design guide. Routledge.

Cheer, J., Mary, M., & Lew, A. (2022). Cultural ecosystem services and placemaking in peripheral areas: a tourism geographies agenda. *Tourism Geographies*, 24, 495 - 500.

Collis, J., & Hussey, R. (2020). Business Research (7th edition). Palgrave Macmillan

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Dauda, S. M., Ojo, M. A., Oyefolahan, I. O., Usman, A. U., Muhammad, I. B., Olaniyi, O. M., Ojeniyi, J. A., Adediran, O. A., Ndajiwo, H., & Yunusa, A. (Eds.). (2023, September). Guidelines for the Preparation of Theses & Reference Management Software Manual. School of Postgraduate Studies, Federal University of Technology Minna.

Deroos, J. (2012). Planning and Programming a Hotel. 321-332.

Dillette, A., Douglas, A., & Andrzejewski, C. (2021). Dimensions of holistic wellness as a result of international wellness tourism experiences. *Current Issues in Tourism*, 24, 794 - 810. https://doi.org/10.1080/13683500.2020.1746247.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail and mixed-mode surveys: The tailored design method (4th ed.). John Wiley & Sons.

Divya, C., & Naachimuthu, K. P. (2020). Human nature connection and mental health: What do we know so far?. *Indian Journal of Health and Well-being*, 11(1-3), 84-92. https://doi.org/10.15614/ijhw.v11i01.18

Dosen, A., & Ostwald, M. (2016). Evidence for prospect-refuge theory: a meta-analysis of the findings of environmental preference research. *City, Territory and Architecture*, 3, 1-14. https://doi.org/10.1186/s40410-016-0033-1.

Elsadek, M., Sun, M., Sugiyama, R., & Fujii, E. (2019). Cross-cultural comparison of physiological and psychological responses to different garden styles. *Urban Forestry & Urban Greening*. https://doi.org/10.1016/J.UFUG.2018.11.007.

Emami, M., Rezaei, S., Sangani, B., & Goh, S. K. (2019). Ethical Considerations in Quantitative Tourism and Hospitality Researches. *Quantitative Tourism Research in Asia: Current Status and Future Directions*, 311-322. https://doi.org/10.1007/978-981-13-2463-5_15

Esu, B.B. (2015). Transforming the Nigeria tourism industry through tourism entrepreneurial development. *African Journal of Business Management*, 9, 569-580.

Geneshka, M., Coventry, P., Cruz, J., & Gilbody, S. (2021). Relationship between green and blue spaces with mental and physical health: a systematic review of longitudinal observational studies. *International Journal of Environmental Research and Public Health*, 18(17), 9010. https://doi.org/10.3390/ijerph18179010

George, D., & Mallery, P. (2024). IBM SPSS Statistics 29: Step by Step — A Simple Guide and Reference (18th ed.). Routledge, NY: USA.

Gifford, R. (2007). Environmental Psychology: Principles and Practice (4th ed.) Optimal Books.

Grimm, A., Oabel, A., Steiner, H., & Winston, R. J., (2023). Curbing sediment: The effects of added surface roughness in the curb and gutter as a novel pretreatment for green infrastructure stormwater control measures. *Journal of Environmental Management*, 344,

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research*, 14(4), 175–194.

He, M., Liu, B., & Li, Y. (2023). Tourist inspiration: How the wellness tourism experience inspires tourist engagement. *Journal of Hospitality & Tourism Researc*h, 47(7), 1115-1135.

Huang, Q., Yang, M., Jane, H. A., Li, S., & Bauer, N. (2020). Trees, grass, or concrete? The effects of different types of environments on stress reduction. *Landscape and Urban Planning*, 193, 103654. https://doi.org/10.1016/j.landurbplan.2019.103654

Hung, S. H., & Chang, C. Y. (2022). How do humans value urban nature? Developing the perceived biophilic design scale (PBDs) for preference and emotion. *Urban Forestry & Urban Greening*, 76, 127730. https://doi.org/10.1016/j.ufug.2022.127730

Hung, S., & Chang, C. (2021). Health benefits of evidence-based biophilic-designed environments: *A Review*. 24, 1-16. https://doi.org/10.11628/KSPPE.2021.24.1.1.

Ifebi, O. C., Obi-George, L. C., Maduka, N. M., Nzewi, N. U., & Ochonogor, H. (2024). Integration of Biophilic Design Elements in Hotel Building Environment Towards Enhancing Users Wellbeing in Abuja, Nigeria. *International Journal of Innovative Environmental Studies Research*, 12(4), 134-151.

Ilovan, O. R., & Markuszewska, I. (2022). Introduction: Place attachment–Theory and practice. In Preserving and constructing place attachment in Europe (pp. 1-29). *Cham*: Springer International Publishing.

Inalhan, G., Yang, E., & Weber, C. (2021). Place attachment theory. In A handbook of theories on designing alignment between people and the office environment (pp. 181-194). Routledge. https://doi.org/10.1201/9781003128830-16

James, E. E., & Essien, A. U. (2019). Infrastructure and sustainable tourism development in Nigeria. *Journal of Humanities and Social Science*s, 24(2), 70-81.

Jiang, S. (2022). Nature through a hospital window: The therapeutic benefits of landscape in architectural design. Routledge.

Jiang, S., Allison, D., & Duchowski, A. (2022). Hospital Greenspaces and the Impacts on Wayfinding and Spatial Experience: An Explorative Experiment Through Immersive Virtual Environment (IVE) Techniques. *HERD: Health Environments Research & Design Journal*, 15, 206 - 228. https://doi.org/10.1177/19375867211067539.

Jimenez, M. P., DeVille, N. V., Elliott, E. G., Schiff, J. E., Wilt, G. E., Hart, J. E., & James, P. (2021). Associations between nature exposure and health: a review of the evidence. *International Journal of Environmental Research and Public Health*, 18(9), 4790. https://doi.org/10.3390/ijerph18094790

Joye, Y., & van den Berg, A. E. (2018). Restorative environments. Environmental psychology: An introduction, 65-75. https://doi.org/10.1002/9781119241072.ch7 Joye, Y., & van den Berg, A. E. (2018). *Restorative Environments. Environmental Psychology: An Introduction*, 65-75. https://doi.org/10.1002/9781119241072.ch7

Kaplan, R., & Kaplan, S. (1989). The Experience of Nature: A Psychological Perspective. (pp. 47-50), Cambridge University Press.

Kaplan, R., Kaplan, S., & Brown, T. (1989). Environmental Preference. *Environment and Behaviour*, 21, 509 - 530. https://doi.org/10.1177/0013916589215001.

Kellert, S. R. (2012). *Birthright: People and nature in the modern world*. Yale University Press.

Kellert, S. R. (2012). *Building for life: Designing and understanding the human-nature connection*. Island Press.

Kellert, S. R., & Wilson, E. O. (1993). *The Biophilia Hypothesis*. https://archive.org/details/biophiliahypothe0000unse/page/n5/mode/2up

Kellert, S. R., Heerwagen, J., & Mador, M. (Eds.). (2008). Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life. Wiley: Hoboken, NJ: USA.

Kellert, S.R., Heerwagen, J., & Mador, M. (2011). *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life.*

Kolawole, G. T., Jude, C., Adedeji, E. O., Omotayo, O. L., Attahiru, H., & Akintade, E. A. (2020). Exploring The Security Challenges In Hospitality and Tourism In Nigeria. Revista De Turism-Studii Și Cercetări in Turism, (29).

Kumar, R. (2018). Research Methodology: A Step-by-Step Guide for Beginners. Sage Publications.

Kwak, S., Choi, K. (2025). Visual perceptions of wood-integrated material combinations: effects on psychological and physiological responses. *J. Wood Sci*. 71, 20. https://doi.org/10.1186/s10086-025-02191-3.

Lefosse, D., van Timmeren, A., & Ratti, C. (2023). Biophilia upscaling: A systematic literature review based on a three-metric approach. *Sustainability*, 15(22), 15702. https://doi.org/10.3390/su152215702

Lehto, X. Y., & Lehto, M. R. (2019). Vacation as a public health resource: Toward a wellness-centered tourism design approach. *Journal of Hospitality & Tourism Research*, 43(7), 935-960. https://doi.org/10.1177/1096348019849684

Lei, Q., Lau, S. S. Y., Yuan, C., & Qi, Y. (2022). Post-occupancy evaluation of the biophilic design in the workplace for health and wellbeing. Buildings, 12(4), 417. https://doi.org/10.3390/buildings12040417

Lencastre, M., Vidal, D., Lopes, H., & Curado, M. (2023). Biophilia in pieces: Critical approach of a general concept. *Environment and Social Psychology*. vol. 8.

Levytska, O. H. (2024). Peculiarities of ecologically oriented recreational complexes of Europe. Bulletin of the National Technical University “KhPI”. Series: Chemistry, *Chemical Technology and Ecology*, 1(11), 69-77. https://doi.org/10.20998/2079-0821.2024.01.09

Li, C., Yuan, Y., Sun, C., & Sun, M. (2022). The Perceived Restorative Quality of Viewing Various Types of Urban and Rural Scenes: Based on Psychological and Physiological Responses. *Sustainability*, 14(7), 3799. https://doi.org/10.3390/su14073799

Li, Y., Lin, X., Li, S., Huang, M., Ren, Z., & Song, Q. (2025). Restorative Environment Design Drives Well-Being in Sustainable Elderly Day Care Centres. *Buildings*, 15(5), 757.

Liu, J., Pan, H., & Zheng, S. (2019). Tourism development, environment and policies: differences between domestic and international tourists. *Sustainability*, 11(5), 1390. https://doi.org/10.3390/SU11051390

Lyu, K., de Dear, R., Brambilla, A., & Globa, A. (2022). Restorative benefits of semi-outdoor environments at the workplace: Does the thermal realm matter?. *Building and Environment*, 222, 109355. https://doi.org/10.1016/j.buildenv.2022.109355

Magomedova, A., & Fatima, G. (2025). Mental health and well-being in the modern era: a comprehensive review of challenges and interventions. *Cureus*, 17(1). https://doi.org/10.7759/cureus.77683

Marois, A., Charbonneau, B., Szolosi, A. M., & Watson, J. M. (2021). The Differential Impact of Mystery in Nature on Attention: An Oculometric Study. *Frontiers in psychology*, *12*, 759616. https://doi.org/10.3389/fpsyg.2021.759616.

Marselle, M. R., Lindley, S. J., Cook, P. A., & Bonn, A. (2021). Biodiversity and health in the urban environment. Current Environmental Health Reports, 8(2), 146–156.

Martínez-Soto, J., de la Fuente Suárez, L. A., & Ruiz-Correa, S. (2021). Exploring the links between biophilic and restorative qualities of exterior and interior spaces in Leon, Guanajuato, Mexico. *Frontiers in Psychology*, 12, 717116. https://doi.org/10.3389/fpsyg.2021.717116

Miller, M., & Rafia-Tracy, J. (2025). Experiential Programming for Resorts. *Tourism and Hospitality*, 6(2), 105.

Mohammed, U.A. (2022). Ecotourism in Nigeria, Challenges and Prospects: A Review. Gadau *Journal of Pure Allied Science*, 1(1): 12-17. https://doi.org/10.54117/gjpas.v1i1.3.

Nwabuko, O. (2024). An overview of research study designs in quantitative research methodology. *American Journal of Medical and Clinical Research & Reviews*, 3(5), 1-6. https://doi.org/10.58372/2835-6276.1169

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B, 19*(7), 305-343.

Papallou, E., Katafygiotou, M., & Dimopoulos, T. (2024). Emerging sustainability trends in tourist facilities: A comparative assessment of multiple hotels and resorts. *Sustainability*, 16(9), 3536. https://doi.org/10.3390/su16093536

Pavli, A., & Maltezou, H. C. (2024). Asclepieia in ancient Greece: pilgrimage and healing destinations, the forerunner of medical tourism. *Le infezioni in Medicina*, 32(1), 113–115.

Peters, T., & D'Penna, K. (2020). Biophilic design for restorative university learning environments: A critical review of literature and design recommendations. *Sustainability*, 12(17), 7064. https://doi.org/10.3390/su12177064

Pham, T. P., & Sanocki, T. (2024). Human attention restoration, flow, and creativity: A conceptual integration. *Journal of Imaging*, 10(4), 83. https://doi.org/10.3390/jimaging10040083

Plotnikova, T. (2021). Biophilic Design Principles-The Power of Individual Initiative. *KIEAE Journal*, 21(4), 5-10. https://doi.org/10.12813/kieae.2021.21.4.005.

Punch, K. F. (2013). Introduction to social research: Quantitative and qualitative approaches (3rd ed.). Sage Publications.

Purani, K., & Kumar, D. S. (2018). Exploring restorative potential of biophilic servicescapes. *Journal of Services Marketing*, 32(4), 414-429. https://doi.org/10.1108/JSM-03-2017-0101

Rak, T., & Wrześniowski, S. (2023). Cronbach's Alpha-what makes it really good? Some advice for planning and criticizing psychological questionnaires. *Przegląd Psychologiczny*, 66(4), 151-167.

Ratcliffe E (2021) Sound and Soundscape in Restorative Natural Environments: A Narrative Literature Review. Front. *Psychol.* 12:570563. https://doi.org/10.3389/fpsyg.2021.570563

Reese, G., Kohler, E., & Menzel, C. (2021). Restore or get restored: The effect of control on stress reduction and restoration in virtual nature settings. *Sustainability*, 13(4), 1995. https://doi.org/10.3390/SU13041995

Russo, A., & Cirella, G. T. (2020). Urban sustainability: integrating ecology in city design and planning. In Sustainable human–nature relations: Environmental scholarship, economic evaluation, *Urban Strategies* (pp. 187-204). Singapore: Springer Singapore. https://doi.org/10.1007/978-981-15-3049-4_10

Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic design patterns: Emerging nature-based parameters for health and well-being in the built environment. *International Journal of Architectural Research: ArchNet-IJAR, 8*(2), 62–76. https://doi.org/10.26687/archnet-ijar.v8i2.436

Sachin, A., & Dash, S. P. (2022). A systematic review on implications of Biophilic design as a Salutogenic approach to wellness tourism. *ECS Transactions, 1*07(1), 17395. https://doi.org/10.1149/10701.17395ecst

San Juan, C., Subiza-Pérez, M., & Vozmediano, L., (2017) Restoration and the City: The Role of Public Urban Squares Volume 8, https://doi.org/10.3389/fpsyg.2017.02093

Sayyora, Safaeva, & Diyora Adilova (2020). MICE: Tourism: Opportunities, Priorities, Problems, Prospects. *The American Journal of Applied Sciences*, 2(11), 116–121. https://doi.org/10.37547/tajas/Volume02Issue11-21

Schumann, F., Steinborn, M. B., Kürten, J., Cao, L., Händel, B. F., & Huestegge, L. (2022). Restoration of attention by rest in a multitasking world: Theory, methodology, and empirical evidence. *Frontiers in Psychology*, 13, 867978.

Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach. John Wiley & Sons.

Shahid, S., & Paul, J. (2022). Examining guests' experience in luxury hotels: evidence from an emerging market. *Journal of Marketing Management*, 38, 1278 - 1306. https://doi.org/10.1080/0267257X.2022.2085768.

Sillmann, T. A., Marques, P. O., & Mattiuz, C. F. M. (2024). Therapeutic gardens: historical context, foundations, and landscaping. *Ornamental Horticulture*, 30, e242740. https://doi.org/10.1590/2447-536x.v30.e242740

Singh, S., Sabahat, M., & Qamrudiin, J. (2021). The impact of architecture in the process of healing & well-being. *International Journal for Research in Applied Science & Engineering Technology*, 9(3), 202-222.

Smith, M. K., & Puczkó, L. (Eds.). (2016). The Routledge handbook of health tourism. Taylor & Francis.

Smith, M., & Ram, Y. (2017). Tourism, landscapes and cultural ecosystem services: a new research tool. *Tourism Recreation Research*, 42, 113 - 119. https://doi.org/10.1080/02508281.2016.1253206.

Suess, C., Legendre, T. S., & Hanks, L. (2024). Biophilic urban hotel design and restorative experiencescapes. *Journal of Hospitality & Tourism Researc*h, 48(8), 1572-1593. https://doi.org/10.1177/10963480241244720

Suta Wayan Purwanta, Nyoman Abdi, & I Putu Mertha Astawa. 2021. Sustainable Tourism Development in Importance and Performance Perspective, 342–346.

Teeroovengadum, V., & Nunkoo, R. (2018). Sampling design in tourism and hospitality research. In Handbook of research methods for tourism and hospitality management (pp. 477-488). Edward Elgar Publishing. https://doi.org/10.4337/9781785366284.00048

Tipler, S., & Ruddell, E. (2025). Understanding Attention Restoration Theory through the Lens of Nature Writers: A Content Analysis. *Journal of Outdoor Recreation, Education, and Leadership*, 17(2), n2. https://doi.org/10.18666/jorel-2025-12134

To, P. T., & Grierson, D. (2024). A study on children's multi-sensorial experiences of nature: design approaches and preferences for primary school architecture case studies in Glasgow, Scotland, UK. Archnet-IJAR: *International Journal of Architectural Research*, 18(2), 225-246. https://doi.org/10.1108/arch-02-2023-0053

Uduma-Olugu, N., & Onukwube, H. N. (2015). Exploring the Coastal Tourism Potentials of Lagos. Lagos Journal of Architecture, 1,

Ugwukah, A., & Obomanu, V. S. O. (2020). Tourism and Economic Development in Nigeria: A Critical Assessment of the Obudu Mountain Resort, Cross River State.

Ukpabi, D. C., & Karjaluoto, H. (2017). Consumers' acceptance of information and communications technology in tourism: A review. *Telematics and Informatics*, 34(5), 618-644.

Ulrich, R. S. (2023). Stress reduction theory. D. Marchand, E. Pol, & K. Weiss (Eds.), 100, 143-146.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201-230.

UNESCO World Heritage Centre. (a.n.d.). The Great Spa Towns of Europe. Retrieved from https://whc.unesco.org/en/list/1613/

Ventriglio, A., Torales, J., Castaldelli-Maia, J. M., De Berardis, D., & Bhugra, D. (2021). Urbanization and emerging mental health issues. CNS spectrums, 26(1), 43-50. https://doi.org/10.1017/S1092852920001236

Wedekind, M. (2021). Blicke von der Veranda: Luxustourismus in den Alpen der Jahrhundertwende. Góry-Literatura-Kultura, 15(1), 101-132. https://doi.org/10.19195/2084-4107.15.7

Wilson, E. O. (1984). Biophilia. Harvard University Press https://archive.org/details/edward-o.-wilson-biophilia/page/n5/mode/2up

Wu, D., Song, H., & Shen, S. (2017). New developments in tourism and hotel demand modelling and forecasting. *International Journal of Contemporary Hospitality Management*, 29, 507-529. https://doi.org/10.1108/IJCHM-05-2015-0249.

Yao, W., Chen, F., Wang, S., & Zhang, X. (2021). Impact of exposure to natural and built environments on positive and negative affect: a systematic review and meta-analysis. *Frontiers in Public Health*, 9, 758457.

Yildirim, M., Gocer, O., Globa, A., & Brambilla, A. (2023). Investigating restorative effects of biophilic design in workplaces: a systematic review. *Intelligent Buildings International*, 15(5), 205-247. https://doi.org/10.1080/17508975.2024.2306273

Yusli NANM., Roslan S., Zaremohzzabieh Z., Ghiami Z., & Ahmad N., (2021) Role of Restorativeness in Improving the Psychological Well-Being of University Students. *Front. Psychol*. 12:646329. doi.org/10.3389/fpsyg.2021.646329

Yusuff, M., & Aliu, A. (2019). Analysis of the pull factors for domestic tourism in Nigeria. *European Journal of Accounting, Finance & Business*, 9(19), 1-13. Https://Doi.Org/10.4316/Ejafb.2019.715

Zhang, L., Liu, S., & Liu, S. (2021). Mechanisms underlying the effects of landscape features of urban community parks on health-related feelings of users. *International Journal of Environmental Research and Public Health*, 18(15), 7888. https://doi.org/10.3390/ijerph18157888

Zhong, L., Deng, B., Morrison, A. M., Coca-Stefaniak, J. A., & Yang, L. (2021). Medical, health and wellness tourism research—A review of the literature (1970–2020) and research agenda. *International Journal of Environmental Research and Public Health*, 18(20), 10875. https://doi.org/10.3390/ijerph182010875

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Assessing Global Covid-19 Recovery Roadmaps for Enhancing Resilience in Nigeria's Construction Sector: A Comparative Framework for Sustainable Adaptation

Tasleemah YUSUF [1*]

ORCID 1: 0009-0007-3073-0556
[1]Ahmadu Bello University, Faculty of Environmental Design, Department of Quantity Surveying, Zaria- Nigeria
tasleemahyusuf@gmail.com (Responsible Author)

Peter Gangas CHINDO [2]

ORCID 2: 0000-0001-9902-7497
[2]Prof, Ahmadu Bello University, Faculty of Environmental Design, Department of Quantity Surveying, Zaria-Nigeria
pcgangas@yahoo.com

Mustapha ABDULRAZAQ [3]

ORCID 3: 0000-0002-3219-0203
[3]Prof, Ahmadu Bello University, Faculty of Environmental Design, Department of Quantity Surveying, Zaria-Nigeria
Musteephd@gmail.com

Abstract

The COVID-19 pandemic posed significant health and social challenges, impacting construction and social environments globally. This study reviewed recovery measures in construction companies and empirically assessed a comparative framework for sustainable adaptation of COVID-19 recovery roadmaps to enhance resilience in Nigeria's construction sector. Conducted in Abuja, Nigeria's capital, the research employed a sequential mixed-methods design with a purposive sample of 20 experts, including policymakers, contractors, professionals, and academics ensuring diversity through snowball sampling. Qualitative analysis used NVivo 14 for coding and theme development, with triangulation to strengthen credibility. The socio-demographic data of participants provided context for interpretation. Findings reveal that global COVID-19 recovery roadmaps converge on risk assessment, digital integration, and sustainability. Recommendations include implementing e-portals and legal mandates for Public-Private Partnerships to streamline approvals, adopting hybrid digital tools like offline BIM with solar backup, and establishing vocational hubs for digital upskilling of informal workers. Additionally, professional bodies such as the Nigerian Institute of Building and academics should pilot multi-regional strategies to validate and test roadmap efficacy, thus fostering resilient recovery in Nigeria's construction industry.

Keywords: COVID-19, roadmaps, resilience, e-portals, construction industry, Nigeria

1. Introduction

The COVID-19 pandemic has brought along an untold hardship on humanity presenting itself as both health and human crisis, and has had direct or indirect effects on people's working and social environments (Idakwo et al., 2022; Umar, 2022). The shutting down restrictions were observed due to the pandemic's adverse bearing on all sectors, including construction companies, manufacturing, Agri-allied industries, and finance (Gültekin & Sarı, 2022). This issue caused acute economic contraction in both developing and industrialized nations (Wang et al., 2020). Before the emergence of Covid-19, tackling hunger and insecurity among the Nigerian populace has been one onerous task confronting the Nigerian government (Idakwo et al., 2022). This trend nosedived even further as the country was thrown into recession in 2020 due to the impact of the pandemic; in a nutshell, the pandemic unleashed unprecedented

disruptions across global economies (Idakwo & Oladimeji, 2024), with the Nigerian construction sector facing severe setbacks, including project suspensions, financial distress, and workforce reductions (Aigbavboa et al., 2023). Since the first case of Coronavirus was reported in Nigeria in early 2020, an unprecedented economic situation has followed, giving rise to increasing prices of economic good including construction materials in the country (Idakwo et al., 2022). Construction materials in Nigeria were under serious threat and prices have been rising drastically, and in most cases recording almost double due to the impact of economic lockdown and social distancing imposed by various governments as measures to curtail the spread of Coronavirus. The aim of this study is to assess global Covid-19 recovery roadmaps for enhancing resilience in Nigeria's construction sector and highlight a comparative framework for sustainable adaptation.

2. Materials and Methods

The study was carried out in Abuja, the Federal Capital Territory (FCT) of Nigeria, selected for its representativeness of the national construction industry's recovery dynamics. Its diverse stakeholder ecosystem, encompassing government agencies, multinational contractors, and professional bodies, facilitates access to key informants, while its economic centrality, contributing significantly to national Gross Domestic Product through construction activities, ensures findings are extrapolable to other Nigerian regions facing similar oil-dependent fiscal constraints and infrastructural deficits (Ebekozien & Aigbavboa, 2023). Data collection was confined to Abuja to optimize logistical feasibility without compromising contextual depth.

A sequential mixed-methods design was utilized, integrating qualitative content analysis of global literature with semi-structured expert interviews, followed by a synthetic phase to derive a tailored roadmap. A purposive sample of approximately 20 experts was targeted, determined by the principle of data saturation, wherein recruitment ceases upon redundancy in emergent themes (Guest et al., 2006). This sample size balances depth with practicality, drawing from qualitative research norms where 15–30 participants suffice for thematic richness in specialized domains (Braun & Clarke, 2021). Inclusion criteria encompassed at least 10 years of relevant experience in Nigeria's construction sector and direct involvement in COVID-19 response or recovery initiatives. Participants were stratified across stakeholder categories (e.g., 5 policymakers, 5 contractors, 5 experts/professionals, 5 academics) to ensure representational diversity, with snowball sampling employed to access hard-to-reach informants. Analysis proceeded qualitatively, utilizing NVivo software (Version 14) for systematic coding and theme generation, with triangulation enhancing credibility.

3. Findings and Discussion

The socio-demographic characteristics of the 20 expert interviewees in Table 1 provide a foundational lens for interpreting the qualitative insights, reflecting a diverse yet representative cross-section of Nigeria's construction stakeholders. Participants were purposively selected from Abuja, encompassing policymakers (n=5), contractors (n=5), construction professionals/experts (n=5), and academics (n=5), with data saturation achieved after the 18th interview, as subsequent responses yielded redundant themes.

Demographically, the sample skewed male (75 per cent, n=15), though female representation (25 per cent, n=5) offered nuanced perspectives on inclusive recovery. Ages ranged from 35 to 62 years (mean=48.2, SD=7.4), with the majority (60 per cent, n=12) aged 45–55, indicative of mid-to-senior career stages where experiential depth informs strategic insights. Professional

experience averaged 18.6 years (range=12–32, SD=5.1), enabling rich discussions on recovery dynamics. Educationally, all held at least a bachelor's degree in construction-related fields, with 55 per cent (n=11) possessing master's or doctoral qualifications. Organisational affiliations varied: 40 per cent (n=8) from public sector entities, 35 per cent (n=7) from private firms, and 25 per cent (n=5) from academia/professional bodies. Geographically, while all were Abuja-based, 65 per cent (n=13) had multi-regional project exposure, broadening applicability. These characteristics underscore the sample's robustness, with balanced representation across categories fostering exhaustive insights into contextual adaptations, such as hybrid digital solutions for informal workers and policy reforms for oil volatility.

Table 1: Socio-Demographic Profile of Respondents

Characteristics	Category	Frequency (n=20)	Percentage (%)
Gender	Male	15	75
	Female	5	25
Age group (years)	35–44	8	40
	45–55	12	60
	56–62	0	0
Professional experience	12–20	12	60
	21–32	8	40
Highest qualification	Bachelor's	9	45
	Master's/Doctoral	11	55
Stakeholder category	Policymakers	5	25
	Contractors	5	25
	Professionals/Experts	5	25
	Academics	5	25
Multi-regional exposure	Yes	13	65
	No	7	35

Analysis of existing COVID-19 recovery roadmaps in the global construction industry

This section synthesizes global recovery roadmaps from the literature, employing NVivo thematic coding to extract core elements such as phases, strategies, metrics, and limitations depicts in Table 2. The analysis distils four key roadmaps into a single comparative table, facilitating lucid comparison while discussing alignments and divergences. This approach reveals a predominant emphasis on dynamic capabilities and risk mitigation, aligning with resilience theory (Folke et al., 2016) but diverging in contextual specificity e.g., China's centralized stimuli contrast U.S. firm-level agility.

Table 2: Comparative Synthesis of Global COVID-19 Recovery Roadmaps

Roadmap/ Source	Key Phases/Structure	Core Strategies	Metrics/KPIs	Strengths	Limitations
U.S. (Chih et al., 2022)	Sensing, Seizing, Reconfiguring	Digital tools (BIM), health protocols, supply diversification	Organizational agility scores, cost variance	Firm-level agility, empirical grounding	Large-firm bias, short timeframe, macro neglect
China (Guo et al., 2023)	Assessment, Deployment, Feedback	Innovation, government subsidies, workforce safeguards	25 KPIs (e.g., ROI, safety incidents)	Quantitative prioritization (AHP), holistic CSFs	Small sample, China-specific, descriptive
China (Wang et al., 2022)	Risk ID, Formulation, Monitoring	4M1E-based (e.g., modular prefab, incentives)	Qualitative assessments (e.g., efficiency gains)	Granular risk decomposition, project-specific	No stats validation, infrastructure focus
Malaysia (Gamil et al., 2022)	Mitigation, Recalibration, Reform	Health/safety, tech adoption, policy advocacy	Thematic outcomes (e.g., productivity recovery)	Practitioner insights, multi-domain	Generalized, no longitudinal eval, regulatory-centric

Thematically, roadmaps converge on phased structures: sensing/identification (e.g., risk assessment), seizing/implementation (e.g., digital adoption), and reconfiguring/evaluation (e.g., sustainability metrics). For instance, Chih et al.'s (2022) dynamic capabilities model emphasizes organizational agility, echoing CAS theory (Burns, 2020) by promoting emergent adaptations like BIM integration, which proved effective in mitigating U.S. supply disruptions but assumes robust infrastructure absent in developing contexts. Guo et al. (2023) extend this with 32 CSFs and 25 KPIs, prioritizing government support a strength in China's V-shaped recovery (Wang & Lui, 2022) yet their AHP-based prioritization aligns with game theory (Potutan et al., 2022) for stakeholder optimization, differing from Malaysia's qualitative, practitioner-driven lessons (Gamil et al., 2022) that stress health protocols over quantitative metrics.

Insightfully, these models underscore digital transformation as a universal lever, with Wang et al.'s (2022) 4M1E framework dissecting risks into actionable domains (e.g., Man: labor training), fostering exhaustive risk decomposition absent in earlier disaster recovery curves (Mileti, 1999). However, divergences emerge in scope: U.S. and Malaysian roadmaps focus on short-term operational tweaks, potentially overlooking long-term TBL sustainability (Elkington, 1997), while Chinese variants integrate environmental KPIs, aligning with Zhao et al. (2022) but critiqued for sample biases (e.g., urban-centric). Overall, this synthesis highlights global roadmaps' efficacy in structured recovery but their one-size-fits-all ethos, setting the stage for Nigerian adaptations.

Conclusion and Recommendations

The investigation concludes that global COVID-19 recovery roadmaps provide valuable phased structures and strategies, such as dynamic capabilities from Chih et al. (2022), and risk-focused 4M1E from Wang et al. (2022), their direct applicability to Nigeria is constrained by unaddressed factors like oil dependency, informal labor vulnerabilities, and infrastructural paucities. Implement e-portals and legal mandates for PPPs to streamline approvals for policymakers such as federal ministry of works; adopt hybrid digital tools (e.g., solar-backed offline BIM) and local sourcing incentives for contractors and firms; and develop vocational hubs for digital upskilling, targeting informal workers for professional bodies such as Nigerian Institute of Building are recommended and academics and researchers should employ SEM and multi-regional pilots for strategy validation, and to test roadmap efficacy.

Thanks and Information Note

The authors contributed to the study as follows: Tasleemah Yusuf conceived and initiated the research and carried out the data collection. Peter Gangas Chindo and Mustapha Abdulrazaq contributed to the survey design, methodology development, and the refinement of the results and discussion sections.

References

Aigbavboa, C. O., Oke, A. E., & Akinradewo, O. F. (2023). COVID-19 impacts on the Nigerian construction industry: Lessons learnt and the way forward. *Journal of Engineering, Design and Technology*. https://doi.org/10.1108/JEDT-11-2022-0596

Babalola, O., & Harinarain, N. (2024). Value management in construction: A systematic review. *Journal of Engineering, Design and Technology*, 22(2), 345-362. https://doi.org/10.1108/JEDT-06-2022-0332

Braun, V., & Clarke, V. (2021). Thematic analysis: A practical guide. SAGE. 376 pp. ISBN: 978-1-4739-5323-9

Burns, T. (2020). Complex adaptive systems in construction. In R. Haigh & D. Amaratunga (Eds.), Post-disaster reconstruction of the built environment: *Rebuilding for Resilience* (pp. 23-40). Wiley-Blackwell.

Burton, H. V., Kang, H., Miles, S. B., Nejat, A., & Yi, Z. (2024). Recovery curves modeling for residential structures in earthquake engineering. *Earthquake Engineering & Structural Dynamics*, 53(3), 1125-1147. https://doi.org/10.1002/eqe.4072

Chih, Y.-Y., Hsiao, C. Y. L., Zolghadr, A., & Naderpajouh, N. (2022). Resilience of organizations in the construction industry in the face of COVID-19 disturbances: Dynamic capabilities perspective. *Journal of Management in Engineering*, 38(2), 04022014. https://doi.org/10.1061/(ASCE)ME.1943-5479.0001014

Chih, Y.-Y., Hsiao, C. Y. L., Zolghadr, A., & Naderpajouh, N. (2023). Leveraging resources and dynamic capabilities for organizational resilience amid COVID-19. *Construction Management and Economics*, 41(8), 689-705. https://doi.org/10.1080/01446193.2023.2188557

Ebekozien, A., & Aigbavboa, C. (2023). COVID-19 impacts on the Nigerian construction industry: Lessons learnt and the way forward. *Journal of Engineering, Design and Technology*, *2*1(3), 721-739. https://doi.org/10.1108/JEDT-11-2022-0596

Ebekozien, A., Aigbavboa, C., Samsurijan, M. S., & Ogbaini, I. F. (2024). COVID-19 recovery for Nigeria's construction industry: Exploring challenges and opportunities. *Journal of Facilities Management*, 22(2), 256-272. https://doi.org/10.1108/JFM-07-2023-0075

Elkington, J. (1997). Cannibals with forks: The triple bottom line of 21st-century business. Capstone. ISBN: 9781900961271, 272pp.

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, 21(3), 41. https://doi.org/10.5751/ES-08748-210341

Gamil, Y., & Alhagar, A. (2020). The impact of pandemic crisis on the survival of construction industry: A case of COVID-19. *Mediterranean Journal of Social Sciences*, 11(4), 122-131. https://doi.org/10.36941/mjss-2020-0047

Gamil, Y., Rahman, I. A., & Nagapan, S. (2022). Lessons and recommendations framework for the Malaysian construction industry post-COVID-19. *Journal of Engineering, Design and Technology*, 20(5), 1257-1273. https://doi.org/10.1108/JEDT-03-2021-0156

Gültekin, A. B., & Sarı, A. (2022). Adaptation of construction sites to Covid-19 pandemic: Safe construction site certificate for Turkish construction sector. *GRID Architecture, Planning and Design Journal*, 5(2), 301-324. DOI: https://doi.org/10.37246/grid.1084132

Guo, B. H. W., Yiu, T. W., & González, V. A. (2023). Critical success factors and performance indicators for post-COVID recovery in Chinese construction projects. *Journal of Management in Engineering*, 39(1), 04022054. https://doi.org/10.1061/JMENE7.MEENG-13000

Guo, B. H. W., Yiu, T. W., & González, V. A. (2024). Integrated framework for post-COVID recovery in Chinese construction projects. *Journal of Construction Engineering and Management*, 150(3), 04023182. https://doi.org/10.1061/JCEMD4.COENG-14000

Haron, N. A., Rahman, W. F. A., Mahat, H., & Nasir, B. M. (2020). Complex adaptive systems in construction. In R. Haigh & D. Amaratunga (Eds.), Post-disaster reconstruction of the built environment: *Rebuilding for resilience* (pp. 41-60). Wiley-Blackwell.

Idakwo, D. A., Oladimeji, Y. U., Ayanlere, A. A., and Hussaini, A. S. (2022). Analysis of COVID-19 Induced Spike in Food Prices and Its Effects on Urban Households' Poverty Status in Northwest, Nigeria. *Alanya Academic Journal*, 6(3), 3009-3028. https://dergipark.org.tr/en/pub/alanyaakademik/issue/72843/1099349

Idakwo, D. A., & Oladimeji, Y. U. (2024). Poverty Dynamics Resulting from COVID-19 and Surge in Food Prices: A Case Study of Northwest Nigeria. *Journal of Agricultural Economics, Extension & Social Sciences*, 6(2), 26 – 37. ISSN: 2714-5018 (Online).

International Labour Organization. (2024). Informal labor Nigeria construction. International Labour Organization.

Mileti, D. S. (1999). Disasters by design: A reassessment of natural hazards in the United States. Joseph Henry Press. ISBN 0-309-06360-4. Pp 65-104.

Oladinrin, T. O., Ogunsemi, D. R., & Aje, I. O. (2023). Recovery measures in Nigerian construction. *Journal of Construction in Developing Countries*, 28(1), 21-40. https://doi.org/10.21315/jcdc2023.28.1.2

Osuizugbo, I. C. (2020). Adaptive networks Nigeria construction. *Journal of Engineering, Design and Technology*, 18(5), 1261-1278. https://doi.org/10.1108/JEDT-03-2020-0100

Potutan, G. E., Balairos, S. A., & Balairos, R. A. (2022). Game theory in construction. *Journal of Construction in Developing Countries*, 27(1), 41-60. https://doi.org/10.21315/jcdc2022.27.1.3

Umar, T. (2022). The Impact of COVID-19 on the GCC Construction Industry. International *Journal of Service Science, Management, Engineering, and Technology* (IJSSMET), 13(2), 1–17. https://doi.org/10.4018/IJSSMET.20220301.oa1

Wang, Z., Liu, Z., & Liu, J. (2020). Risk Identification and Responses of Tunnel Construction Management during the COVID-19 Pandemic. *Advances in Civil Engineering*, 2020, e6620539. https://doi.org/10.1155/2020/6620539

Wang, C., & Lui, A. K. H. (2023). China construction recovery COVID. *Journal of Construction Engineering and Management*, 149(1), 04022150. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002215

Wang, J., Ritchie, B. W., Yao, Y., & Pan, D. (2022). 4M1E risks China construction COVID. *Journal of Hospitality and Tourism Management*, 50, 1-12. https://doi.org/10.1016/j.jhtm.2022.01.001

Wood, G., & Gidado, K. (2008). Blockchain stakeholder coordination construction. Journal of Construction Project Management and Innovation, 8(1), 1-10.

Zhao, L., Rasoulinezhad, E., Sarker, T., & Taghizadeh-Hesary, F. (2022). Green procurement construction. *Sustainability*, 14(3), 1456. https://doi.org/10.3390/su14031456

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Evaluating Human Impact in Urban Areas, with the example of Sofia, Bulgaria

Stefan STAMENOV [1]*

ORCID 1: 0000-0001-6010-8142
[1]Chief Assit. Prof. Dr., Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia - Bulgaria
stamenovstefan@yahoo.bg **(**Responsible Author)

Vanya STAMENOVA [2]

ORCID 2: 0000-0002-8933-5426
[2] Associate Prof., Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia - Bulgaria
vanya_stamenova@yahoo.com

Abstract

The human impact on nature is traditionally one of the most important topics in science, due to its direct link with the quality of life, especially in cities, sustainability, sustainable development, and the preservation of nature. Various methods for assessing and evaluating it have been elaborated, some of which are based on remote sensing and GIS data, including air pollution and aerosols, as well as water pollution, and also urban sprawl, land degradation, land fragmentation, etc. This paper aims to present the results of a method developed by the authors, based on reinterpreting the classes of readily available land cover products. In this particular case, this is the CORINE Land Cover product, chosen for its detailed classification. The example area is the city of Sofia, Bulgaria, selected for its size, which is large enough to have a significant human impact on the area of its location, the Sofia Valley. The elaborated method was presented for the first time at the ESRI User Conference in 2025, as a poster entitled Human Impact Index in Education, included in the ESRI Map Gallery. The essence of the method is based on changing the descriptive approach of CORINE Land Cover classes into an interpretative one, in the consequent integration of the assessment index.

Keywords: Human impact, land cover, remote sensing, GIS

1. Introduction

The human impact on nature is traditionally one of the most important topics in science, due to its direct link with the quality of life, especially in cities, sustainability, sustainable development, and the preservation of nature.

Various methods for assessing and evaluating it have been developed, some of which use remote sensing and GIS data, including air pollution and aerosols, water pollution, urban sprawl, land degradation, and land fragmentation.

This paper presents the results of a method developed by the authors, which reinterprets the classes of readily available land cover products. In this particular case, the CORINE Land Cover product was chosen for its detailed classification.

The capital city of Bulgaria, Sofia, is selected as a study area for its size, which is large enough to have a significant human impact on the surrounding area—the Sofia Valley. The city of Sofia is at the foot of the Vitosha Mountain in Southwest Bulgaria. Sofia city is part of the Metropolitan (Sofia) Municipality, which also serves as a district as an administrative territorial unit (Sofia Municipality, 2022). Even though it is the smallest district in Bulgaria, it is home to the biggest city and agglomeration – Sofia, which has the highest population in the country. The territory of the modern city of Sofia covers 210 sq. km, calculated from the construction

border in the master plan of Sofia Municipality (Sofia Municipality Architecture and Town Planning Directorate & Municipal Enterprise "Sofproect – Master Plan", 2009).

Sofia lies in the southern part of the Sofia hollow (field), surrounded by the mountains – Lyulin, Vitosha, Plana, and Lozenska Mountains from west to east (*Sofia – 120 years capital: Jubilee book*, 2000). The landscape of the study areas is characterized by varied relief, including flat areas, foothills, valleys, and mountain areas. The average altitude of Sofia city is approximately 550 m a.s.l., and its southern periphery gradually rises (Sofia Municipality, 2024). The diversity of land cover is also significant, and the Sofia city territories and surrounding areas are occupied by various types of urbanized areas, agricultural lands, forests, shrubs, and open spaces with sparse vegetation. Due to the high rate of urbanization, the natural relief is significantly transformed by anthropogenic factors, resulting in several anthropogenic landforms, including artificial reservoirs (such as Iskar Dam, Pancherevo Dam, Passarel Dam), transport and industrial infrastructure, quarries, embankments, etc. (Stamenova & Stamenov, 2016).

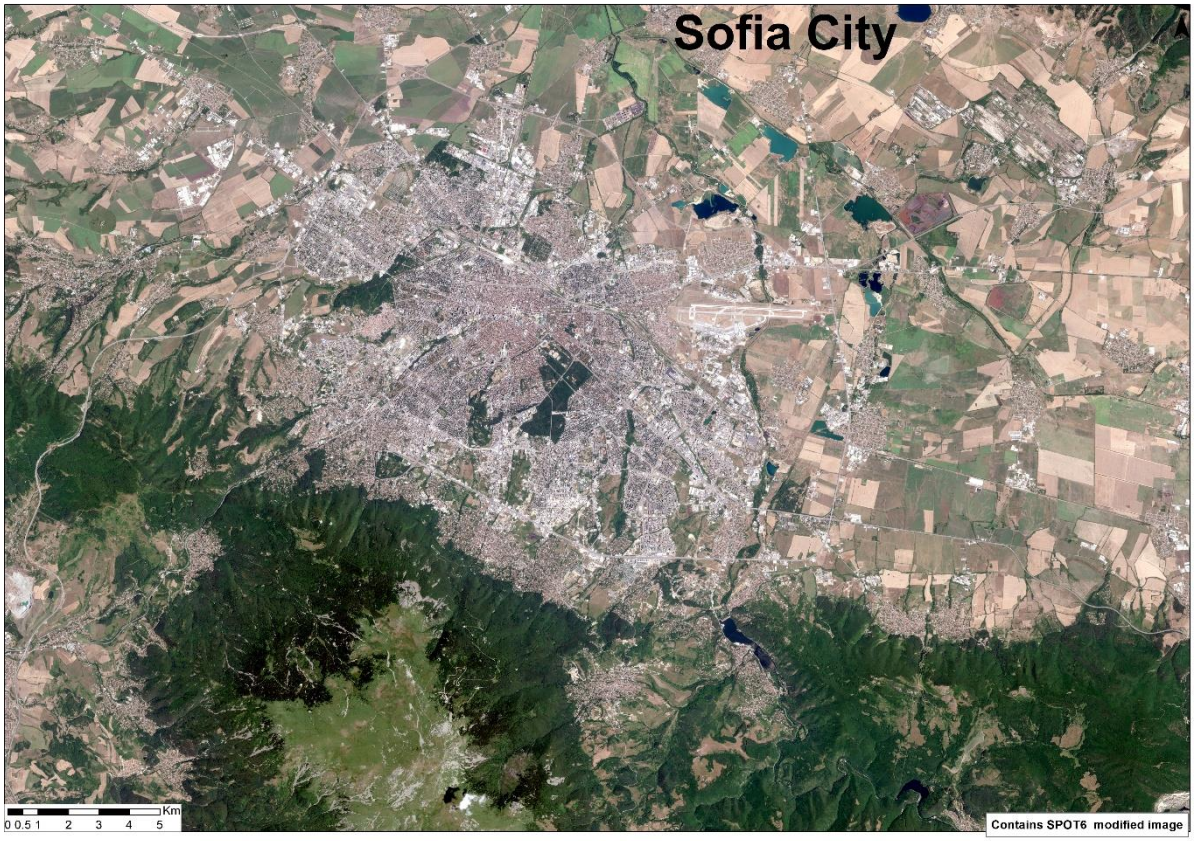


Figure 1. Study area – SPOT 6 satellite image of Sofia city

2. Materials and Methods

The data used for the project include high-resolution satellite images of Sofia City and satellite-derived land cover products for the period 2000-2024. Land cover products from the official land cover mapping of the European countries, CORINE Land Cover, have been used for this study. New datasets have been produced every 6 years since 1990, providing detailed information on land cover. The years chosen for our research are 2000 and 2018. CORINE Land Cover uses a three-level classification system with 44 classes at level 3, but only 24 are

present in the study area (European Environment Agency, 2021; Kosztra, B., Büttner, G., Hazeu, G., & Arnold, S., 2019). The data are obtained from the Copernicus Land Monitoring Service, released in May 2020, in vector format (Copernicus Land Monitoring Service, 2019). The satellite images are needed for visual representation of the study area and to provide an up-to-date snapshot. The approbation and validation of the human impact on the study area require the most recent high-spatial- and high-spectral resolution satellite data, and the chosen sensors are SPOT 6 and WorldView 3. SPOT 6, which provides suitable parameters for urban mapping (eoPortal Directory, *SPOT-6 and SPOT-7 (Azersky)*, is a cloud-free satellite image acquired on August 1, 2024. It covers the territory of Sofia city and its surroundings. WorldView 3 satellite images are also cloud-free and were acquired on 28 July and 23 August 2024. Its very high spatial resolution (European Space Agency, *WorldView-3*) provides a detailed picture of Sofia's urban area, allowing a precise distinction between the built-up areas and the small green patches.

The elaborated method was presented for the first time at the ESRI User Conference in 2025 as a poster titled "Human Impact Index in Education," which was included in the ESRI Map Gallery (Stamenov & Stamenova, 2025). Previous works on the topic of human impact were presented at the same forum in 2022 and 2023 (Stamenov & Stamenova, 2022, 2023). The essence of the method is based on changing the descriptive approach to CORINE Land Cover classes into an interpretative one, thereby enabling the integration of the assessment index. The method is based on five human impact levels, presented in Table 1. These human impact levels, as described, are assigned to the land cover classes for the Sofia city area (Table 2). In the study area, 22 of the 44 CORINE land cover classes are observed, as shown in Table 2.

Table 1. Human impact levels

Human Impact Levels		Description
Level 1	Minimal human influence	Areas with no human influence or minimal human influence. No artificial changes in land surface or underground. These are areas of natural landscapes with no permanent human structures, no artificial land surface changes, and natural vegetation, bare lands, inland waters, and wetlands.
Level 2	Weak human influence	Semi-natural territories with or without single permanent human structures or road networks - natural landscapes and vegetation with no or minimal artificial changes in the land surface, bio-agriculture, perennial crops, pastures.
Level 3	Moderate Human Influence	Regular artificial changes of the land surface - regular land cultivation and use of synthetic chemicals, no permanent human buildings, and agriculture.
Level 4	Strong Human Influence	Permanent human structures - buildings and road networks with artificial coverage, artificial changes of land surface due to construction purposes, urban discontinuous surfaces, small patches of open ground, tailing ponds, and inland waters close to significant industrial zones.
Level 5	Very Strong Human Influence	Areas with constant human influence, permanent artificial surfaces, and artificial relief, including industrial areas and continuous urban surfaces.

Table 2. CORINE Land Cover nomenclature and assigned human impact values (only for 22 land cover classes observed at the study area)

CORINE Land Cover classification			Human Impact value
Level 1	Level 2	Level 3	
1. Artificial Surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric	5
		1.1.2 Discontinuous urban fabric	4
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units	5
		1.2.2 Road and rail networks and associated land	5
		1.2.4 Airports	5
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites	5
		1.3.2 Dump sites	5
	1.4 Artificial, non-agricultural vegetated areas	1.4.1 Green urban areas	3
		1.4.2 Sport and leisure facilities	3
2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land	3
		2.2.2 Fruit trees and berry plantations	2
	2.3 Pastures	2.3.1 Pastures	2
	2.4 Heterogeneous agricultural areas	2.4.2 Complex cultivation patterns	3
		2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation	2
3. Forest and seminatural areas	3.1 Forest	3.1.1 Broad-leaved forest	1
		3.1.2 Coniferous forest	1
		3.1.3 Mixed forest	1
	3.2 Shrub and/or herbaceous vegetation associations	3.2.1 Natural grassland	1
		3.2.4 Transitional woodland/shrub	1
	3.3 Open spaces with little or no vegetation	3.3.2 Bare rock	1
		3.3.3 Sparsely vegetated areas	1
4. Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes	1
		4.1.2 Peatbogs	1
5. Water bodies		5.1.2 Water bodies	2

- **Findings and Discussion**

The CORINE Land Cover maps of Sofia city and its surroundings show the land cover distribution, which is determined by the town's location in the southern part of the Sofia valley at the foothills of Vitosha Mountain. Agricultural areas surround the city to the west, north, and east, while on the southern side, it borders the Vitosha Nature Park (Figures 2 and 3). The city comprises most of the Artificial surfaces' classes. Still, the most prevailing are Discontinuous urban fabric (class 112) and Industrial and commercial units (class 121). As shown in the pie charts, the four land cover classes with percentages above 5% are the same in both years: non-irrigated arable land (class 211), discontinuous urban fabric (class 112), broad-leaved forest (class 311), and industrial or commercial units (class 121) (Figures 4 and 5). The most widely represented class is 211, which over these 18 years decreases by about 2.5%, from 38.58% to 36.03%. An increase is observed for class 121, which went from 5.81% to 7.55%. The other two classes (112 and 311) remain almost unchanged from 2000 to 2018, respectively, class 112 (16.29% to 16.27%), and class 311 (10.01% to 9.87%).

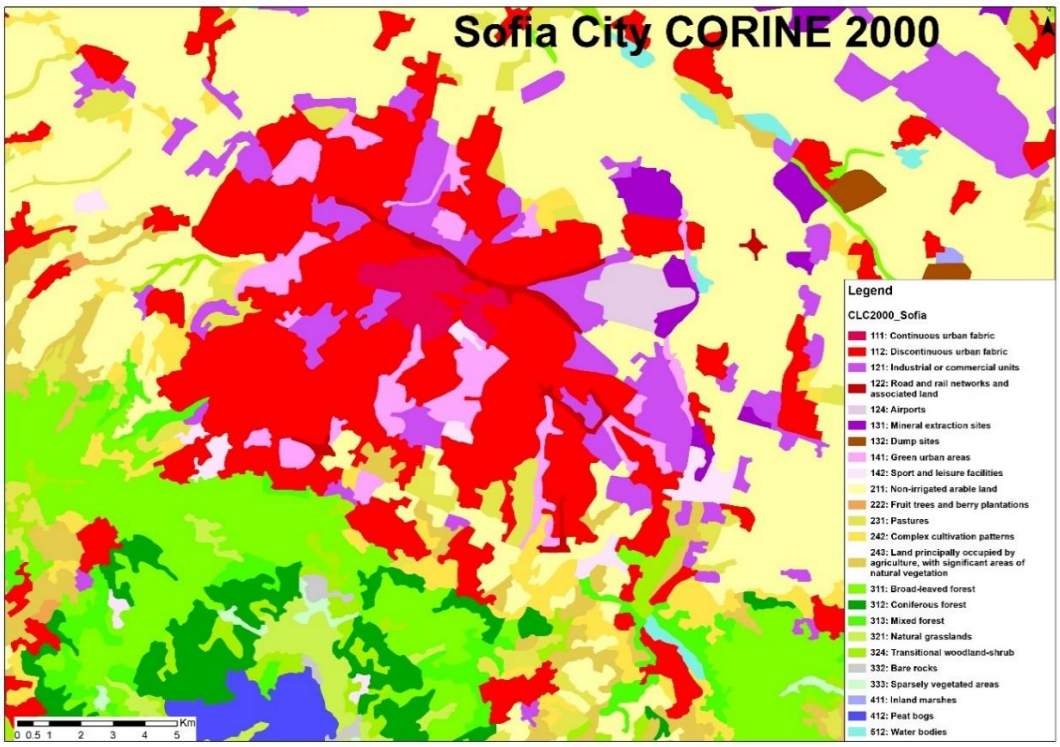


Figure 2. Map of CORINE Land Cover of Sofia city and its surroundings for 2000

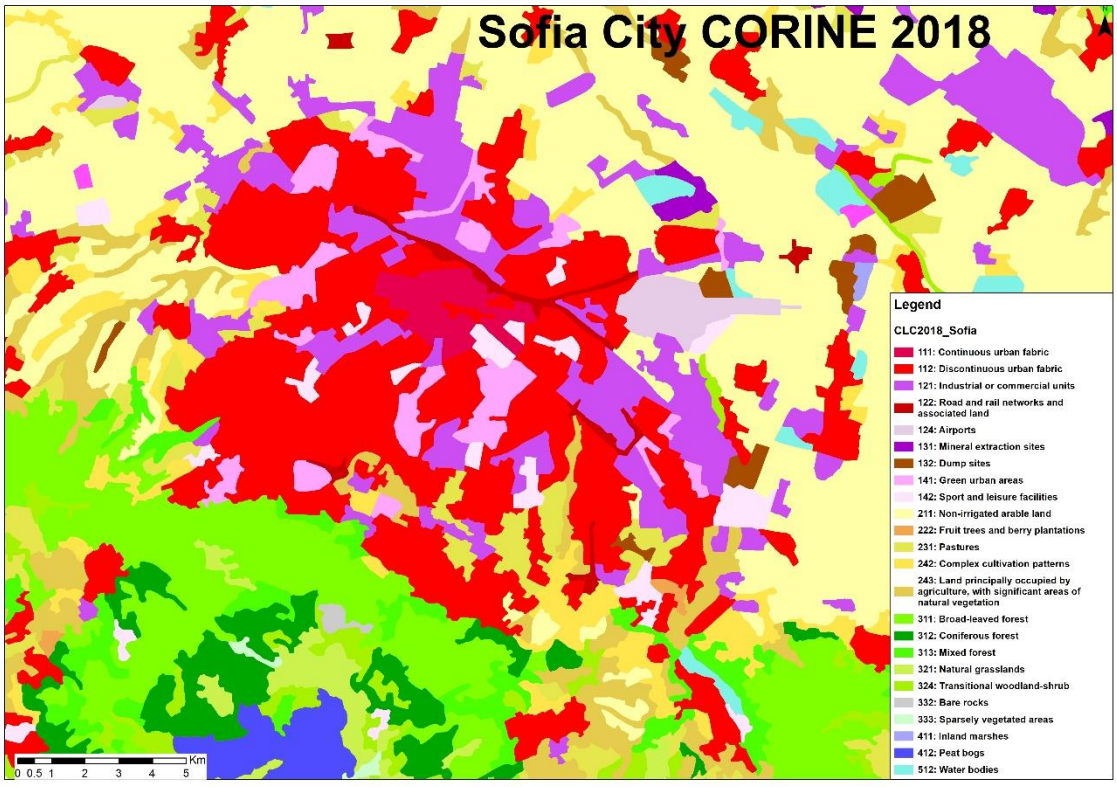


Figure 3. Map of CORINE Land Cover of Sofia city and its surroundings for 2018

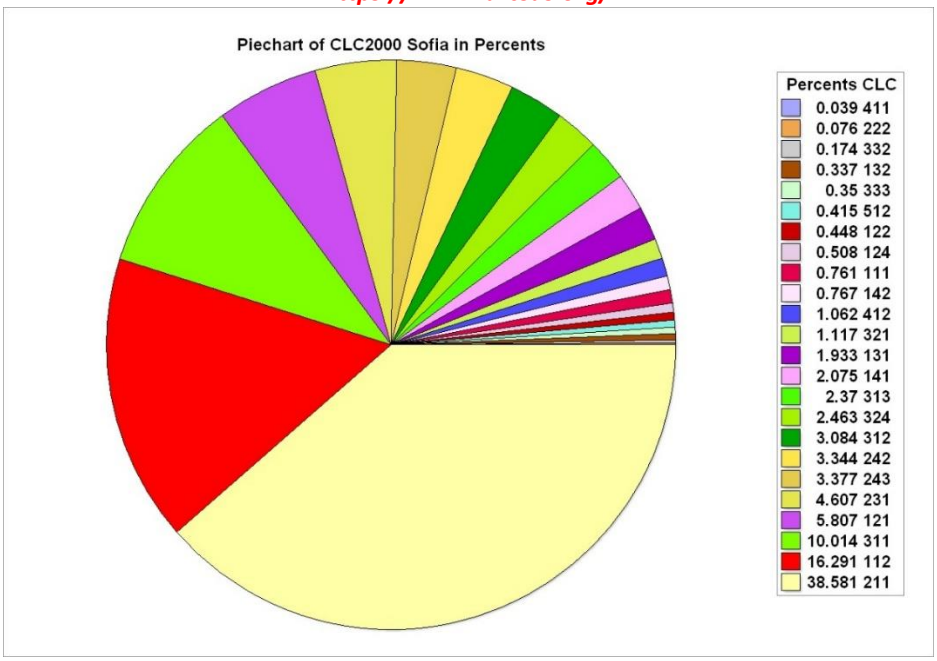


Figure 4. Pie chart of the percentage distribution of CORINE Land Cover classes for 2000

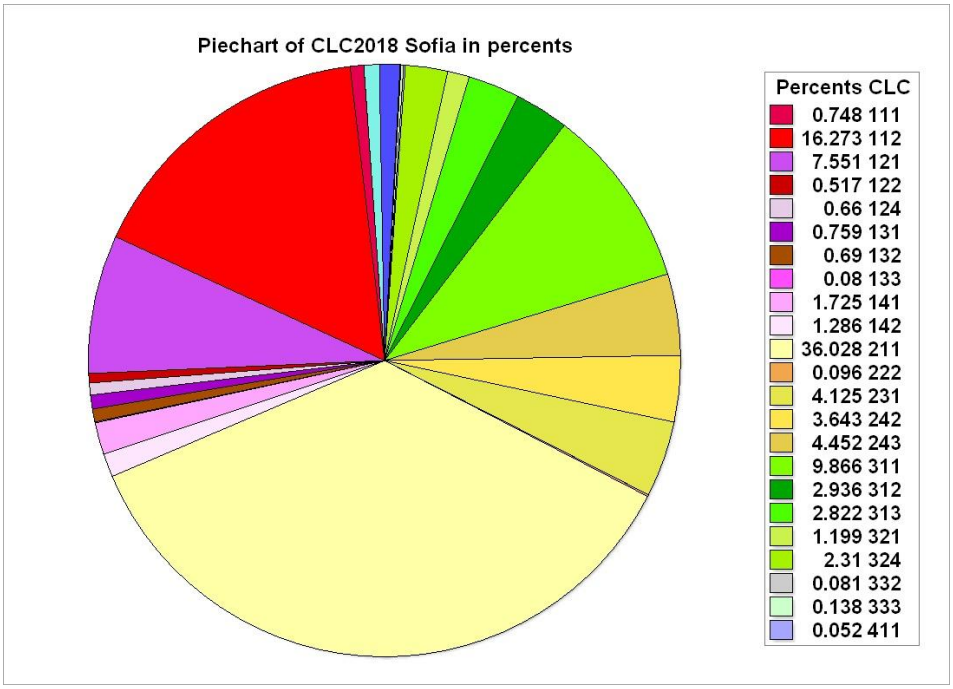


Figure 5. Pie chart of the percentage distribution of CORINE Land Cover classes for 2018

Using the CORINE Land Cover products for 2000 and 2018, along with the abovementioned human impact levels, the human impact index for Sofia city and its surroundings in 2000 and 2018 has been mapped and assessed (Figures 6 and 7). The minimal human impact with level 1 is observed in the southern part of the study area, in the mountainous region of Vitosha, Plana, and Lozenska. As seen on the maps, a significant part of the study area is occupied by territories with substantial human impact—levels 4 and 5. Least presented are areas with human impact values 2 – weak human influence.

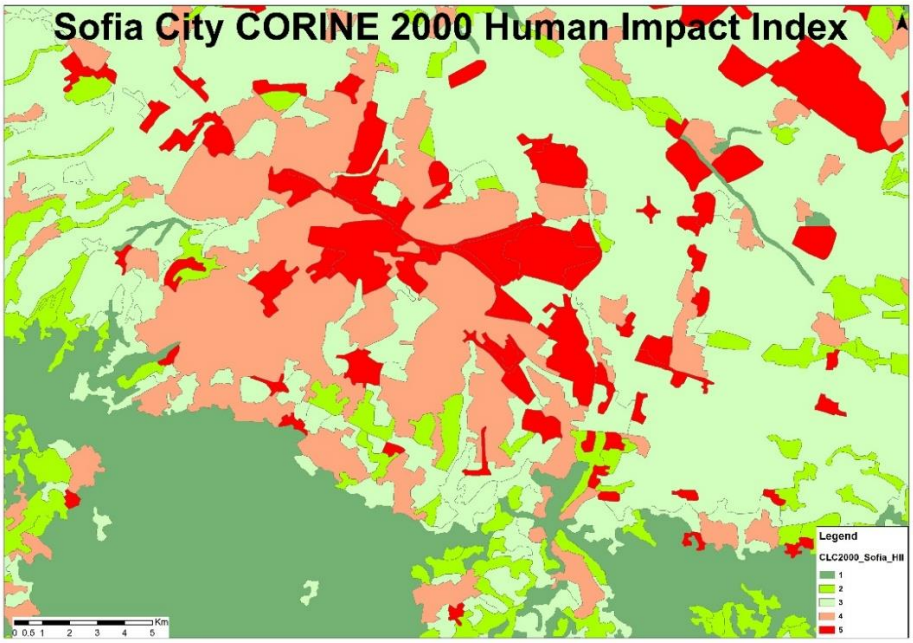


Figure 6. Human impact index map of Sofia city and its surroundings for 2000

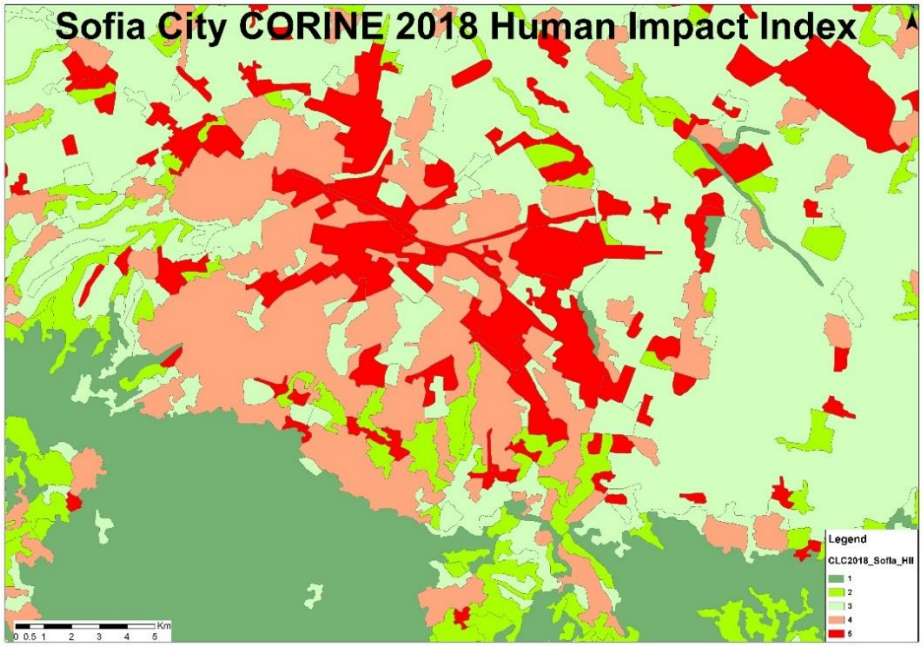


Figure 7. Human impact index map of Sofia city and its surroundings for 2018

As for the maps of human impact for the city of Sofia, within its construction border defined by the General City Plan from 2009, the distribution of impact classes differs (Figures 8 and 9). The least represented are the classes with the lowest impact, 1 and 2, as class one covers a narrow strip in the southern part of the city where the foothills of Vitosha Nature Park are located. The areas with a value of human influence of 3 and 4 are the most widely represented, while the share of 1 and 2 is the smallest.

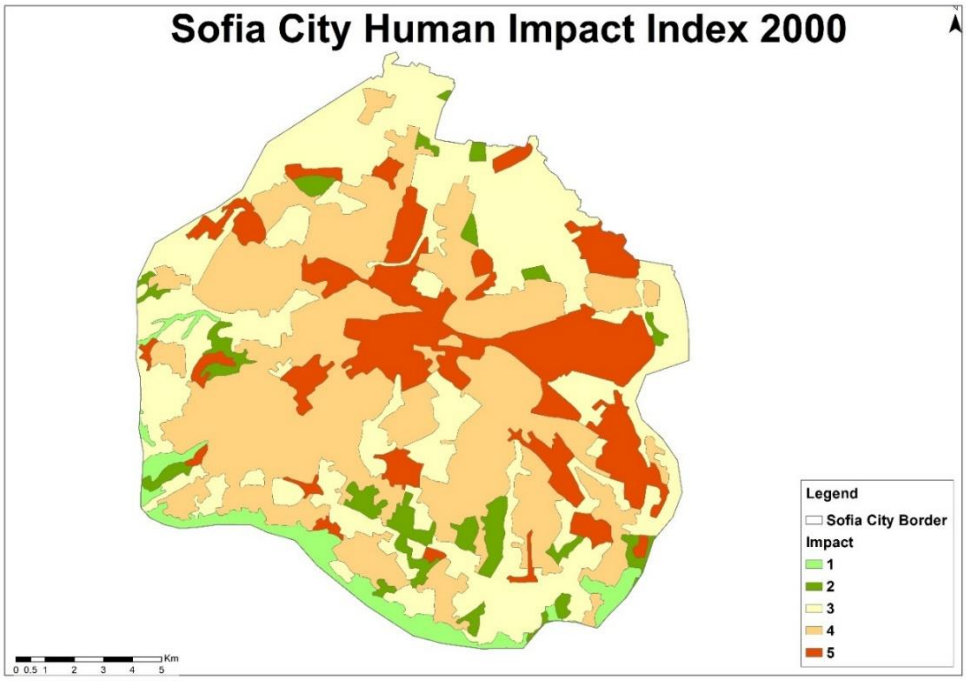


Figure 8. Human impact index map of Sofia city for 2000

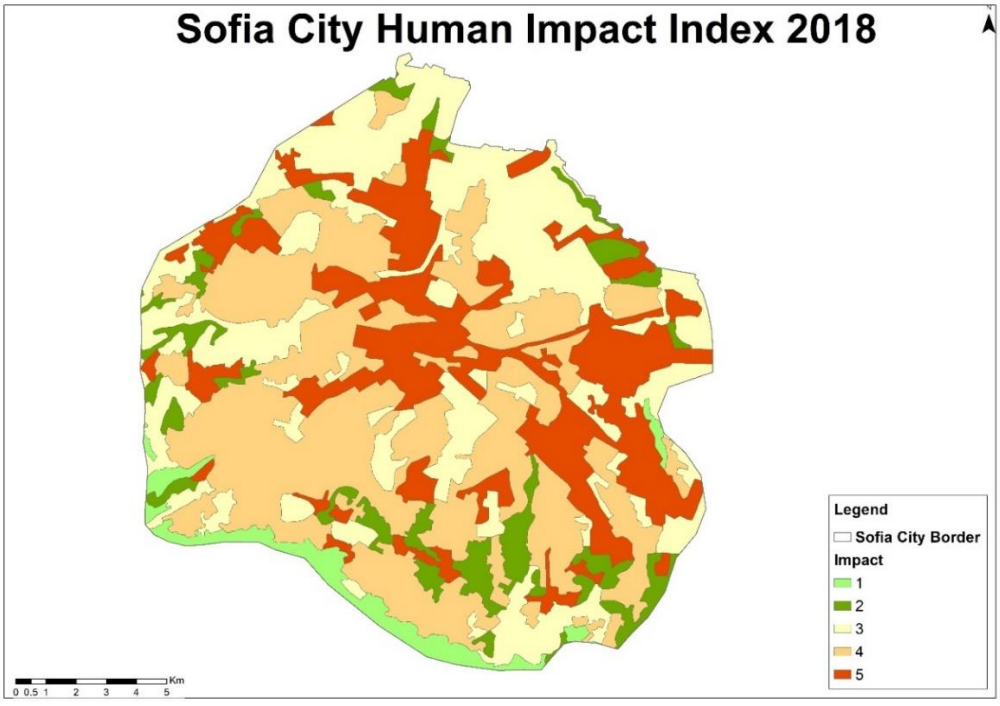


Figure 9. Human impact index map of Sofia city for 2018

In the pie charts of the Human Impact Index for 2000 and 2018, it is noticeable that the areas with the highest human impact value of 5 have increased from 17.7% in 2000 to 22.8% in 2018 (Figure 10). The broadly presented areas with human impact values 3 and 4 show a slight decrease since 2000, respectively for impact value four (4) from 38.9% to 37.6%. For impact value 3, the decrease is approximately 6% from 34.4% to 28.4%. A slight decrease is also

observed in areas with an impact value of 1, but the change is less than 1%. Part of these territories have been transferred to areas with an impact value of 2, increasing their area by about 3%. Some of them have been transformed to areas with a higher impact value – human impact 5.

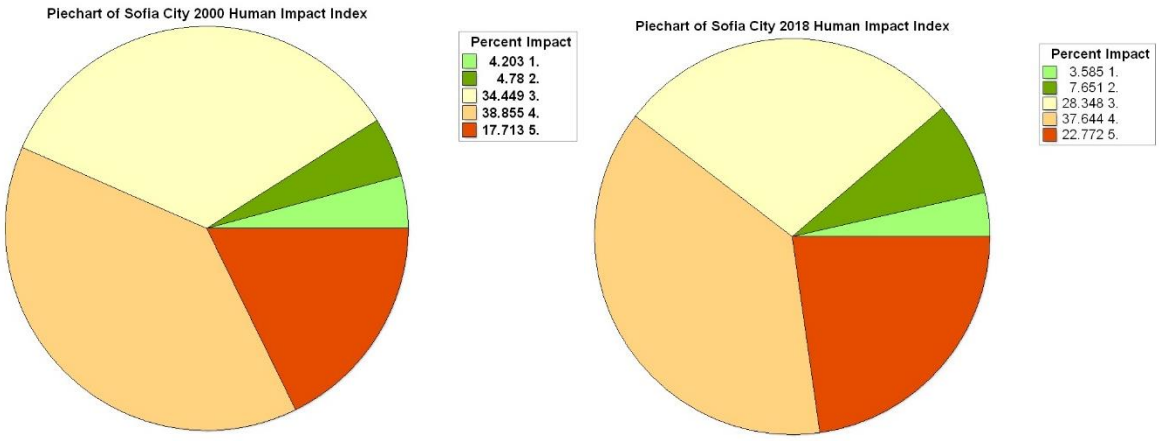


Figure 10. Human impact index map of Sofia city for 2000 and 2018

Conclusion and Recommendations

The analysis, mapping, and understanding of human impact on nature are critically important for sustainable development, environmental preservation and conservation, and the development of smart, sustainable cities. The results of the Sofia city analysis of human impact over almost 20 years (2000-2018) show an increase in areas with very strong human influence, mainly due to urban expansion. The presented Human Impact Index mapping method effectively reinterprets CORINE Land Cover data, enabling the assessment of human impact within a given area. It can be easily applied to other regions, regardless of their size, and the impact values can be adapted and assigned to different land cover products, making it a versatile tool for assessing human impact on nature.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. This paper is part of the implementation of an ESA TPM Project № PP0101070 “Classifying human impact areas on the territory of Bulgaria, 2024-2025” All authors contributed equally to the article.

References

Copernicus Land Monitoring Service. (2019). *CORINE Land Cover*. European Environment Agency. https://land.copernicus.eu/en/products/corine-land-cover?tab=datasets

eoPortal Directory. (n.d.). *SPOT-6 and SPOT-7 (Azersky)*. Retrieved November 14, 2025, from https://www.eoportal.org/satellite-missions/spot-6-7

European Environment Agency. (2021). *Copernicus Land Monitoring Service: CORINE Land Cover user manual* (Version 1.0). Copernicus Land Monitoring Service. https://land.copernicus.eu/

European Space Agency (ESA). (n.d.). *WorldView-3*. European Space Agency. Retrieved November 14, 2025, from https://earth.esa.int/eogateway/missions/worldview-3#instruments-section

Kosztra, B., Büttner, G., Hazeu, G., & Arnold, S. (2019). Updated CLC illustrated nomenclature guidelines (Task 3, D3.1 – Part 1). European Topic Centre on Urban, Land and Soil Systems (ETC/ULS), European Environment Agency. Retrieved November 10, 2025, from https://land.copernicus.eu/content/corine-land-cover-nomenclature-guidelines/html

Sofia Municipality. (2022). *Sofia Municipality - municipal district*. Ministry of Electronic Government. Retrieved November 14, 2025, from https://sfoblast.egov.bg/wps/portal/district-sofia-grad/district/municipalities/Sofia%20municipality

Sofia Municipality. (2024). *Geographic characteristics of Sofia*. Sofia Municipality. Retrieved November 14, 2025, from https://www.sofia.bg/en/web/tourism-in-sofia/geographic-characteristics-of-sofia

Sofia Municipality Architecture and Town Planning Directorate & Municipal Enterprise "Sofproect – Master Plan". (2009). *Master plan of Sofia Municipality*. Sofia Municipality.

Sofia – 120 years capital: Jubilee book (София – 120 години столица: Юбилейна книга). (2000). Sofia: Bulgarian Academy of Sciences, Academic Publishing House "Prof. Marin Drinov." ISBN 9544307451.

Stamenov, S., & Stamenova, V. (2016). Man-made relief: Anthropogenic impact on natural earth surface. In *Proceedings of the Third European SCGIS Conference "Geoinformation Technologies for Natural and Cultural Heritage Conservation"* (pp. 127–133). Sofia: SRTI-BAS.

Stamenov, S., & Stamenova, V. (2022). Human land in the Anthropocene: Assessing the impact on the land cover. *ESRI User Conference 2022*, July 11–15. San Diego, CA, USA. Retrieved December 21, 2024, from https://mapgallery.esri.com/submission-detail/30860

Stamenov, S., & Stamenova, V. (2023). Human footprint and landscape dynamics at the Black Sea region of Bulgaria. *ESRI User Conference*, 2023, July 10–14. San Diego, CA, USA. Retrieved December 21, 2024, from https://mapgallery.esri.com/submission-detail/32906

Stamenov, S., & Stamenova, V. (2025). Human impact index in education. *ESRI User Conference, 2025*, July 14-18. San Diego, CA, USA. Retrieved November 10, 2025, from https://mapgallery.esri.com/submission-detail/40088

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Cybersecurity Risks in Smart Building Infrastructure

Moses Adeolu AGOI[1]

ORCID 1: 0000-0002-8910-2876
[1]Lagos State University of Education, Lagos Nigeria
* agoi4moses@gmail.com **(**Responsible Author)

Samuel Olayiwola AJAGA[2]

[2]Lagos State University of Education, Lagos Nigeria.
olayiwolaz@gmail.com

David Oladimeji AJIBODE[3]

[3]Lagos State University of Education, Lagos Nigeria.
olaflexgraphics@gmail.com

Oluwanifemi Opeyemi AGOI[4]

[4]Obafemi Awolowo University, Osun Nigeria.
oluwanifemiagoi@gmail.com

Abstract

Smart buildings integrate networked sensors, building automation systems (BAS), IoT devices, and cloud-based analytics to deliver energy efficiency, occupant comfort, and operational cost savings. However, the IT-OT convergence that enables such benefits also expands the cyberattack surface: unencrypted IoT endpoints, legacy building controllers, and subsegmented networks create routes for attackers to insert physical disruption or exfiltrate sensitive data. This study investigates cybersecurity risks in smart building infrastructure using a mixed-methods design. The key findings illustrate runaway growth of IoT endpoints (tens of billions globally), high and rising percentage of devices with critical vulnerabilities (industry sources report substantial year-over-year increases), and common architectural vulnerabilities such as flat network topologies, default passwords, and unpatched firmware that persist across deployments. From data-driven risk metrics that draw on NIST guidance and industry threat intelligence reports, we show that 10–100 networked BAS/IOT devices in building infrastructure can create numerous high-severity vulnerabilities if proper practices are not being practiced and that attacks can disable HVAC, access control and energy systems with real physical and economic impact. We bring together robust mitigations segmentation, device lifecycle and inventory management, zero trust principles, secure procurement and recommend a research agenda that includes federated intrusion detection for building automation systems and standardized security certification for IoT building infrastructure.

Keyword: Smart buildings, BAS, IoT, cybersecurity, NIST, vulnerability metrics.

Introduction

Smart buildings are buildings that use networked sensors, controllers and analytics to automate HVAC (heating, ventilation and air conditioning), lighting, security and other systems, which have rapidly expanded since 2020. Advances in low-cost sensors, ubiquitous wireless connectivity and cloud analytics made it economical for organizations to deploy dozens to thousands of connected endpoints per facility. Cisco's industry data projects that by 2023 there were tens of billions of networked devices globally, underscoring the scale of endpoints that can be present in urban digital infrastructure. The increasing density of connected devices in buildings has two important security implications: first, the absolute number of potentially vulnerable endpoints rises linearly with adoption; second, heterogeneity of device types (IT devices, OT controllers, IoT sensors) increases integration complexity and misconfiguration risk. Convergence of IT (information technology) and OT (operational technology) in smart buildings create hybrid attack surfaces. Traditionally, BAS and OT systems were air-gapped or on segregated networks; today many controllers communicate over IP, use common protocols

(BACnet, Modbus, OPC UA) and often rely on cloud services for analytics and remote management. This shift introduced new classes of cyber risks: device-level vulnerabilities in embedded firmware, insecure default credentials, exposed management interfaces, and inadequate network segmentation that allows lateral movement from an infected sensor to critical control equipment. Industry analyses show a marked increase in mixed IT/IoT threats and that a nontrivial share (~20–30%) of connected devices in enterprise environments are non-traditional IT devices (OT/IoT), which historically have weaker security controls. Why smart-building security matters beyond data theft. Compromises can result in physical harm, occupant safety risks, operational outages and reputational and financial damage. Attack scenarios range from denial of service on building access control to manipulated HVAC setpoints that cause equipment damage or occupant health hazards. Because building systems are critical infrastructure for enterprises, universities, healthcare and government campuses, their security posture is subject both to regulatory scrutiny and to business continuity risk. Recent NIST guidance for IoT and the NIST Cybersecurity Framework 2.0 stresses risk management and cross-discipline governance; an indication that building cybersecurity is now both a technical and organizational problem (NIST CSF 2.0; NIST IoT guidance). This paper aims to synthesize published evidence (2020-2025), quantify risk exposure using available statistics, and recommend practical mitigations aligned with industry standards.

Literature Review

Academic and industry literature since 2020 has converged on several recurring themes in smart building cybersecurity: (1) proliferation of IoT endpoints and device heterogeneity, (2) systemic architectural weaknesses in BAS deployments, (3) common vulnerability classes (default credentials, unencrypted telemetry, open management ports), and (4) emerging defense strategies (segmentation, zero trust, device certification, testbeds). Several reviews and meta-analyses (Li et al., 2023; Sandor & Rajnai, 2023) summarize the landscape of BAS vulnerabilities, noting that many legacy controllers were designed without security and are still in operation, often with long lifecycles and limited update mechanisms (Li, 2023; Sándor & Rajnai, 2023). Industry threat reports quantify the problem scale. For example, Forescout's analyses (2022-2025) observed increases in mixed IT/IoT threats and reported that a growing percentage of enterprise devices are non-traditional IT endpoints subject to unique vulnerabilities; their research also identified categories of the "riskiest" connected devices (routers, IoT sensors, OT controllers) that disproportionately appear in exploit databases (Forescout, 2022; 2025). The IoT device population itself is large and growing: Cisco and other market trackers estimated tens of billions of connected devices by 2023, while IoT Analytics and similar trackers reported 16.6 billion connected IoT devices in 2023 with projections to increase further — emphasizing the attack surface scale. Quantitative studies place the average number of attacks against IoT devices in the thousands per month across studied environments (PSA Certified / industry estimates). These statistics provide a quantitative basis for risk modeling and motivate prioritized mitigation of the most exploitable classes. Standards & guidance: NIST's IoT guidance (SP 800-213) and the broader Cybersecurity Framework (CSF 2.0) provide device-agnostic risk management guidance that applies to building IoT (NIST SP 800-213; NIST CSF 2.0). These documents encourage lifecycle security, from procurement to decommissioning, and emphasize inventory, secure configuration, and risk-based prioritization. Complementary industry guidance (IoTSF 2023, RICS digital risks) addresses facilities managers and suggests operational controls and procurement checklists specific to built environments (IoTSF, 2023; RICS). Empirical testbeds such as the NREL cybersecurity testbed

for smart buildings demonstrate experimentally how attacks on building controllers manifest in physical metrics (temperature, power consumption) and how detection can distinguish mechanical faults from cyberattacks, offering evidence-based approaches to detection and response (NREL, 2024). Gaps identified across studies include insufficient longitudinal incident datasets specific to buildings, lack of universally adopted security certification for building IoT devices, and limited vendor accountability for secure-by-default design. Many academic studies call for cross-disciplinary approaches combining cybersecurity, controls engineering, and facilities management. This paper addresses these gaps by combining published statistical indicators with architecture-level analysis and a synthetic risk model informed by NIST guidance and industry threat metrics.

Materials And Methods

This study adpts a mixed-methods approach combining systematic literature review, quantitative synthesis of published statistics, and a small secondary-analysis of published testbed attack outcomes. The methods are designed to be reproducible using publicly-available PDFs and datasets from 2020-2025. We collected authoritative PDFs and technical reports from NIST (CSF 2.0, SP 800-213), industry whitepapers (Forescout IoT threat reports, IoTSF guidance), academic papers (peer-reviewed articles on BAS and cyber-physical security), and sector reviews (NREL testbed report; IEA Annex 81). Search keywords included "smart building cybersecurity," "building automation system vulnerabilities," "IoT devices vulnerabilities 2020-2025," and "BAS cyber testbed." Documents were selected for inclusion if they contained empirical or technical data (vulnerability counts, device population projections, attack case studies) and were published between 2020 and 2025. Representative PDFs: NIST CSF 2.0 (2024), NIST SP 800-213 (2021), IoTSF (2023), Forescout threat roundups (2022–2025), HRCAK (Sándor & Rajnai, 2023), and the NREL smart-building testbed (2024). From the collected sources we extracted numerical indicators: global connected device counts (Cisco; IoT Analytics), reported vulnerability growth rates and proportions of non-traditional IT devices (Forescout), attacks-per-month or dataset estimates (PSA/industry), and specific testbed results (NREL). Where reports gave ranges or projections (e.g., 16.6 billion IoT devices end-2023; 13–18% growth), those were recorded with citation and used to compute conservative scenario estimates. For instance, to quantify probable vulnerability burden in a typical medium-sized building, we used published device proportions and vulnerability prevalence rates from industry reports to simulate an expected number of vulnerable endpoints. This produces numerical scenarios (e.g., building with 200 connected endpoints → estimated 20-40 endpoints with medium-to-critical vulnerabilities under reported vulnerability prevalence ranges). We reviewed published NREL testbed experiments and other case studies where cyberattacks on BAS affected physical system metrics (temperature, energy use) to derive impact multipliers, i.e., how a cyber-induced setpoint change translated into energy or occupant comfort deviations. These multipliers allow us to translate a hypothetical compromise of x controllers into projected operational impacts (e.g., % increase in HVAC energy use, hours of occupant discomfort). The testbed reports include logged network and physical sensor traces that informed this mapping. Using NIST CSF and Zero Trust guidance, we created a simple risk scoring method (device criticality × vulnerability severity × exploitability) to prioritize mitigations. Device criticality was informed by facility function (e.g., access control = high criticality), vulnerability severity used published CVE/severity trends from Forescout and industry threat lists, and exploitability considered whether a device is internet-exposed or reachable from enterprise networks (per Forescout findings). We then mapped mitigations

(inventory, segmentation, secure procurement, patch/firmware lifecycle, monitoring/testbed-based detection) to the highest-scored categories.

Results & Discussion

Quantitative findings

Consolidated device population estimates indicate a large and growing attack surface.

Conservative device counts place connected IoT devices in the tens of billions globally (Cisco; IoT Analytics), with industry trackers reporting ~16.6 billion connected IoT devices by end-2023 and projections into 2024-2025 that push totals higher (IoT Analytics, 2024).

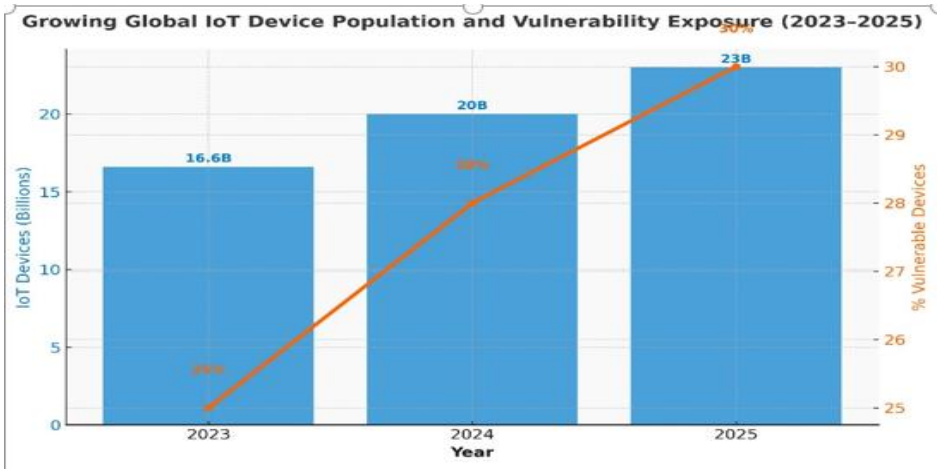


Fig.1. Graph showing the growth of IoT devices and their rising vulnerability exposure (2023–2025).

Forescout's analyses of enterprise environments show that roughly 20-30% of connected devices are non-traditional IT endpoints (IoT/OT), a category that often lacks enterprise-grade security controls, and the number of devices with known vulnerabilities increased notably from 2023 to 2024 (Forescout; IoT vulnerability trackers). Industry data cited by PSA and others also estimate thousands of attacks on IoT devices monthly across studied networks, with millions of records compromised daily in aggregated estimates. These figures illustrate that any smart building deployment that includes tens to hundreds of endpoints is likely to harbor multiple vulnerable devices unless explicit lifecycle controls are applied.

Expected vulnerable endpoints in a typical building

Using the quantitative synthesis method described, a medium-sized office building with ~200 connected endpoints (sensors, controllers, cameras, access controllers, routers) would, under conservative prevalence rates (10–25% vulnerability prevalence), contain approximately 20-50 endpoints with medium-to-critical vulnerabilities. If even 10% of those endpoints expose reachable management interfaces or reside on flat networks, lateral movement could enable attackers to reach high-criticality assets (e.g., building controller, access control server). Tests and case studies in the literature show that such compromises can cause real operational impacts: NREL testbed exercises demonstrated that manipulated HVAC setpoints could cause multi-degree temperature deviations and measurable energy changes; in practice, that can

translate to occupant health risks, comfort complaints, and increased energy cost. These modeled numbers align with industry warnings that mixed IT/IoT attacks are growing in frequency and sophistication.

Common attack vectors & architectural weaknesses

The literature and reports converge on recurring vulnerabilities: default or hardcoded credentials, unpatched firmware, unsecured protocols (unencrypted BACnet/Modbus traffic), exposed management interfaces, and flat network topologies lacking segmentation. Vendor supply-chain issues and remote management platforms (with critical vulnerabilities) also appear in threat histories (e.g., Axeda/Access:7 vulnerabilities affecting embedded device management). Attack patterns often begin with an internet-accessible or internal IoT device compromise and proceed via lateral movement into OT space due to insufficient micro-segmentation.

Evidence-based and prioritized Mitigation

The strongest mitigations indicated by guidance and testbed findings are: (1) complete device inventory and asset classification; (2) network segmentation (separate IT, OT, IoT and guest networks) combined with strict access controls; (3) secure procurement and device hardening (disable default accounts, enforce strong authentication); (4) patch/firmware management and supplier vulnerability disclosure; (5) monitoring and anomaly detection informed by combined network+physical telemetry (testbeds show physical telemetry helps distinguish cyberattacks from mechanical faults); and (6) adoption of zero-trust principles and alignment with NIST CSF outcomes. NIST CSF 2.0 and SP 800-213 give specific outcomes and practices that can be operationalized by facilities teams in collaboration with IT security.

Discussion

Building cybersecurity in smart facilities extends beyond technical controls to encompass deep organizational and policy transformation. Effective protection requires procurement policies that enforce minimum security baselines, cross-functional governance between IT, facilities, and operations, and clear vendor accountability across device lifecycles. Studies emphasize that governance structures bridging traditional silos between operational technology (OT) and information technology (IT) significantly reduce risks by promoting accountability and continuous oversight (IoT Security Foundation [IoTSF], 2023). Procurement plays a critical role, as embedding cybersecurity requirements, such as secure boot, encrypted communications, patchability, and transparent supply chains, into contract terms ensures devices are secure by design. The IoTSF Security Assurance Framework (2021) recommends enforcing supplier clauses mandating vulnerability disclosure, update commitments, and long-term support. Moreover, certification and labeling schemes such as the U.K.'s "secure by design" initiative and PSA labels promote market-wide accountability by rewarding manufacturers who meet high security standards (Morgner et al., 2019). Device lifecycle management, including automated inventory, microsegmentation, and decommissioning protocols, is equally vital; without these, organizations struggle to identify and isolate vulnerable devices (Meidan et al., 2017). Microsegmentation and zero-trust models have been shown to curtail lateral attack movement by 60-90%, offering superior risk reduction per dollar spent compared to ad hoc patching alone (Nardine et al., 2021). This is particularly significant given that patching in IoT contexts is plagued by heterogeneity, delayed updates, and legacy constraints (Dissanayake et al., 2020). Thus, prioritizing investments in comprehensive device

discovery, network segmentation, and structured patch triage yields higher operational resilience and ROI studies indicate security investments can reduce downtime up to 75% and yield 4:1 financial returns (Cybervizer, 2024). At the same time, human capacity building remains crucial: facilities managers, often lacking cybersecurity training, benefit from accessible guidelines like the IoTSF's *IoT Cybersecurity for Facilities Professionals*, which outlines practical steps for enforcing security within building operations. Training and certification programs for facility professionals can institutionalize cyber-awareness and competence, while standardized security labels for IoT devices enhance user trust and purchasing clarity. Despite progress, challenges persist: vendors may resist tighter security requirements, legacy systems create persistent exposure, and balancing patching with operational uptime remains difficult. However, with cross-departmental governance, regulatory incentives, continuous monitoring, and well-defined procurement standards, organizations can systematically raise the cybersecurity baseline of smart buildings. The path forward involves aligning technical defenses with institutional accountability, regulatory compliance, and informed procurement practices, ensuring that every connected endpoint, whether a thermostat or access control sensor, operates within a secure, auditable, and well-managed lifecycle framework, thus transforming building cybersecurity from a reactive IT problem into an embedded organizational function.

Conclusion

Smart buildings deliver substantial benefits in energy efficiency, occupant comfort and operational insight but these benefits come with expanded cyber risk. Between 2020 and 2025, a growing body of literature and industry reports documents increasing device counts, rising prevalence of vulnerabilities in IoT/OT endpoints, and frequent mixed IT/IoT threats that can materially affect building operations (Cisco; Forescout; IoT Analytics). The evidence presented here synthesizes those findings into a clear risk narrative: the more endpoints and the more heterogeneous the device ecosystem, the greater the probability that building infrastructure contains exploitable assets, and the greater the potential for cyber incidents to produce physical effects. From a technical standpoint, the most impactful mitigations are well-known but under-implemented: accurate device inventories, segmentation of IT/OT/IoT networks, secure-by-default procurement requirements, strong authentication, monitored patch lifecycles, and layered detection that includes both network and physical telemetry. NIST guidance (CSF 2.0, SP 800-213) provides a practical framework for prioritization, linking outcomes (identify, protect, detect, respond, recover) to building-specific controls. Deploying testbeds and conducting regular red-team exercises (as NREL and others demonstrate) helps facilities teams validate that detection controls can distinguish between mechanical faults and cyber manipulation, a critical capability for operational resilience. Organizationally, meaningful improvement requires that facilities managers, IT security, procurement and executive leadership coordinate on security requirements and budgets. Policy levers that could accelerate improvement include certification programs for building IoT devices, procurement clauses demanding vulnerability disclosure and update guarantees, and sector guidance tailored to facilities professionals. The industry guidance (IoTSF, RICS) and NIST standards show a path forward, but there remains a gap between guidance availability and real-world adoption that must be addressed through training, incentives and regulatory clarity. Limitations of this study include dependence on publicly reported statistics and industry reports (methodologies vary) and the lack of a centralized incident repository specifically for building-level cyber incidents. Nonetheless, the cross-source convergence on issues and the experimental evidence from

testbeds support the central conclusions: smart buildings are attractive targets because of their scale and heterogeneity, but risk can be materially reduced through prioritized, standards-aligned controls and organizational changes.

Future Research

Building on gaps identified in the 2020-2025 literature, future research should prioritize developing longitudinal, anonymized databases of smart building cyber incidents to support empirical analysis of attack frequency, causes, and impacts. Equally important are studies on certified security baselines and procurement policies that evaluate the effectiveness of secure-by-default requirements, firmware update guarantees, and SBOM integration in reducing vulnerability prevalence. Research should also advance hybrid detection algorithms that merge network data with physical telemetry for enhanced anomaly detection, supported by federated learning models to preserve privacy. Economic modeling of building cyber incidents is needed to quantify financial losses, downtime, and energy inefficiencies. Additionally, human factors research should assess how training, governance models, and policy interventions affect security adoption and sustainability. Finally, establishing standardized, interoperable testbeds across diverse building types would enable consistent benchmarking and accelerate innovation through collaboration among academia, NIST, IoTSF, Forescout, and other industry partners.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

References

[1] Cisco. (2018). *Cisco Annual Internet Report (2018–2023) White Paper.* Retrieved from Cisco website (device projections).

[2] Cybervizer. (2024). *The ROI of OT security: Quantifying the value of protection.* https://www.cybervizer.com/p/the-roi-of-ot-security-quantifying-the-value-of-protection

[3] Dissanayake, N., Jayatilaka, A., Zahedi, M., & Babar, M. A. (2020). *Software security patch management—A systematic literature review of challenges, approaches, tools, and practices. arXiv.* https://doi.org/10.48550/arXiv.2012.00544

[4] Forescout. (2025). *The riskiest connected devices of 2025.* Forescout Research. Retrieved from Forescout research pages.

[5] Forescout Research Labs. (2022). *Threat roundup: The emergence of mixed IT/IoT threats.* Forescout Research. Available (web report/PDF).

[6] IoT Security Foundation. (2021). *IoT security assurance framework: Release 3.0.* https://www.iotsecurityfoundation.org/wp-content/uploads/2021/11/IoTSF-IoT-Security-Assurance-Framework-Release-3.0-Nov-2021-1.pdf

[7] IoT Security Foundation. (2023). *IoT cybersecurity for facilities professionals in the smart built environment.* (Release 1.0). https://iotsecurityfoundation.org/wp-content/uploads/2023/03/IoT-Cybersecurity-for-Facilities-Professionals-in-the-Smart-Built-Environment-RELEASE-1-0-FINAL-30-03-2023.pdf

[8] Li, G., et al. (2023). *A critical review of cyber-physical security for building automation systems. Journal* (abstract).

[9] Meidan, Y., Bohadana, M., Shabtai, A., Ochoa, M., Tippenhauer, N.-O., Guarnizo, J. D., & Elovici, Y. (2017). *Detection of unauthorized IoT devices using machine learning techniques. arXiv.* https://doi.org/10.48550/arXiv.1709.04647

[10] Morgner, P., Mai, C., Koschate-Fischer, N., Freiling, F., & Benenson, Z. (2019). *Security update labels: Establishing economic incentives for security patching of IoT consumer products. arXiv.* https://doi.org/10.48550/arXiv.1906.11094

[11] Nardine Basta, I., Kaafar, M. A., & Walker, A. (2021). *Towards a zero-trust micro-segmentation network security strategy: An evaluation framework. arXiv.* https://doi.org/10.48550/arXiv.2111.10967

[12] National Institute of Standards and Technology. (2021). *IoT device cybersecurity guidance for the federal government (SP 800-213).* https://doi.org/10.6028/NIST.SP.800-213

[13] National Institute of Standards and Technology. (2024). *The NIST cybersecurity framework (CSF) 2.0.* NIST CSWP 29. https://doi.org/10.6028/NIST.CSWP.29

[14] NIST. (2020). *Zero trust architecture (SP 800-207).* https://doi.org/10.6028/NIST.SP.800-207

[15] PSA Certified / Industry Reports. (2022). *The IoT industry action plan to reduce the cost of security.* PSA Certified (report).

[16] Sándor, B., & Rajnai, Z. (2023). *Cyber security analysis of smart buildings from a cyber security architecture point of view. HRČAK / University Review.* Retrieved from https://hrcak.srce.hr/file/433533

[17] U.S. Department of Energy / NREL. (2024). *A cybersecurity testbed for smart buildings. NREL Technical Report.* https://docs.nrel.gov/docs/fy24osti/85639.pdf

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Design Principles for Urban Open Parking Lots in the Climate Change Adaptation Process: The Case of Isparta

Fatma ÖZKAN BAYINDIR[1*]

ORCID 1: 0000-0002-7292-905X

[1]Dr., Süleyman Demirel University, Department of Architecture Planning and Design, Landscape Architecture, Isparta-Türkiye
fatma.ozkan.bayindir@gmail.com (Corresponding Author)

Ali ÖZ [2*]

ORCID 2: 0000-0002-0814-4020
[2]Assoc. Prof. Dr., Mehmet Akif Ersoy University, Technical Sciences Vocational School, Department of Motor Vehicles and Transportation Technologies, Burdur, Türkiye
alioz@mehmetakif.edu.tr

Atila GÜL[3*]

ORCID 3: 0000-0001-9517-5388
[3]Prof. Dr., Süleyman Demirel University, Department of Landscape Planning and Design, Landscape Architecture, Isparta, Türkiye
atilagul@sdu.edu.tr

Abstract

The increasing impacts of climate change necessitate adaptation-focused approaches in the design of urban open spaces. In this process, open parking lots are recognised as crucial urban spaces for enhancing resilience to climate change, beyond serving as mere vehicle storage areas. Elements such as the permeability of surface materials, rainwater management, shading opportunities, vegetative landscaping, and energy-efficient lighting systems directly impact the potential of these spaces to adapt to climate change. This study examines the design principles of urban open parking lots in the context of climate change adaptation, drawing on relevant literature. Sustainable design practices prominent in the literature are evaluated, focusing on the use of permeable pavement, rainwater harvesting, green infrastructure integration, and solutions for regulating the microclimate. Three existing open parking lots in Isparta's city centre—the Isparta Intercity Bus Terminal Parking Lot, the Iyaş Parking Lot, and the Delta Parking Lot—are presented as examples, and the opportunities and potential development opportunities of these areas in terms of climate-adapted urban design are highlighted. In conclusion, the evaluations conducted using the Isparta example demonstrate that open-air parking lots, when integrated with climate change adaptation strategies, can contribute to sustainable and climate-resilient urban planning processes.

Keywords: Urban open-air parking lots, climate change, parking lot design principles

1. Introduction

With the rapid increase in urbanisation, the pressure urban areas place on natural processes is becoming increasingly evident. As emphasised in the reports of the Intergovernmental Panel on Climate Change (IPCC, 2021), the increasing population density, energy consumption, transportation activities, and surface impermeability in cities worldwide are both accelerating climate change and making them more vulnerable to this change. Impacts such as heat waves, sudden rainfall, and increased surface runoff, in particular, directly impact the character of urban open spaces. This situation highlights the need to reconsider urban spaces not only in terms of use but also in terms of climate adaptation and environmental sustainability (UN-Habitat, 2022; EEA, 2023).

In this context, open parking areas, traditionally defined solely as vehicle storage, stand out as a significant space-consuming area within the urban fabric. Because parking surfaces are generally composed of impermeable materials such as asphalt or concrete, they prevent rainwater from seeping into the ground, which increases runoff and flooding (Hong & Lee, 2021). Furthermore, due to their high heat storage capacity, these surfaces exacerbate the urban heat island effect, negatively impacting environmental thermal comfort (Razzaghmanesh & Beecham, 2019). These effects necessitate considering parking lots not only as infrastructural elements but also as a type of open space with the potential to regulate urban microclimate (Graça, 2022).

In recent years, a notable trend has emerged in the international literature towards redefining parking areas within the framework of sustainable urban design (Figure 1). For example, Chen and Zhang (2023) stated that autonomous and shared vehicle systems will inevitably lead to the functional transformation of parking areas in the future, and these areas could transform into "green infrastructure-focused public spaces." Aldridge and Medina (2021) propose four principles for parking planning. These are: demand management, resource conservation, ecological integration, and linking it to urban systems. These principles advocate that parking lot designs should be considered as public open spaces integrated with ecological systems, rather than solely as technical requirements.



Figure 1. Example of sustainable parking compatible with green infrastructure (sustainabletechnologies.ca 2018)

The planning and design of urban parking spaces is a multifaceted process that encompasses not only vehicle storage but also environmental sustainability, user comfort, and adaptation to climate change. Today, parking lots are recognised as crucial open spaces for reducing cities' carbon footprints, supporting rainwater management, and balancing the microclimate (UN-Habitat, 2022; EEA, 2023). Therefore, modern parking design has evolved beyond technical efficiency to incorporate climate-compatible design approaches that integrate ecological, energy, and social considerations.

In international literature, prominent principles in parking design include the use of permeable surfaces, rainwater management, integration with green infrastructure, energy efficiency, and accessibility.

UN-Habitat (2022) recommends designing parking lots as "climate-resilient open space systems," emphasising that the combined use of permeable surfaces, rainwater storage, photovoltaic shading systems, and vegetative landscaping reduces the heat island effect in cities (Figure 2).



Figure 2. Example of a car park using photovoltaic shading systems (AmperaPark, 2025).

Similarly, the European Environment Agency (2023) states that increasing the permeable surface ratio and implementing design solutions that support the natural water cycle, together with tree shading, strengthen urban resilience (Figure 3).



Figure 3. Example of permeable paving system in parking lots (totallandscapecare.com, 2025).

In the United States, the U.S. Environmental Protection Agency (EPA, 2020) and Federal Highway Administration (FHWA, 2019) guidelines also consider sustainable parking design as an "extension of green infrastructure" and highlight the following criteria:

• Reducing impervious surfaces and using materials that allow water to infiltrate the ground;

• Integrating biofilters, rain gardens, and infiltration swales for stormwater management;

• Using sensor-controlled LED systems and solar-powered shading structures to ensure energy efficiency;

• Creating microclimatic balance with vegetative shading and green border elements;

• Developing inclusive solutions for people with disabilities, pedestrians, and cyclists within the framework of accessibility and safety principles.

These principles suggest that parking lots should not be viewed as merely static structural areas, but rather as active environmental components of the urban ecosystem (Aldridge & Medina, 2021; Zhang & Li, 2025).

The basic framework for parking lot planning in Türkiye is outlined in the Parking Regulation published by the Ministry of Environment, Urbanisation and Climate Change (2018). However, the current regulation primarily focuses on technical issues, such as capacity, area size, and location selection. It fails to include environmental indicators, including climate adaptation, the use of permeable surfaces, green infrastructure integration, and energy efficiency. This deficiency causes parking lots to remain environmentally unsustainable, even if they are physically functional.

In contrast, the TMMOB Chamber of Urban Planners Report (2021) and the TSE 12576 standards recommend incorporating green infrastructure as a mandatory design element in urban parking lots, enhancing the permeability of surface materials, and implementing energy-efficient systems. Furthermore, some local governments (e.g., Izmir, Konya, Eskişehir) have taken significant steps at the implementation level in recent years by preparing "climate-friendly parking guides." However, these initiatives have not yet been translated into a systematic standard at the national level. When global and national standards are considered together, it becomes clear that parking design should be based on a holistic approach shaped by the intersection of architecture, urban planning, landscape, and environmental engineering. Parking lots can play an active role in sustainable urban planning only by integrating climate-focused design principles, not just technical standards, into the planning scale. Such a transformation could transform parking lots into "urban micro-ecosystems" that reduce carbon emissions, generate energy, and contribute to the ecological cycle.

2-Materials and Methods

This study examines three open-air parking garages located in Isparta's city centre: the Delta Parking Garage, the İyaş Parking Garage, and the Isparta Intercity Parking Garages (Figures 4, 5, and 6) to discuss and illustrate climate change-adapted parking garage design principles. Isparta is a medium-sized city where environmental impacts can be observed in parking garage planning due to its topography, which includes limited flat areas, and increasing vehicle density. The parking garages were strategically located in different neighbourhoods within Isparta.

The Delta Parking Garage, with an area of approximately 1,722 m², is located in the Çelebiler neighbourhood of Isparta's central marketplace.

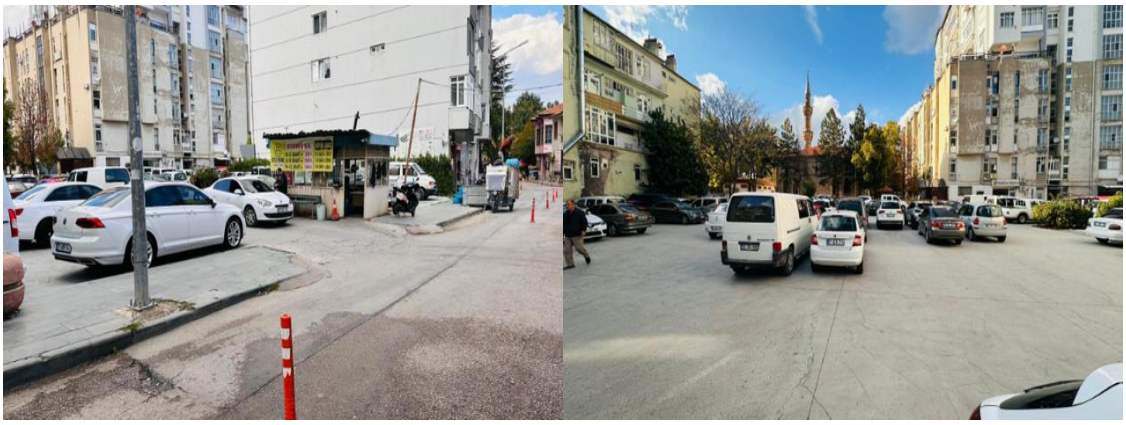


Figure 4. Delta Parking Lot

İyaş Car Park; This car park, approximately 9,211 m² in size, is an area formed after the demolition of the old bus terminal in the Bahçelievler neighbourhood of Isparta (Figure 5).



Figure 5. İyaş Parking Lot

Isparta Intercity Bus Terminal is located in the Çünür neighbourhood. The terminal opened for use on May 1, 2024. The terminal's parking lot is approximately 15,126 m² and is heavily used (Figure 6).



Figure 6. Isparta Intercity Bus Terminal Parking Lot

In this context, the study analyses the status of existing parking lots through the use of permeable surfaces, rainwater management, vegetative shading, and green infrastructure integration, as well as energy-efficient lighting systems and accessibility, which are fundamental design principles prominent in the literature. Thus, the evaluations conducted on these three existing and currently in use parking lots in Isparta will contribute to both local governments and sustainable urban design policies.

3. Findings and Discussion

In this study, three open-air parking lots located in Isparta's city centre—Delta Parking Lot, İyaş Parking Lot, and Isparta Intercity Bus Terminal Parking Lot—were evaluated within the context of climate change-adapted design principles. The findings were interpreted under the headings of permeability, rainwater management, vegetative landscaping and green infrastructure, energy efficiency and lighting, surface temperature and microclimatic conditions, accessibility, and user comfort. The urban context, physical conditions, and existing design features of all three areas differ significantly from one another. These differences also lead to a variation in the capacity to adapt to climate change (Graça, 2022; UN-Habitat, 2022). The surface materials of the three sample parking lots do not show significant differences in terms of climate adaptation potential. A private company operates the Delta Parking Lot as a paid parking lot. It has a capacity of approximately 90 to 95 vehicles. There are no plantings, vehicle boundaries, or accessible parking spaces (Figure 4). Its asphalt and concrete paving make the surface completely impermeable. This causes water to accumulate on the surface after precipitation, preventing natural infiltration. Furthermore, the dark surface absorbs high levels of sunlight, leading to increased heat accumulation and causing the area to experience thermal stress during the summer months.

İyaş Parking Lot has a capacity of approximately 300–310 vehicles and is a free parking area. Despite the large open spaces surrounding it, there are no green spaces. The ground impermeability rate is high, and there are no designated vehicle boundaries, designated parking areas for people with disabilities, or pedestrian accessways. However, the openness of the area on three sides provides a partial advantage in terms of air circulation. However, because there is no permeable ground or drainage infrastructure to direct water, surface runoff after rainfall is dispersed in an undirected manner.

The bus terminal parking lot has a capacity of approximately 500 to 510 vehicles. Thanks to its interlocking paving stone pavement, it exhibits a partially permeable surface. This feature allows water to naturally infiltrate, albeit slightly, without accumulating on the surface, especially during light to moderate rainfall. The literature indicates that similar systems reduce surface runoff, maintain groundwater balance, and mitigate the urban heat island effect (Cacciuttolo et al., 2023; Hong & Lee, 2021). However, observations indicate that the paving gaps in the bus terminal parking lot fill over time, and permeability decreases with usage. Overall, all three parking lots exemplify urban typologies with a high proportion of impermeable surfaces. This poses sustainability risks in terms of both the water cycle and thermal comfort in a city like Isparta, which experiences hot and dry summers, large daily temperature fluctuations, and cold and rainy winters.

Field observations revealed that none of the three parking lots has integrated rainwater harvesting, biofiltration, or directed drainage infrastructure. Because the ground level of the Delta Parking Lot is slightly lower than its surroundings, water accumulation after rainfall is typical. This accumulation does not seep through cracks in the ground, accelerating surface deterioration and reducing user safety. Rainwater runoff is more prevalent in the İyaş Parking Lot due to its large surface area; however, due to the lack of a drainage system, controlled removal of this water is impossible. Small cracks in concrete surfaces, in particular, lead to uneven water flow. In such areas, without the use of nature-based solutions such as rain gardens, surface gutters, or permeable drainage strips, water infiltration into the soil remains minimal (EEA, 2023). While the Bus Terminal Parking Lot appears to have an advantage over the other

two sites due to its interlocking stone paving surface, it also lacks a planned rainwater harvesting system or biofiltration system. In this context, all the parking lots in the Isparta example lack systems that contribute to the water cycle. Under their current conditions, they function as impermeable spaces that rapidly drain rainwater away from the surface.

Green infrastructure integration, one of the most effective tools for adaptation to climate change, is not present in any of the three parking lots. The Delta Parking Lot is physically unsuitable for the addition of green space due to the dense construction surrounding it. Although the İyaş Parking Lot is optimally located for potential green infrastructure applications due to its open three sides, the area lacks any vegetative landscaping. The large surface area reduces user comfort in the summer months due to the lack of shade, leading to increased interior temperatures. The Bus Terminal Parking Lot is similarly devoid of green spaces. Due to the lack of shaded walkways and planted borders, microclimatic comfort is limited. All these observations indicate that none of the "climate-resilient open space" criteria defined by UN-Habitat (2022) are met.

In terms of energy use, none of the three parking lots exhibits an energy-efficient design approach. The Delta Car Park has no lighting; nighttime use is provided by indirect light from surrounding commercial buildings and street lighting outside the parking area. Similarly, the Iyaş Car Park lacks a standalone lighting system; a few floodlights placed on the shopping mall facade provide limited light. This poses problems for both user safety and energy efficiency. In the Bus Terminal Car Park, lighting provided by high-mast floodlights covers the entire area but consumes a significant amount of energy. Such systems are not compatible with the low-carbon and sensor-based lighting strategies recommended by UN-Habitat (2022) and the EEA (2023). No area contains solar panels, motion sensors, LED-based lighting, or energy storage systems. Therefore, all three car parks offer significant opportunities for improvement in energy efficiency and reducing carbon emissions.

Field observations indicate that surface temperatures, particularly in the Delta and Iyaş parking lots, can be higher than the surrounding average. This difference is related to the absorption of solar radiation by dark-colored asphalt and concrete surfaces. The fact that such surfaces store heat during the day and release it slowly at night reinforces the urban heat island effect (Razzaghmanesh & Beecham, 2019). The Bus Terminal Parking Lot, thanks to its open location, offers relatively better air circulation. However, due to the lack of shade structures or tree cover, surface temperatures remain high. Microclimatic comfort cannot be achieved unless light-colored pavements or shaded transition areas are used in parking areas (Graça, 2022). In this context, all three areas lack heat-reducing strategies in terms of climate-adaptive design. Heat accumulation is thought to be particularly high around the Delta Parking Lot, particularly when combined with the reflective surfaces of surrounding structures.

None of the three parking lots has designated parking areas for people with disabilities. This is a significant shortcoming in terms of both accessibility standards and inclusive urban design principles. Additionally, elements that would increase user comfort, such as pedestrian paths, bicycle parking areas, or shaded pedestrian crossings, are absent. Despite being located in an area with heavy pedestrian traffic, the Iyaş Parking Lot lacks any designated pedestrian safety areas. This demonstrates that the parking lot is designed solely for vehicles and has strayed from its public function. Aldridge & Medina (2021) emphasise the importance of transforming parking lots into multifunctional public spaces for social sustainability. In this context, no trace of this transformation approach was found in any of the examples in Isparta.

The findings revealed that parking lots in Isparta are primarily composed of impermeable surfaces. This creates a critical vulnerability in terms of rainwater management. Hong and Lee (2021) demonstrated that permeable surfaces contribute to the prevention of urban floods by increasing rainwater infiltration capacity, while Cacciuttolo et al. (2023) demonstrated that permeable paving systems significantly reduce surface runoff. However, these systems were not found in the parking lots examined. In medium-sized cities like Isparta, rainwater management relies heavily on sewer infrastructure, resulting in the exclusion of nature-based solutions (such as rain gardens, biofilters, and surface gutters) from design processes. This not only increases surface runoff but also hinders groundwater recharge and weakens the water cycle balance of the urban ecology (EEA, 2023). Therefore, converting parking lots to permeable surface systems should be considered a priority action area in the city's climate adaptation strategies.

The lack of vegetative landscaping or green infrastructure in all three parking lots has a direct negative impact on microclimatic conditions. Graça (2022) emphasises that planting trees in urban open spaces is one of the most effective ways to reduce surface temperatures and improve thermal comfort. The primary reason for the lack of green infrastructure in Isparta's examples is that parking lot designs are solely focused on "vehicle capacity."

The Delta Parking Lot in the city centre, with its surrounding high-rise buildings, blocks microclimatic air circulation, leading to heat accumulation and deterioration of air quality. Despite its enormous open space potential, the Iyaş Parking Lot lacks vegetative shading. While the Bus Terminal Parking Lot offers better airflow due to its open surroundings, it falls short in terms of "heat island reduction" due to its lack of green infrastructure. These conditions clearly contradict UN-Habitat's (2022) principles of "landscape-based solutions to urban heat risk."

Energy efficiency is an often-overlooked yet critical element in the adaptation of parking areas to climate change. None of the three parking lots examined has LED lighting, solar panels, or intelligent energy management systems. This increases both carbon emissions and energy costs. UN-Habitat (2022) states that solar-powered lighting systems in urban open spaces are effective in reducing carbon emissions. Furthermore, Aldridge and Medina (2021) emphasise that photovoltaic shading structures in parking lot designs provide dual benefits in terms of both energy production and heat reduction. Therefore, parking lots in Isparta are classified as "passive energy-consuming spaces" in this respect. Even simple interventions for energy efficiency (e.g. LED conversion or solar panel pergola systems) can both reduce carbon emissions and become part of sustainable urban infrastructure.

Accessibility assessments indicate that parking lots in Isparta are designed with a focus on vehicles. Accessible parking spaces, pedestrian paths, and bicycle parking are not available in any area. This situation is inconsistent with the "inclusive and multifunctional open space" principles recommended by UN-Habitat (2022). Aldridge and Medina (2021) emphasise that transforming parking lots into multifunctional urban spaces is crucial for social sustainability. In this context, the Iyaş Parking Lot, thanks to its connection to the shopping mall, may have potential as an urban meeting space in the future. However, all three parking lots currently lack user comfort and social accessibility.

The Parking Regulation (2018), the fundamental legislation for parking lot planning in Türkiye, focuses on capacity and site selection criteria but does not include climate change adaptation or environmental performance criteria. This situation is clearly observed in the Isparta example. The lack of nature-based solutions, energy-efficient systems, or green infrastructure integration

in the parking lots examined is related to the legislation's failure to define physical environmental performance. In Isparta, parking areas have mainly been planned to meet short-term urban needs without considering long-term climate resilience. However, the city's topography, open space potential, and climate conditions provide a suitable foundation for implementing nature-based designs. In this context, the Bus Terminal Parking Lot, with its partially permeable surface structure, is a good starting example.

This study's evaluation of three open-air parking lots in Isparta's city centre within the context of climate change-adaptive design principles is crucial for revealing the current status and potential for improvement of open-air parking areas in Türkiye. The findings demonstrate that the risks stemming from climate change, clearly emphasised in the literature, are clearly observed in open-air parking lots in cities (IPCC, 2021; EEA, 2023). When the strengths and weaknesses of the current situation are evaluated, it is clear that parking lots are in dire need of transformation in terms of both their physical infrastructure and environmental performance. Firstly, the predominance of impermeable surfaces creates serious problems, such as rising surface temperatures and a decrease in in-situ water infiltration capacity in Isparta's arid-semi-continental climate. Particularly in the Delta and Iyaş parking lots, the heat stored by asphalt and concrete surfaces during the day and released at night hurts the microclimate. This is identified in the literature as one of the main factors contributing to the urban heat island effect (Razzaghmanesh & Beecham, 2019). While the partially permeable structure of the Bus Terminal Parking Lot is a positive example, the joint gaps that fill over time reduce permeability and limit the system's effectiveness. This finding is consistent with studies demonstrating that permeable pavement systems require regular maintenance (Hong & Lee, 2021; Cacciuttolo et al., 2023). One of the most critical shortcomings in adapting to climate change is stormwater management. None of the three parking lots features nature-based infrastructure solutions, such as rain gardens, biofilters, infiltration trenches, or storage systems, which can increase surface runoff and lead to water accumulation after sudden rainfall. UN-Habitat (2022) and EPA (2020) guidelines identify the integration of parking areas with rainwater management systems as a fundamental requirement for climate-resilient design. In this context, the current approach, as illustrated by the Isparta example, is insufficient to mitigate the risks associated with extreme precipitation resulting from climate change. The lack of green infrastructure is the most significant environmental vulnerability revealed by the findings. The lack of afforestation, green border elements, and shade both exacerbates the heat island effect and reduces user comfort. Extremely high vehicle interior temperatures, thermal stress on surfaces, and unshaded pedestrian crossings, particularly in summer, are factors that negatively impact microclimate. The literature indicates that green infrastructure can reduce surface temperatures in parking lots by 3–8°C (Graça, 2022). Nevertheless, the absence of green infrastructure in all three parking lots examined indicates a significant loss of opportunity for climate adaptation in urban open spaces.

When evaluated from an energy efficiency perspective, the absence of LED systems, sensor-activated lighting, or solar panels in parking lots exacerbates their negative impact on the carbon footprint. However, numerous studies have demonstrated the benefits of photovoltaic shading structures in terms of both energy production and thermal control (Aldridge & Medina, 2021). The fact that all existing parking lots in Isparta are passive energy-consuming spaces leaves a picture far behind modern parking standards in the context of climate change. Findings regarding accessibility and social sustainability, however, indicate that parking designs in the city are entirely vehicle-focused. The lack of accessible parking spaces, pedestrian paths, and

bicycle lanes, as well as the absence of user-centred design elements in any area, indicates that parking lots are deviating from their role as urban public spaces. However, the current approach recommends transforming parking lots into multifunctional, inclusive public spaces integrated with green infrastructure (UN-Habitat, 2022; Aldridge & Medina, 2021).

Furthermore, the study findings reveal not only shortcomings but also potential opportunities. The Iyaş Parking Lot's large surface area offers substantial potential for rainwater management and shading applications. The partially permeable structure of the Bus Terminal Parking Lot provides an important starting point for climate-adapted transformation. With these features, existing parking lots in Isparta can be transformed into sustainable microecosystems that adapt to climate change with the right interventions.

4. Conclusion and Recommendations

Analysis of three parking lot examples reveals that open-air parking lots in Isparta have not yet been integrated into climate change adaptation strategies.

These findings indicate that open-air parking lots continue to increase environmental impacts unless they are integrated with climate change-adapted urban infrastructure systems. The results explicitly obtained for Isparta suggest that open-air parking areas in similar medium-sized cities in Türkiye also pose similar environmental risks.

The findings align with the international literature, which emphasises the transformative potential of open-air parking lots in combating climate change (Graça, 2022; UN-Habitat, 2022; EEA, 2023). However, limited studies conducted in Türkiye suggest that this issue remains a voluntary environmental choice, rather than an infrastructural necessity.

The Isparta example provides a typical example for cities in the early stages of this transformation process. It demonstrates that local governments should integrate climate adaptation criteria into zoning plan decisions in parking lot designs. This research was conducted using field observations and existing physical data. Future studies are recommended to be supported by numerical modelling and simulation-based approaches, such as:

- Surface temperature measurements,
- Water permeability analysis,
- Modelling the microclimatic effects of plant species,
- Energy efficiency analyses of photovoltaic shading systems. Furthermore, conducting similar analyses in cities in different climatic zones will contribute to the classification of climate-adapted parking typologies on a national scale.

The use of permeable paving systems (permeable interlocking paving, grass flooring, permeable concrete) in parking lot surfaces will reduce surface runoff and encourage groundwater infiltration. Integrating afforestation, green strips, and shaded walking areas will reduce surface temperatures and increase microclimatic comfort. Solar panel-supported pergola systems can provide both energy generation and shading. On-site water management, including biofilters, rain gardens, and water storage systems, will help control sudden surface runoff in the city. The widespread adoption of LED-based, sensor-controlled, or solar-powered lighting systems will reduce energy consumption and lower carbon emissions. Parking lots should be repurposed as user-centred public spaces, not just vehicle-centred ones, through the provision of accessible parking spaces, bicycle racks, and shaded pedestrian crossings. A "climate-

compatible parking design guide" should be prepared for municipal parking projects, and performance indicators such as permeable surface area, percentage of green space, and energy efficiency should be made mandatory for projects.

- Quantitative microclimate measurements: In future research, in situ measurements of microclimatic parameters such as surface temperatures, humidity, wind speed, and the heat island effect will contribute to the scientific validation of climate-adaptive parking designs.
- Simulation-based analyses: The thermal impacts of different surface material scenarios can be modelled using geographic information systems (GIS) and energy modelling software (e.g., ENVI-met, i-Tree, and Rhino-Grasshopper plugins).
- Comparative regional studies: Comparing parking lot examples located in different climate zones in Türkiye (e.g., Mediterranean, Central Anatolia, and Black Sea) will reveal the impact of regional climate differences on design criteria.
- User behaviour and comfort perception: Social studies assessing parking lot users' perceptions of temperature, shading, accessibility, and safety can help develop user-based adaptation strategies.
- Nature-based infrastructure solutions: Rain gardens, biofiltration swales, and permeable soil combinations can play an important role in stormwater management and microclimate balance.
- Photovoltaic shading systems: Solar panel-supported shading structures can both reduce surface temperatures and reduce the carbon footprint of parking lots through energy production.
- New material research: Engineering studies on light-colored, permeable surface materials with high heat reflection coefficients (e.g., "cool pavement" technologies) should be increased.
- Smart lighting systems: Energy consumption can be reduced by integrating solar-powered LED lighting with motion sensors and timers.
- Municipal-level climate adaptation guidelines: A "Climate-Compatible Open Space Design Guide" should be prepared for parking lot projects; indicators of permeable surface area, percentage of green space, energy efficiency, and social inclusion should be made mandatory in this guide.
- Strengthening the legal framework: The current Parking Regulation (2018) focuses only on capacity and location selection. Future revisions should include climate adaptation criteria, green infrastructure requirements, and energy efficiency criteria.
- Planning based on local climate data: Parking lot design standards supported by microclimatic data should be developed in every city. These standards should be integrated into zoning plans and made applicable to ensure consistency. • Education and awareness campaigns: In-service training programs on climate-compatible design should be organised for architects, engineers, and urban planners; this content should be incorporated into university architecture and urban planning curricula.

In the future, parking lots should not only serve as vehicle storage areas but also be multifunctional open spaces that are integral to the urban ecology. Successfully achieving this

transformation requires a holistic approach that encompasses not only engineering or architecture but also urban policy, management, and community engagement.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Aldridge, C., & Medina, R. (2021). Building a new framework for urban parking facilities: Principles for planning. *Sustainability, 13*(7), 3629. https://doi.org/10.3390/su13073629

AmperaPark. (2025). *Solar carport installations*. Retrieved July 11, 2025, from https://www.amperapark.nl/solar-carports

Cacciuttolo, C., et al. (2023). Evaluation of the use of permeable interlocking concrete paving (PICP) system for a parking-lot in Temuco, Chile: A sustainable urban drainage system (SUDS) case study. *Water, 15*(24), 4219. https://doi.org/10.3390/w15244219

Chen, H., & Zhang, X. (2023). Sustainable renewal methods of urban public parking spaces under the scenario of shared autonomous vehicles (SAV): A review and a proposal. *Sustainability, 15*(4), 1267. https://doi.org/10.3390/su15041267

Çevre, Şehircilik ve İklim Değişikliği Bakanlığı. (2018). *Otopark Yönetmeliği*. Resmî Gazete (30340, 22 Şubat 2018). https://www.resmigazete.gov.tr

European Environment Agency (EEA). (2023). *Urban adaptation to climate change in Europe 2023: Transforming cities in a changing climate*. Publications Office of the European Union. https://www.eea.europa.eu/publications

Federal Highway Administration (FHWA). (2019). *Green infrastructure design guide for urban drainage and parking facilities*. U.S. Department of Transportation.

Graça, M. (2022). Designing urban green spaces for climate adaptation: A critical review of research outputs. *Urban Climate, 42*, 112616. https://doi.org/10.1016/j.uclim.2022.100902

Hong, Y. M., & Lee, J. (2021). The simplified design method of permeable pavement in the context of sponge city research. *Journal of Infrastructure Systems, 27*(2), 04021016. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000610

Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate change 2021: The physical science basis*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

Razzaghmanesh, M., & Beecham, S. (2019). Long-term effects of three types of permeable pavements on urban runoff and water quality. *Science of the Total Environment, 698*, 133–146. https://doi.org/10.1016/j.scitotenv.2019.132281

Sustainable Technologies Evaluation Program (STEP). (2018). *Green parking lots – Low impact development examples*. Retrieved July 11, 2025, from https://sustainabletechnologies.ca

TMMOB Şehir Plancıları Odası. (2021). *Sürdürülebilir Kent İçin Otopark Planlama Ilkeleri Raporu*. TMMOB Yayınları.

Total Landscape Care. (2025). *Permeable pavement: Addressing common questions and concerns*. Retrieved September 15, 2025, from https://www.totallandscapecare.com/business/article/15042229/permeable-pavement-addressing-common-questions-and-concerns

Türk Standartları Enstitüsü (TSE). *TS 12576 erişilebilirlik standartları*. https://www.imarkadastro.com/userfiles/file/Dokuman/Erisilebilirlik%20Standartlar%C4%B1.pdf

U.S. Environmental Protection Agency (EPA). (2020). *Stormwater management and green parking lots guide*. U.S. EPA. https://www.epa.gov

United Nations Human Settlements Programme (UN-Habitat). (2022). *Guidelines for climate-resilient urban design*. UN-Habitat. https://unhabitat.org

Zhang, L., & Li, J. (2025). Evaluating surface materials in parking lots: Their influence on microclimate and urban heat mitigation. *Environmental Sustainability Indicators, 22*, 100350. https://doi.org/10.1016/j.ensi.2025.100350

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Urban Green Space-Sensitive Parking Lot Planning: An AI-supported Sustainable Approach

Fatma ÖZKAN BAYINDIR[1*]

ORCID 1: 0000-0002-7292-905X
[1]Dr., Süleyman Demirel University, Department of Architecture Planning and Design, Landscape Architecture, Isparta-Türkiye
*fatma.ozkan.bayindir@gmail.com (Corresponding Author)

Ali ÖZ [2]

ORCID 2: 0000-0002-0814-4020
[2]Assoc. Prof. Dr., Mehmet Akif Ersoy University, Technical Sciences Vocational School, Department of Motor Vehicles and Transportation Technologies, Burdur, Türkiye
alioz@mehmetakif.edu.tr

Atila GÜL[3]

ORCID 3: 0000-0001-9517-5388
[3]Prof. Dr., Süleyman Demirel University, Department of Landscape Planning and Design, Landscape Architecture, Isparta, Türkiye
atilagul@sdu.edu.tr

Abstract

In recent years, the rapid increase in urbanisation and the parallel rise in the number of motor vehicles have created a significant demand for parking in cities, often leading to the shrinkage of green spaces and disruption of the ecological balance. Therefore, current urban planning approaches reveal that parking lots are not only functional spaces but also areas that must be evaluated in terms of sustainability and ecological integrity. This study is a compilation that examines how AI-supported planning approaches can contribute to the protection of green spaces. Literature reviews demonstrate that AI is a crucial tool for analysing spatial data to determine optimal parking locations and making design decisions that minimise environmental impacts. Furthermore, AI applications integrated with nature-based solutions strengthen environmental sustainability. Consequently, AI-based parking planning approaches have strategic potential for protecting green spaces, reducing carbon emissions, and creating cities adaptable to climate change. This study provides a comprehensive perspective that will contribute to the development of sustainable urban planning policies.

Keywords: Artificial Intelligence, parking planning, urban green spaces, sustainability.

1. Introduction

Rapid urbanisation observed worldwide since the beginning of the 21st century has led to significant increases in energy consumption, transportation demand, and spatial pressures. According to the United Nations' World Cities Report 2024, approximately 68% of the world's population is projected to live in cities by 2050, with the rate of urbanisation expected to double, particularly in developing countries (UN-Habitat, 2024). This process creates significant pressure on existing infrastructure capacity and threatens the sustainability of urban systems. The increase in the number of motor vehicles, in particular, has become a significant problem in terms of both energy consumption and urban land use.

Car ownership in cities has increased dramatically over the last three decades, and the resulting demand for parking has become one of the most critical elements of urban spatial planning (Shoup, 2021). While traditional transportation planning aims to facilitate vehicle mobility, this approach has inevitably led to adverse outcomes, including the shrinking of green spaces, the expansion of impervious surfaces, and the disruption of the ecological balance (Cheng et al.,

2022; Zhang et al., 2023). The increasingly concretised urban fabric strengthens the urban heat island effect, accelerates surface runoff, increases flood risk, and reduces carbon sequestration capacity (Wang et al., 2022). Therefore, parking planning is not only a functional necessity but also an area that requires re-evaluation in terms of ecological sustainability, climate adaptation, and the integration of green infrastructure (Qiao & Zhou, 2023).

In this context, artificial intelligence (AI) technologies offer revolutionary opportunities in urban planning. Thanks to the integration of advanced data analytics, deep learning, geographic information systems (GIS), and remote sensing data, complex spatial relationships can be analysed with higher accuracy (Kandt & Batty, 2021). AI stands out not only for its ability to interpret past data but also for its capacity to generate future scenarios. This enables the development of predictive and adaptive models in urban planning, allowing for multidimensional balances among transportation demand, land use, energy efficiency, and environmental impacts (Li et al., 2024).

Parking lot planning is one area where these technologies can be directly applied, as site selection is not only about spatial suitability but also involves the combined evaluation of environmental, social, and economic indicators. Machine learning-based systems can determine the most appropriate parking locations by analysing variables such as topography, population density, traffic flows, green space density, and carbon emissions (Saha et al., 2023). Thus, AI not only optimises the site selection process but also functions as a decision support mechanism that increases environmental awareness.

Current literature clearly demonstrates the potential of AI-supported urban planning to contribute to environmental sustainability. Vinuesa et al. (2020) stated that artificial intelligence is directly related to at least 134 targets of the Sustainable Development Goals, and that this technology has a transformative impact, particularly in climate action, clean energy, intelligent transportation, and sustainable cities. Similarly, the European Commission's 2023 AI for the Green Deal report emphasised the need to develop artificial intelligence in line with environmentally friendly policies and green transformation goals (European Commission, 2023).

The use of artificial intelligence in urban planning is not only a technical innovation but also enables transparency, accuracy, and the strengthening of data-driven decision-making processes. Thanks to big data infrastructures and sensor-based systems, dynamic indicators such as parking demand, traffic density, and air quality can be monitored in real time, and this information can be integrated into planning policies (Kitchin, 2020; Zhang et al., 2023). This transforms parking planning from a static engineering problem into a holistic systems approach encompassing environmental, social, and technological dimensions. On the other hand, increasing vehicle use impacts not only spatial sustainability but also economic and social sustainability. The time vehicles spend in traffic searching for parking can account for approximately 8–10% of total carbon emissions in cities (Shoup, 2021). Therefore, the integration of intelligent parking systems and green space protection policies is strategically important for cities' goal of becoming carbon neutral (Tan et al., 2021). AI-powered sensor networks can monitor parking lot occupancy rates and guide vehicles, thereby reducing fuel consumption, emissions, and traffic congestion.

In Türkiye, innovative urban planning applications have gained significant momentum in recent years. The National Smart Cities Strategy and Action Plan (2020–2025) report emphasises that AI-supported data analytics can be integrated with urban planning, parking management,

energy efficiency, and green space protection policies (Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change, 2021). However, most applications in Türkiye are still at the operational level; the use of AI-supported decision systems at the spatial planning scale appears to be limited (Yılmaz & Aydınoğlu, 2023). This creates a significant gap in academic research and local government policies.

Integrating parking planning with green space management is important not only for environmental reasons but also for social well-being. Urban green spaces offer a range of multifaceted ecosystem services, including microclimate regulation, recreation, and public health benefits (Haase et al., 2021). Therefore, combining nature-based solutions with AI analyses in parking planning is a critical strategy for achieving sustainable urban planning goals.

Existing research demonstrates that AI is not only a technological tool in urban planning but also a new paradigm that supports environmental awareness, spatial efficiency, and social sustainability (Batty, 2021; Li et al., 2024). This study examines this paradigm shift in parking lot planning, specifically examining how AI-based models can contribute to the preservation of green spaces. Through a literature review, it is demonstrated that the integrated use of AI in spatial decision-making processes, combined with nature-based approaches, is a strategic direction for ecologically resilient cities of the future.

2. Materials and Methods

This study is a qualitative review examining the contributions of artificial intelligence technologies to parking lot planning and the protection of green spaces. The research aimed to develop a conceptual framework by integrating current scientific trends, theoretical approaches, and application examples from the literature. The study was designed with an interdisciplinary approach, encompassing publications in the fields of urban planning, environmental engineering, computer science, and sustainability studies.

During the research process, a systematic search was conducted for published academic studies on the intersection of artificial intelligence and sustainable planning. National and international databases, including Scopus, Web of Science (WoS), ScienceDirect, Google Scholar, and TR Index, were utilised for data collection. International policy documents and reports (e.g., United Nations-Habitat, European Commission, World Bank, OECD, and IPCC) were also included as reference sources.

The main keywords used in the search process were: “artificial intelligence,” “urban parking planning,” “green space,” “sustainability,” “machine learning,” “spatial analysis,” “ecological urbanism,” and “nature-based solutions.” In the Turkish literature review, the terms “artificial intelligence,” “parking lot planning,” “green space management,” “sustainable urbanisation,” and “smart cities” were used.

These keywords ensured that the scope of the research remained within the intersection of parking lot planning, green infrastructure, and artificial intelligence technologies. The DOI, journal impact factor, and citation counts of the selected publications were checked against the Web of Science database. For ethical reasons, the study was conducted using only open-access and publicly available data. No participant or personal data was used, and all sources were cited. Consequently, the study was structured as a literature-based qualitative analysis, and the obtained information was synthesised within a conceptual framework.

3. Findings and Discussion

3.1. The Role of Artificial Intelligence in Urban Planning Processes

In recent years, artificial intelligence (AI) has evolved from a data analysis tool to a predictive and transformative decision support mechanism in urban planning. By integrating big data analytics, remote sensing, and geographic information systems (GIS), AI algorithms can assess the spatial dynamics of cities in a multidimensional manner and establish complex relationships between population density, land use, transportation flows, and environmental indicators (Batty, 2021; Li et al., 2024). In this context, AI has transformed the traditional planning approach from a static analysis into a learning and continuously updating system. For example, convolutional neural networks (CNNs) can identify the distribution of green spaces, surface temperature differences, and urban heat island (UHI) density from high-resolution satellite imagery and integrate this data into spatial decision models (Wang et al., 2022). Such analyses enable the quantitative measurement of environmental impacts in parking lot planning and the selection of alternatives that will cause minimal ecological damage.

The most significant contribution of AI-based models is their ability to incorporate ecological planning criteria into spatial optimisation processes. This enables the development of planning approaches compatible with the carrying capacity of urban ecosystems and is of great importance for environmental sustainability (Kandt & Batty, 2021).

3.2. Artificial Intelligence Applications in Parking Lot Planning

Parking lot planning is a critical component that directly impacts both transportation efficiency and environmental quality in urban systems. Four main application areas of AI-based parking lot planning stand out in the literature:

(1) Location selection optimisation,

(2) Real-time occupancy prediction,

(3) Dynamic pricing and traffic routing,

(4) Environmental impact modelling (Saha et al., 2023; Cheng et al., 2022).

For example, in the "Smart Green Parking System" model developed in Singapore, deep learning algorithms reduced parking time by 28% by monitoring parking lot occupancy rates in real-time (Tan et al., 2021). This not only increased energy efficiency but also significantly reduced exhaust emissions.

Similarly, AI-powered parking management systems in European cities (especially in Amsterdam and Copenhagen) have developed spatial decision models to maintain connectivity with green spaces. These systems feature integrated parking spaces with permeable surfaces and planted lanes, which support both rainwater drainage and contribute to microclimate regulation (Jensen & Löfström, 2020).

Similar trends are emerging in Turkish examples. Metropolitan municipalities, in particular, aim to identify parking locations with ecological sensitivity by analysing the relationship between parking demand and green space density in their "smart city data platforms" (Yılmaz & Aydınoğlu, 2023).

3.3. Strategic Contributions of Artificial Intelligence in the Protection of Green Spaces

Green spaces are vital components that form the ecological backbone of cities. These spaces reduce greenhouse gas emissions by acting as carbon sinks, mitigate the urban heat island effect, provide habitats for biodiversity, and support urban health by regulating microclimates (Haase et al., 2021). However, the expansion of parking and transportation infrastructure, particularly in regions with high urbanisation rates, poses a threat to the sustainability of these spaces (Zhang et al., 2023). Artificial intelligence technologies offer revolutionary tools for creating early warning and monitoring mechanisms to prevent this loss. Deep learning models developed using satellite imagery, LiDAR data, and multispectral analysis can accurately classify the spatial distribution of green spaces and monitor their changes over time (Gao et al., 2022). For example, analysing "Normalised Difference Vegetation Index (NDVI)" data with AI algorithms can identify the decrease in green space due to parking lot expansion at the pixel level, providing planners with a scientific decision basis for spatial interventions.

Another strategic contribution of AI in this area is the quantification and spatialisation of ecosystem services. In traditional planning processes, indicators such as carbon sequestration, air quality improvement, or contribution to the water cycle are assessed qualitatively. However, AI-based models can analyse these impacts quantitatively, for example, estimating the potential carbon loss or surface temperature increase of a parking lot project (Qiao & Zhou, 2023). Thus, the planning process transforms from a physical location selection into a holistic decision-making mechanism that includes ecological cost analysis. With this method, ecosystem continuity can be preserved by recommending multi-story or underground alternatives instead of constructing new parking lots in areas with low green space density (Li et al., 2024). AI also enhances the performance of green infrastructure systems by integrating with nature-based solutions. Sensor-based monitoring networks transform green space management into a dynamic process by collecting real-time data on plant health, soil moisture, and surface temperature (Song et al., 2020). Thus, maintenance, irrigation, and restoration decisions for green belts surrounding parking lots can be optimised in a data-driven manner.

In the Turkish context, AI-supported green space monitoring systems have begun to be developed, particularly in major cities such as Istanbul and Ankara. The Istanbul Metropolitan Municipality's 2022 "Smart City Strategy" report states that green infrastructure mapping projects supported by satellite data strengthen the urban ecosystem and provide guidance for maintaining green connectivity in parking lot projects (IMM, 2022).

Consequently, AI-based analyses support the protection of green spaces at three levels:

1. Predictive monitoring—Pre-detection of green space loss,
2. Quantitative assessment—Measurability of ecosystem services,
3. Adaptive management—Planning decisions based on real-time environmental data.

When these three levels are considered together, it becomes clear that AI is not merely a technical tool for preserving the integrity of urban ecology but a strategic sustainability tool.

Nature-based solutions (NBS) are planning approaches that mimic ecological processes or draw direct inspiration from nature. When integrated with AI, these solutions become much more measurable, manageable, and scalable. AI-supported NBS approaches aim to increase ecosystem resilience in cities by analysing indicators such as permeable surface ratio, vegetation density, and water retention capacity (Raymond et al., 2017; Bhaduri et al., 2021).

For example, the "AI-Green Parking" system developed in China combines NDVI data, city temperature maps, and rainwater runoff models to reduce the environmental impact of parking lots (Liu et al., 2023). Similarly, the European Union's Nature for Cities project optimises the compatibility of parking lots, green roofs, and vertical gardens with carbon neutrality targets through AI-supported multi-criteria analyses (European Commission, 2021).

Such hybrid systems transform parking areas from passive infrastructure elements into active ecological components. In this transformation, AI adds a new dimension to nature-based planning by enabling continuous monitoring of environmental performance and automatically recommending necessary corrective measures.

Such hybrid systems transform parking areas from passive infrastructure elements into active ecological components. In this transformation, AI adds a new dimension to nature-based planning by enabling continuous monitoring of environmental performance and automatically recommending necessary corrective measures.

Artificial intelligence (AI)-supported parking planning is an innovative approach that has the potential to protect the integrity of green spaces while meeting the increasing demand for vehicles in cities. However, this approach represents not only a technical transformation but also a multi-layered change that presents new opportunities and challenges at the spatial, ecological, and governance levels (Batty, 2021; Qiao & Zhou, 2023).

The most significant contribution of AI is its ability to analyse complex spatial relationships with high accuracy and make ecological sustainability measurable. Deep learning and remote sensing-based systems can quantitatively assess the environmental impacts of parking areas, addressing variables such as impervious surface ratio, plant density, carbon emissions, and surface temperature within the same model (Gao et al., 2022; Liu et al., 2023). Another strength of AI-based systems is their ability to integrate with nature-based solutions. Raymond et al. (2017) and Bhaduri et al. (2021) emphasise that AI offers the possibility of "measurable nature-based planning" by modelling the impact of applications such as permeable pavement, rain gardens, vertical gardens, and green roofs. This approach moves design decisions from intuitive to data-driven and predictive.

Furthermore, AI stands out as a tool that facilitates multi-criteria decision-making processes for designers. Optimal parking locations can be determined by simultaneously evaluating various factors, including topography, traffic density, land use, green space distribution, and social access (Saha et al., 2023). This reduces human error and offers significant advantages in terms of time and cost.

However, the success of these models is highly dependent on the quality and accessibility of the data. In developing countries like Türkiye, the lack of high-resolution spatial data limits the accuracy of AI systems (Yılmaz & Aydınoğlu, 2023). It is also worth noting that AI models inherently consume large amounts of energy and have a significant carbon footprint. This could reverse some of the environmental gains (Vinuesa et al., 2020). Therefore, it is necessary to adopt the principles of "green AI" and design models with energy efficiency in mind.

AI-assisted planning creates both new opportunities and new challenges for designers. The most significant advantage is the increased speed and accuracy of spatial analysis processes. AI tools integrated with geographic information systems can process multi-layered data to determine the most suitable parking locations in seconds, thus significantly accelerating the design process (Li et al., 2024). However, to use this technology effectively, designers must possess digital

literacy and data analytics skills. The limited availability of these competencies in traditional planning education poses a significant obstacle to implementation (Kitchin, 2020).

Furthermore, there is uncertainty about how to integrate the results produced by algorithmic systems into planning decisions. While AI proposals often offer the most technically efficient option, they may not sufficiently account for qualitative factors such as social justice, aesthetics, or local identity (Floridi & Cowls, 2019). This requires designers to possess not only data but also the ability to provide contextual interpretation. Another challenge of AI-assisted planning is the ethical and governance dimension. According to the European Commission's "Trustworthy AI" framework, algorithms used in urban planning must be transparent, accountable, and subject to human oversight (European Commission, 2021). However, many local governments lack the institutional capacity to implement these standards. This could lead to the risk of algorithmic biases creating spatial injustices without being noticed (Haase et al., 2021). Therefore, for AI-based parking planning to succeed, technological innovations must be supported by ecological ethics, participatory planning, and multidisciplinary design principles. Once this integration is achieved, AI will not only be a tool for optimising planning processes but also a key to urban transformation in harmony with nature.

4. Conclusion and Recommendations

Generally, AI-assisted parking planning is an innovative approach that strengthens the environmental sustainability of cities, preserves the continuity of green spaces, and improves the quality of social life. This method surpasses traditional planning processes by developing a data-driven, ecologically sensitive, and human-centred approach to urban management. Examples from Türkiye and around the world demonstrate the practical applicability and measurability of this approach. Therefore, future policy and research agendas must focus on holistic planning models that incorporate the ethical, ecological, and social dimensions of AI. Consequently, when combined with nature-based solutions, AI-assisted planning processes will enable cities to transform into not only sustainable but also livable and resilient ecosystems.

The study's results offer multifaceted implications for urban planning and environmental policies. First, municipalities and planning authorities should redefine parking areas not simply as spaces for vehicle storage, but as urban components with ecological functions and social benefits (Grimmond, 2018; Mullaney et al., 2015). Secondly, sustainable parking policies should be integrated with the parameters of carbon emission, green space integrity, and water management. AI systems are powerful decision-support tools that enable this integration, providing planning authorities with digitally based environmental analysis (Kabisch et al., 2016; Johnson et al., 2022). Thirdly, local governments need to develop their data collection, sensor networks, and spatial analysis capacities. AI-based planning applications in Türkiye are still in their early stages; therefore, joint data sharing and research networks should be established among universities, public institutions, and the private sector (IMM, 2022; T.C. ÇŞİDB, 2021). Fourthly, ethical principles and transparency standards should be integrated into planning processes. The principles of data security, accountability, and public scrutiny in AI-based decision systems should be implemented in line with the European Union's "Trustworthy Artificial Intelligence" framework (Floridi & Cowls, 2019; European Commission, 2021). Finally, parking planning should be considered an integral element of the transportation system, integrated with sustainable mobility policies by being planned alongside public transportation, bicycle paths, and pedestrian-focused areas (Newman & Kenworthy, 2015; Tan et al., 2021).

While the protection of green spaces has long been a goal emphasised in sustainable urbanism literature, in practice, it has often been relegated to the background due to spatial pressures. AI has the transformative potential to re-establish this balance. AI enables the development of adaptive planning models that preserve the continuity of green spaces. Thus, AI dynamically processes environmental data, becoming a "living" part of urban ecosystems. Furthermore, AI enables ecological criteria to be measurable in planning decisions by transforming ecosystem services (e.g., carbon sequestration, air quality, microclimate regulation) into numerical planning variables. This encourages the evaluation of green spaces not only as an aesthetic but also as a functional planning component (Haase et al., 2021). AI-supported parking planning also has strong parallels with climate adaptation policies. In this context, parking lots no longer merely serve as vehicle storage; they have also become an integral part of the urban ecosystem.

Although AI-assisted urban planning applications in Türkiye are still in their infancy, the National Smart Cities Strategy (2020–2025) and various metropolitan projects developed over the past few years have created a strong trend in this area (Republic of Türkiye, ÇŞİDB, 2021). However, the biggest obstacle to protecting green spaces in Türkiye is the integrity of data and limited access to open data. For AI models to function effectively, high-resolution spatial data must be regularly updated and shared among local governments. Furthermore, it is crucial that planning institutions possess the necessary institutional capacity to integrate AI-based analyses into their decision-making processes.

This study contributes to the literature on the relationship between AI and sustainable planning, suggesting some directions for future research. Long-term impact analyses: Studies that monitor the environmental, social, and economic impacts of AI-assisted parking and green space integration using long-term datasets are necessary. This will enable us to evaluate the performance of AI models over time.

- Multi-scale modelling: AI-based planning models developed at the neighbourhood, city centre, and regional levels will provide decision-makers with more comprehensive scenario analysis capabilities.
- Increasing public participation: Developing participatory planning approaches that measure social acceptance of AI-based decisions is crucial. Public environmental awareness and local knowledge should be incorporated into the process (Gulsrud et al., 2020).
- Integrated data management: Open data platforms and standardised spatial databases should be created for AI models; this will facilitate international comparability.
- Integration with sustainable mobility: Parking planning should contribute to carbon footprint reduction by integrating with bicycle, pedestrian, and public transportation systems (Qiao & Zhou, 2023).

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Batty, M. (2021). *The New Science of Cities*. MIT Press.

Bhaduri, B., et al. (2021). Nature-based solutions and AI integration. *Sustainable Cities and Society*, *69*, 102855.

Cheng, X., Liu, J., & Yang, W. (2022). Smart parking management using deep learning: A sustainability perspective. *Sustainable Cities and Society, 80*, 103811. https://doi.org/10.1016/j.scs.2022.103811

European Commission. (2021). Ethics Guidelines for Trustworthy AI. Brussels.

European Commission. (2023). AI for the Green Deal: Digital tools for sustainable transformation. Brussels.

Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. *Harvard Data Science Review*, *1*(1), 1–15.

Gao, L., Zhao, P., & Huang, Y. (2022). AI-based monitoring of urban green space dynamics using satellite imagery. *Remote Sensing of Environment*, *278*, 113091.

Grimmond, S. (2018). Urban climate and sustainable design. *Urban Climate*, *25*, 1–3.

Gulsrud, N. M., et al. (2020). Citizens and green space governance. *Urban Forestry & Urban Greening*, *47*, 126–138.

Haase, D., Kabisch, N., & Haase, A. (2021). Green spaces and urban sustainability: A global review. *Land Use Policy*, 108, 105556.

IBB. (2022). Environmental Sustainability Projects in Smart Cities. Istanbul Metropolitan Municipality Publication.

Jensen, T., & Löfström, S. (2020). Green parking systems in Scandinavian cities. *Sustainable Cities and Society*, 55, 102031.

Johnson, T., Lee, D., & Kim, H. (2022). Smart urban infrastructure planning with machine learning. *Cities*, *120*, 103439.

Kabisch, N., et al. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas. *Ecology and Society*, *21*(2), 39.

Kandt, J., & Batty, M. (2021). Smart cities, big data and urban policy. *Urban Studies*, *58*(4), 759–776.

Kitchin, R. (2020). *Data Lives: How Data Are Made and Shape Our World*. Bristol University Press.

Li, S., Chen, L., & Zhang, Y. (2024). Integrating AI-based spatial modeling into urban ecological planning. *Sustainable Cities and Society*, 109, 105655.

Liu, Y., Zhang, H., & Chen, L. (2023). AI-Green Parking: Integrating environmental monitoring with parking management. Computers, *Environment and Urban Systems*, 95, 101842.

Mullaney, J., Lucke, T., & Trueman, S. (2015). A review of previous pavement research. *Water*, *7*(6), 3021–3055.

Newman, P., & Kenworthy, J. (2015). *The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning*. Island Press.

Qiao, X., & Zhou, Y. (2023). Green infrastructure planning for low-carbon cities: An AI-enabled approach. *Cities*, *141*, 104431.

Raymond, C., et al. (2017). A framework for nature-based solutions in urban planning. *Global Environmental Change*, 43, 103–112.

Saha, R., Pal, S., & Das, S. (2023). Multi-criteria parking site selection using machine learning and spatial analysis. *Transportation Research Part C*, 152, 104166.

Shoup, D. (2021). *The High Cost of Free Parking* (Updated Edition). Routledge.

Song, X., et al. (2020). Integrating AI and remote sensing for urban ecosystem management. *Ecological Indicators*, 113, 106263.

T.R. Ministry of Environment, Urbanisation and Climate Change. (ÇŞİDB) (2021). National Smart Cities Strategy and Action Plan (2020–2025). Ankara.

Tan, T., Lim, J., & Wong, M. (2021). Smart parking and green mobility system in Singapore. *Journal of Transport Geography*, *95*, 103144.

UN-Habitat. (2024). World Cities Report 2024: Urban future and sustainability. Nairobi: United Nations.

Vinuesa, R., et al. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications*, *11*, 233.

Wang, T., Xu, C., & Zhao, P. (2022). Urban impervious surface expansion and environmental sustainability. *Environmental Research Letters*, 17(8), 084012.

Yılmaz, T., & Aydınoğlu, M. (2023). Geographic information systems-based parking planning approaches: Examples from Türkiye. *Journal of Planning*, 33(2), 145–162.

Zhang, H., Li, Y., & Wang, J. (2023). Assessing the ecological impact of parking expansion in urban areas using GIS and AI models. *Journal of Cleaner Production*, 406, 136965. https://doi.org/10.1016/j.jclepro.2023.136965

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Reimagining the City: Utopian and Dystopian Perspectives in Contemporary Urban Planning

Mehmet Can AKDAĞ [1*]

ORCID 1: 0009-0008-6359-1254
[1]Master Student, Süleyman Demirel University, Institute of Natural and Applied Sciences City and Regional Planning Program Isparta-Türkiye
*yl2330134006@ogr.sdu.edu.tr (Responsible Author)

Şirin Gülcen EREN [2]

ORCID 2: 0000-0002-2038-3905

[2]Assoc. Prof. Dr., Süleyman Demirel University, Faculty of Architecture, Department of City and Regional Planning, Isparta-Türkiye
sirineren@sdu.edu.tr

Abstract

Utopias envision ideal urban orders and visions of urban life and urban structure grounded in equality, sustainability, and collective welfare, while dystopias expose the social and environmental contradictions that arise when these ideals are distorted by power, capital, or inequality. The tension between these two paradigms provides a critical framework for interpreting the evolution of contemporary cities and their prospective futures. The concepts of utopia and dystopia have become increasingly central to theoretical debates in contemporary urban planning. Nevertheless, the ways in which these notions shape contemporary urbanization, urbanism, and visions of future cities remain insufficiently explored. Based on this problem, this study aims to analyze how utopian and dystopian perspectives are reflected in urban planning discourse and how they influence the conceptualization of urban futures. Based on the perspective Eren (2023) has presented for the future of cities and futuristic cities, this paper targets to illustrate how utopian urban ideals often lead to dystopian urban realities. Methodologically, this study adopts a qualitative research design that employs thematic content analysis of scholarly literature indexed in the Web of Science and Scopus databases between 1980-2025, using key terms such as utopia, dystopia, city planning, and sustainability. The analysis of 15 selected key publications identifies three recurring themes: Utopia as a design ideal, dystopia as a critical mirror of modern urbanism, and the need for a dialectical synthesis toward resilient and just urban futures. The paper concludes that utopian imagination and dystopian awareness should be viewed as complementary frameworks guiding city planning toward balance, responsibility, and inclusivity for the future of cities.

Keywords: Utopia, Dystopia, city planning, sustainability, future cities

1. Introduction

Cities have always represented far more than physical agglomerations of buildings, streets, and infrastructure. They are living manifestations of humanity's collective imagination, anxieties, and moral aspirations. Since the earliest settlements, the city has functioned as both a habitat and a projection of how societies imagine the good life. As Mumford (1962) observed, "the city is a product of nature, a symbol of society, and a projection of human values," embodying "the theater of social action" in which technological progress, cultural identity, and ethical order converge. Urban planning has historically mediated between these tangible and intangible dimensions, negotiating the relationship between material realities, political power, and idealized visions of the future of cities. Up to date, utopia and dystopia concepts have profoundly shaped the theory and practice of city planning. Contemporary urban theory views the city not merely as a physical space but as a historical arena where capitalist accumulation, class relations, and power structures are materially expressed (Turut & Özgür, 2018). Within this continuous negotiation, the concepts of utopia and dystopia have profoundly shaped the

theory and practice of city planning (e.g., star-shaped cities such as Palmanova (1593) and Scamozzi's polygonal models (1615), and Renaissance ideal city plans including Filarete's Sforzinda (1972) and Alberti's schemes (1485)).

The notion of utopia, originating in Plato's *Republic* and later articulated in Thomas More's *Utopia* (1516), occupies a foundational place in Western political and urban imagination. Plato's *Republic* is a philosophical inquiry into the nature of the ideal city. Deriving from the Greek ou-topos ("no place") and eu-topos ("good place"), the term denotes both an ideal society and the impossibility of its full realization. More's utopia was not merely a literary experiment, but an early critique of social inequality and moral corruption, using spatial order as a metaphor for justice and harmony. Utopian thinking thus provided a framework for envisioning cities as instruments of moral and social reform (Mumford, 1962; Levitas, 1990). Building on More's ideas, Leon Battista Alberti developed ideal urban schemes that later influenced the Renaissance ideal city plans of Albrecht Dürer, Cataneo, Maggi, and Filarete.

From Ebenezer Howard's Garden City (1902) to Le Corbusier's Ville Radieuse (1924) or the Walking City of Ron Herron (1964) modern urbanism has been profoundly shaped by the belief that spatial design could regenerate society through order, rationality, and aesthetic coherence (Fishman, 1982). Utopian plans promised balance between nature and industry, community and individuality, and progress and morality (Harvey, 2000; Hall, 2002). As Schubert (2004) argues, the tension between utopian design and social reality became increasingly evident in late-modern urbanism, where visionary spatial ideals often collided with everyday social complexities.

Howeve r, utopian imagination inherently carries the risk of control and exclusion when visions of order become totalizing. In this sense, dystopia emerges not as the opposite of utopia but as its critical counterpart. The term dystopia, coined by John Stuart Mill in the nineteenth century to describe "a place where everything has gone wrong," reflects the recognition that the pursuit of perfection can generate new forms of domination. Within urban planning, this critique resonates with the concept of "total design," in which architecture, landscape, transportation, and social life are subsumed under a single, centralized vision (Banham, 1960; Choay, 1997). When such comprehensive rationality suppresses diversity or spontaneity, the utopian project risks becoming dystopian.



Figure 1. Team Disney Building (Michael Graves, 1991), Burbank, California.

As Harvey (2000) and Soja (2010) emphasize, cities simultaneously embody progress and inequality, creativity and control. The commodification of space, social fragmentation, and the erosion of public life illustrate how ideals of efficiency and order can inadvertently reproduce alienation and exclusion. These dual narratives—utopia as vision and dystopia as warning—

are not opposites but dialectically intertwined (Jameson, 2005; Baeten, 2002). Each concept both defines and critiques the other, shaping the theoretical and practical possibilities of urban planning.

The twentieth century's grand experiments in modernist planning, such as Le Corbusier's Radiant City, Brasília, and numerous postwar new towns, exemplify this dialectic. Animated by utopian ideals of order and efficiency, they often resulted in socially fragmented, environmentally destructive, or authoritarian urban forms. Fainstein (2010) argues that the central challenge for contemporary planning is to sustain normative ideals—justice, equality, and sustainability—without succumbing to technocratic control or aesthetic abstraction.

In the contemporary era, the dialectic between utopia and dystopia has become more complex. Neoliberal restructuring, digitalization, and the global climate crisis have transformed how cities are imagined and produced (Brenner & Schmid, 2015). Contemporary utopian visions, epitomized by smart city and sustainability paradigms, promise efficiency, innovation, and ecological responsibility. Yet, as Kitchin (2014) and Greenfield (2013) observe, such frameworks often reproduce existing hierarchies, consolidate power within corporate and governmental domains, and marginalize citizens' voices. Similarly, sustainability agendas may inadvertently depoliticize inequality or commodify ecological values. In this sense, dystopian critique remains vital, revealing how contemporary "good city" narratives may conceal exclusion, surveillance, and environmental degradation (Baba, 2020; Eren, 2023).

City planning today operates within a paradox: It must harness utopia's creative vision while remaining vigilant to dystopia's ethical warnings. Bridging these modes of thought is not merely theoretical. This is a practical gap. When planning abandons imagination, it risks cynicism; when it abandons critique, it risks authoritarian optimism. Marcuse (2009) 's concept of "critical utopianism" offers a path forward, advocating for a planning approach that is simultaneously visionary and self-reflexive. City planners are thus called to design not for perfection, but for adaptability, inclusiveness, and ethical awareness (Gehl, 2010).

There is a need to study the influence of utopian and dystopian imaginaries and their role in redefining urban planning thought. This study argues that the dialectical relationship between utopia and dystopia constitutes an underexplored foundation for reimagining the city in the twenty-first century. It aims to understand the dialectical relationship between utopia as a design ideal and dystopia as a critical mirror of modern urbanism.

By synthesizing insights from urban theory, political philosophy, and environmental ethics, it examines how these paradigms shape planning discourse and practice. The goal is not to abandon utopian dreaming, but to ground it in pluralism, participation, and care (Eren, 2023). This synthesis transforms city planning into an act of dreaming and an act of responsibility — bridging ideals with the realities of urban life. A future-oriented city would prioritize equity over spectacle, participation over control, and ecological balance over profit (Lefebvre, 1991; Fainstein, 2010). According to Eren, the planning institution mediates between aspiration and constraint, imagination and responsibility. Ultimately, the critical question for scholars and practitioners is not only what kind of city is built, but what kind of society is cultivated (Harvey, 2008). In this evolving dialectic, utopia and dystopia remain essential coordinates guiding humanity's ongoing project of reimagining the city. Within this perspective, the study investigates how utopian and dystopian perspectives are reflected in urban planning discourse and how they influence the conceptualization of urban futures.

2. Materials and Method

This study employs a qualitative content analysis method to examine the theoretical and historical evolution of utopian and dystopian thought within the discipline of urban planning. The literature review was conducted through a systematic search of Web of Science and Scopus databases between January 1980 and November 2025, covering the period in which contemporary planning theory began to engage with critical urbanism and neoliberal restructuring. Table 1.

Table 1. Frequency of Utopia and Dystopia in Academic Literature

Concept / Years	Total	1980-1990	1991-2000	2001-2010	2011-2025
Dystopia	1026	14	12	71	929
Utopia	3107	29	75	393	2610
Utopia and Urban Planning	51	1	0	9	41
Dystopia and Urban Planning	9	0	0	2	7
Dystopia, Utopia, and Urban Planning	2	0	0	0	2

The analysis comprises fifteen core publications selected for their direct relevance to utopia, dystopia, and contemporary urban planning. These works were chosen because they make substantial theoretical contributions, are frequently cited within the field, and clearly articulate the conceptual foundations of the debate. In addition to these main sources, broader literature was reviewed to clarify key concepts, frame the research problem, and provide contextual support. The study employs a qualitative content analysis approach, focusing on identifying major themes and conceptual patterns across the literature, ensuring both depth in the selected works and a comprehensive understanding of the wider academic discourse. The selection criteria included peer-reviewed journal articles, book chapters, and theoretical works addressing the intersection of utopia, dystopia, and city/urban planning. The inclusion of authors such as David Harvey (2000; 2008), Henri Lefebvre (1991), Peter Marcuse (2009), Susan Fainstein (2010), and Dirk Schubert (2004) was guided by their foundational contributions to the dialectical relationship between space, power, and ideology in urban thought.

The reading list was further refined based on citation frequency, relevance to urban theory, and representation across different paradigms—classical utopian models (Howard, Le Corbusier, Mumford), critical urban theory (Lefebvre(1991), Harvey(2000), Soja(2010)), and integrative justice-oriented planning (Fainstein, Eren). Each text was coded thematically to identify recurring concepts such as spatial justice, participatory governance, technological utopia, environmental dystopia, and critical urbanism.

This methodological framework ensures a balanced evaluation of both utopian (visionary) and dystopian (cautionary) narratives, situating the paper within the broader intellectual tradition of

urban theory while maintaining methodological rigor and transparency in source selection. How visionary and critical approaches jointly inform contemporary urban planning is examined. Through qualitative content analysis, recurring patterns, thematic convergences, and critical tensions within the academic discourse on the future of cities are identified. The study examines how utopian ideals—such as justice, inclusivity, and sustainability—interact with dystopian critiques, highlighting the implications for contemporary urban planning practices.

By integrating theoretical contributions across disciplines such as urban studies, political philosophy, and environmental design, this methodological framework enables a comprehensive understanding of how idealized visions of the city, alongside their dystopian critiques, inform contemporary debates and contribute to reimagining more inclusive, resilient, and sustainable urban futures.

This methodological framework, based on qualitative content analysis of selected sources, enabled the identification of key themes across utopian and dystopian perspectives. In doing so, it clarified how these approaches are addressed within contemporary urban debates and provided the analytical basis for the evaluations and recommendations presented in the conclusion.

3. Findings and Discussion

The reviewed literature spans classical utopian models, modernist planning experiments, and contemporary dystopian critiques (Table 2). This corpus reveals a highly nuanced and evolving discourse in urban studies, highlighting how utopian and dystopian perspectives shape both conceptual and practical understandings of city planning. Table 2 presents a structured overview of these sources, summarizing their main focus, approach, and the parallel or contrasting insights they offer regarding urban utopian and dystopian frameworks.

Table 2. Structural summary of key articles

#	author(s) & year	focus / theme	approach / perspective	parallel & contrasting insights
1	howard, 1902	garden city, spatial order, social harmony	utopian	inspires modern city planners; limited empirical grounding contrasts with dystopian critiques (harvey, 2000)
2	le corbusier, 1933	radiant city, rational urban design	utopian	similar to howard in idealism; criticized by mumford (1962) for ignoring social realities
3	mumford, 1962	historical and social context of cities	critical-utopian	supports normative ideals but emphasizes social complexity; parallels fainstein (2010) on justice-oriented planning
4	harvey, 2000	neoliberal urbanism, privatization	dystopian	contrasts howard/le corbusier; parallels soja (2010) on spatial injustice

5	soja, 2010	spatial justice, critical geography	dystopian	aligns with harvey on inequality; challenges utopian notions of rational city planning
6	fainstein, 2010	justice-oriented urban planning	integrative	bridges utopian aspiration and dystopian critique; parallels eren (2023) on participatory governance
7	hall, 2014	intellectual history of urban planning	utopian / analytical	supports howard/le corbusier for historical context; highlights limits of idealism
8	baba, 2020	dystopian urbanism, gated communities	dystopian	aligns with harvey and soja; contrasts utopian ideals of openness and equality
9	eren, 2023	participatory governance, resilience	integrative	supports fainstein; contrasts technocratic utopias that ignore social feedback
10	marcuse, 2009	right to the city, social justice	dystopian / critical	challenges idealized spatial order; parallels integrative approaches advocating equity
11	brenner & schmid, 2015	urban theory, city as socio-spatial process	integrative / analytical	bridges theoretical debates; supports dystopian critique but acknowledges utopian imagination
12	lefebvre, 1991*	production of space, urban social relations	dystopian / critical	contrasts idealized utopias; aligns with harvey on socio-spatial inequalities
13	foucault, 1977*	discipline and spatial control in cities	dystopian / critical	provides analytical lens for exclusionary urban structures; contrasts participatory utopias
14	gehl, 2010	human-scale urbanism, livability	utopian / practical	supports utopian ideals with empirical focus; contrasts technocratic dystopian mega-projects
15	smith, 2018	smart cities, technological governance	dystopian / analytical	critiques tech-driven smart-city models for their risks of surveillance, inequality, and centralized control.

Table 2 summarizes the main themes emerging from the analysis, showing how utopian studies focus on desirable values, while dystopian works highlight structural risks and contradictions. After presenting these findings, the following section discusses how the literature conceptually frames these two approaches. In this way, the discussion connects the empirical patterns in Table 2 with the broader theoretical debates on utopian and dystopian thinking.

Utopian thinking gives direction it fuels creativity, sets ethical ideals, and keeps alive the belief that cities can embody justice and collective well-being. Dystopian critique, on the other hand,

grounds that imagination — it exposes inequality, exclusion, and the unintended consequences of unchecked idealism.



Figure 2. Moore house (Charles Moore, 1991), Orinda, California.

Classical utopian studies largely concentrate on spatial order, rationality, and the ethical or aesthetic ideals of city form (Howard, 1902; Le Corbusier, 1933). In addition, Gürel Üçer and Yılmaz (2004) show how utopian housing typologies function as spatial expressions of idealized social structures, reinforcing the link between built form and normative visions of urban life. In the field of city planning, other than star shaped cities and ideal city plans, Ebenezer Howard's Garden City (Welwyn and Letchworth) model proposes an integrated urban-rural design emphasizing social equality and environmental coherence, while Le Corbusier's Radiant City focuses on geometric order, functional segregation, and rational spatial planning. These models operate as imaginative and normative tools, guiding city planners to view cities as embodiments of societal ideals, where order, rationality, and aesthetic harmony were believed to lead to social progress (Le Corbusier, 1933). These utopian models offered a sense of hope and direction, emphasizing order, rationality, and aesthetic harmony as pathways to social progress (Le Corbusier, 1933; Howard, 1902). However, as Mumford (1962) and Fainstein (2010) observe, such idealized frameworks often neglected participation, social diversity, and the everyday realities of urban life. As a result, utopia functions not simply as a blueprint but as a conceptual lens—one that inspires creativity and normative aspiration while simultaneously revealing its own limitations. This is precisely where dystopian thought gains relevance: it questions the limits of perfection by exposing how visions of order or efficiency can, under certain conditions, drift toward control, inequality, or exclusion. In urban planning, dystopian moments emerge when ideal visions harden into rigid systems, surveillance-oriented environments, or profit-driven spatial arrangements. However, as Mumford (1962) and Hall (2014) argue, classical utopias often remain theoretical constructs, prioritizing moral and spatial perfection over socio-political complexities. Fainstein (2010) critiques these frameworks for insufficiently addressing social justice and participatory governance, highlighting the normative gaps that dystopian thought later addresses. Collectively, these studies demonstrate that utopia functions as a dynamic conceptual lens that balances visionary creativity with normative aspiration (Mumford, 1962).

Contemporary literature increasingly emphasizes dystopian critiques under neoliberal urbanization, identifying different mechanisms through separate lines of scholarship:

privatization as a driver of spatial inequity (Eren, 2007), gentrification as a form of dispossession linked to market-led restructuring (Harvey, 2000), and social segregation as a manifestation of uneven spatial justice (Soja, 2010). Although smart cities (e.g., Hollands, 2008; Batty et al., 2012; Kitchin, 2014) are often promoted through utopian narratives of innovation and sustainability, a growing body of research highlights that these visions can obscure underlying risks related to surveillance, data governance, and socio-spatial inequality. They risk reproducing neoliberal forms of inequality and social exclusion (Kemeç, 2023). Baba (2020) illustrates how gated communities and speculative mega-projects reproduce socio-spatial inequality, a pattern also emphasized in broader scholarship on fortified and exclusionary urbanism (Blakely & Snyder, 1997; Caldeira, 2000; Low, 2003). This body of research shows that such developments, while often justified through narratives of order, security, and efficiency, tend to deepen segregation and limit equitable access to urban resources, revealing the tensions between utopian promises and their unequal real-world outcomes. Similarly, Smith (2018) critiques smart cities, demonstrating that technology-driven efficiency can exacerbate social inequities and marginalize vulnerable populations. Marcuse (2009) underscores the political nature of urban space, warning that utopian visions may unintentionally reproduce structural injustices.

Lefebvre (1991) and Foucault (1977) provide frameworks to understand how spatial control and power relations transform idealized visions into lived dystopian realities. These analyses collectively demonstrate that dystopian perspectives act as corrective mechanisms. This grounds urban imaginaries in socio-political and environmental realities.

A growing body of research proposes integrative frameworks that reconcile utopian creativity with dystopian caution, aiming to develop more just, resilient, and participatory urban models. Recent thinkers such as David Harvey (2000) and Susan Fainstein (2010) argue that these perspectives are not opposites but complementary tools for understanding and improving contemporary cities. Fainstein (2010) advocates justice-oriented planning, incorporating social equity, participatory governance, and ethical accountability to mitigate the limitations of classical utopias and dystopian critiques.



Figure 3. Niban-kan Building (Kazuo Shinohara, 1970), Osaka.

Eren (2023) extends this by analyzing contemporary participatory governance models, demonstrating how community engagement can counter exclusionary dynamics highlighted by neoliberal urban processes. Brenner and Schmid (2015) situate these integrative approaches within broader urban theory, framing cities as socio-spatial processes where utopian and

dystopian dynamics intersect. Gehl (2010) operationalizes utopian ideals through human-scale design and livability principles, contrasting with technocratic mega-projects that often generate dystopian effects. Collectively, instead of treating utopia and dystopia as opposing categories, several scholars discuss them as interrelated analytical perspectives that illuminate different dimensions of urban transformation (Harvey, 2000; Fainstein, 2010; Schubert, 2004). These works argue that imaginative aspirations and critical evaluations function together in understanding how cities negotiate ideals, inequalities, and lived realities.Empirical insights reveal that urban conceptualization has shifted from prioritizing aesthetic order and formal coherence toward reflexive, justice-oriented paradigms (Marcuse, 2009; Brenner & Schmid, 2015; Lefebvre, 1991). Utopian and dystopian perspectives together provide a lens to bridge imaginative vision and grounded practice, guiding planners toward inclusive, resilient, and sustainable urban futures. For example, Fainstein's (2010) justice-oriented planning framework resonates with Howard's egalitarian ideals while extending them through explicit commitments to participation and equity, thereby addressing some of the limitations that dystopian critiques highlight under contemporary urban conditions (Harvey, 2000; Baba, 2020).

This combined utopian and dystopian perspective emphasizes that meaningful urban transformation depends on ethically informed, socially responsive, and environmentally conscious planning practices, fostering inclusive, resilient, and forward-looking urban environments.

Conclusion and Recommendations

This study examined how utopian and dystopian perspectives have shaped urban planning over time. The findings indicate that these perspectives function as complementary lenses that inform both the imaginative and critical dimensions of city planning. Utopian visions inspire creativity, normative ideals, and aspirational thinking, while dystopian perspectives provide critical reflection, highlighting potential unintended consequences and ethical considerations.

When combined, they form a dynamic dialogue between aspiration and realism. This dialogue helps city planners design cities that are visionary yet responsible, innovative yet inclusive, and imaginative and aware of their social limits. Looking ahead, planning education and practice should embrace both perspectives: To dream boldly like utopians, but to question critically like dystopian.

Only by holding these two ways of thinking together we can build cities that are not only smarter or more efficient, but truly humane, just, and resilient.

The analysis revealed several key insights: First, utopian frameworks continue to serve as generative tools, offering city planners models that foreground equity, environmental integration, and participatory values. Historical examples such as Howard's Garden City and Le Corbusier's Radiant City illustrate this imaginative function, although contemporary literature note that these models often abstract from socio-political realities. The second insight is that dystopian analyses function as corrective mechanisms, identifying risks such as social exclusion, inequality, and environmental vulnerability that arise when planning prioritizes order or efficiency over social and ecological considerations.

A third insight is the emergence of integrative approaches that combine utopian aspiration with dystopian caution. In line with Schubert's (2004) observation that urban design must continually negotiate between visionary ideals and socio-political realities, contemporary integrative approaches aim to balance creativity with ethical vigilance. These studies emphasize

resilience, participatory governance, and social justice, providing practical strategies for balancing creativity with critical vigilance. The reviewed literature shows that planning approaches which adopt this integrative perspective are better equipped to address contemporary urban challenges. Several studies (Arnstein, 1969; Kitchin, 2014; Soja, 2010) including those examining participatory governance, smart city interventions, and socio-spatial equity demonstrate that such frameworks can mitigate the risks highlighted by dystopian critiques while maintaining aspirational goals (Fainstein, 2010; Eren, 2023).

Based on the findings, the following recommendations are proposed:

- Education and capacity-building: City planners should be encouraged to consider both aspirational and cautionary perspectives in training and professional development.
- Participatory governance: Urban interventions should involve communities and stakeholders to ensure inclusivity and social accountability.
- Ethical and socially grounded technology use: Technological tools should be deployed in ways that balance efficiency with equity and cultural considerations.
- Integrated resilience strategies: Planning should address environmental, social, and infrastructural resilience simultaneously.
- Continuous reflexivity: Policies and urban designs should be regularly evaluated and adapted based on emerging social, ecological, and technological developments.

Conclusively, this study suggests that meaningful urban transformation requires combining imaginative aspiration with critical awareness. By blending the creative optimism of utopia with the critical awareness of dystopia, city planners can shape cities that are visionary yet inclusive, innovative and humane. The analysis conducted in this study indicates that utopian and dystopian perspectives are not strict opposites but function as complementary guides for understanding urban futures. This combined utopian and dystopian perspective emphasizes that meaningful urban transformation depends on planning practices that balance imaginative aspiration with critical awareness, enabling cities to become innovative, socially responsive, and environmentally conscious. This conclusion aligns with historical and contemporary examples in the literature, which increasingly recognize integrative approaches as effective strategies for addressing contemporary urban challenges.

The urban future depends on our capacity to sustain a dialogue between imagination and responsibility-between the desire to transcend the present and the obligation to confront its realities.

Thanks and Information Note

This article complies with national and international research and publication ethics standards. No ethical committee approval was required for this theoretical study. Both authors contributed equally to the manuscript. The authors declare that there is no conflict of interest.

References

Akkoyunlu, E. K. (2012). Ütopya tasarımlarında kent. *İdealkent Dergisi*, 5(1), 38–67.

Alver, K. (2009). Ütopya: Mekan ve kentin ideal formu. *Sosyoloji Dergisi* 3. Dizi, 18(1), 139–153.

Alberti, L. B. (1988). On the Art of Building in Ten Books (J. Rykwert, N. Leach & R. Tavernor, Trans.). Cambridge, MA: MIT Press.

Baba, E. C. (2020). The risks of mega urban projects creating a dystopia: Canal Istanbul. *City and Environment Interactions,* 6, 100039. https://doi.org/10.1016/j.cacint.2020.100039

Bagchi, B. & Chatterjee, S. (2022). Modern Indian utopian art and literature: An introduction. *Open Library of Humanities*, 8(1), 1–10. https://doi.org/10.16995/olh.8771

Banham, R. (1960). Theory and Design in the First Machine Age.

Baeten, G. (2002). The city of the entre-deux: Urban planning, dystopia and critical theory. Geografiska Annaler: Series B, *Human Geography*, 84(2), 165–176.

Blakely, E. J. & Snyder, M. G. (1997). Fortress America: Gated communities in the United States. Brookings Institution Press.

Brenner, N. & Schmid, C. (2015). Towards a new epistemology of the urban? *City*, 19(2–3), 151–182.

Caldeira, T. P. R. (2000). City of walls: Crime, segregation, and citizenship in São Paulo. University of California Press.

Choay, F. (1997). The Rule and the Model: On the Theory of Architecture and Urbanism.

Eren, Ş. G. (2007). Neoliberal politikalar çerçevesinde kent mekânının dönüşümü: Özelleştirme, parçalanma ve sosyal dışlanma. *Planlama,* 2007(2),

Eren, Ş. G. (2023). Future Cities. In K. C. Çamur & Ş. G. Eren (Eds.), Architectural Sciences and Recent Approaches and Trends in Urban and Regional Planning (pp. 340–420). Ankara: IKSAD Publishing House.

Fainstein, S. S. (2010). The just city. Ithaca, NY: Cornell University Press.

Filarete, A. (1972). Filarete's Treatise on Architecture (J. R. Spencer, Ed. & Trans.). New Haven, CT: Yale University Press.

Fishman, R. (1982). Urban utopias in the twentieth century: Ebenezer Howard, Frank Lloyd Wright, and Le Corbusier. New York, NY: Basic Books.

Foucault, M. (1977). Discipline and Punish: The Birth of the Prison (A. Sheridan, Trans.). New York: Pantheon Books.

Gehl, J. (2010). Cities for People. Washington, DC: Island Press.

Giordano, C. (2019). El invisible hilo de Raissa: Deseo utópico y conflicto urbano en Le città invisibili de Italo Calvino. *Cuadernos de Filología Italiana,* 26, 285–300.

Gordon, R. S. C. (2022). Rings of Saturn: Fellini Rosi. *Journal of Italian Cinema & Media Studies*, 10, 449–474. https://doi.org/10.1386/jicms_00139_1

Greenfield, A. (2013). Against the smart city. New York: Do Projects.

Gürel Üçer, Z. A., & Yılmaz, G. (2004). Housing typologies in the context of urban utopias. *Gazi Üniversitesi Fen Bilimleri Dergisi,* 17(4), 133–147.

Hall, P. (2002). Cities of Tomorrow: An Intellectual History of Urban Planning and Design in the Twentieth Century. Oxford: Blackwell.

Harvey, D. (2000). Spaces of hope. Berkeley, CA: University of California Press.

Harvey, D. (2008). The right to the city. *New Left Review*, 53, 23–40.

Howard, E. (1902). Garden Cities of To-Morrow. London: Swan Sonnenschein & Co.

Jacobs, J. (1961). The death and life of great American cities. New York, NY: Random House.

Jameson, F. (2005). Archaeologies of the Future: The Desire Called Utopia and Other Science Fictions.

İmga, O. & Olgun, H. (2010). "Akademyanın velut kalemi": Prof. Dr. İlhan Tekeli ile kent üzerine. *İdealkent Kent Araştırmaları Dergisi,* 1(1), 8–27.

Kemeç, A. (2023). Sıfırdan akıllı bir kent yaratmak ütopya mı? distopya mı? S*tratejik ve Sosyal Araştırmalar Dergisi*, 7(2), 321–340.

Kim, D. (2017). Utopian design experiments, from Le Corbusier's Radiant City to a ghost town in China. Visual Culture.

Kitchin, R. (2014). The data revolution: Big data, open data, data infrastructures & their consequences. London: Sage.

Lefebvre, H. (1991). The production of space (D. Nicholson-Smith, Trans.). Oxford: Blackwell.

Levitas, R. (1990). The Concept of Utopia. Syracuse University Press.

Low, S. (2003). Behind the gates: Life, security, and the pursuit of happiness in fortified communities. Routledge.

Luckett, T. (2024). Hope in the debris of capitalist dys/utopia? Historical progress and the intricacies of everyday life in Lephalale. Sociology Department, University of the Witwatersrand, Johannesburg, South Africa.

Marcuse, P. (2009). From critical urban theory to the right to the city. *City*, 13(2–3), 185–197.

Marques, R. N., Müller, F., Kanegae, M. M. & Morgade, M. (2024). Two childhoods, two neighborhoods, and one city: Utopias and dystopias in Brasilia. School of Education, University of Brasilia; Autonomous University of Madrid.

Mumford, L. (1962). The City in History: Its Origins, Its Transformations, and Its Prospects. New York: Harcourt, Brace & World.

Murray, L. & Robertson, S. (2020). Illuminating urban street (u)topias. Mobilities, 15(1), 39–53. https://doi.org/10.1080/17450101.2019.1678906

Olgun, H. (2010). Ütopya'dan distopya'ya: "Modern şehircilik" ve kritiği. *İdealkent*, 1(1), 96–111.

Pospisil, J. (2016). The historical development of dystopian literature. Univerzita Palackéhov Olomouci.

Ramírez Barredo, B. (2022). La ciudad construida y filmada. Influencia de la arquitectura moderna en el imaginario distópico de Gattaca y Blade Runner 2049. *Fotocinema. Revista Científica De Cine Y Fotografía,* 24, 175–193. https://doi.org/10.24310/Fotocinema.2022.vi24.13686

Scamozzi, V. (1615/2003). The Idea of a Universal Architecture (H. Millon, Ed.). Cambridge, MA: MIT Press.

Schubert, D. (2004). Utopia and reality: Urban design between modernism and postmodernism. Berlin: Jovis Verlag.

Soja, E. W. (2010). Seeking spatial justice. Minneapolis, MN: University of Minnesota Press.

Turut, H. & Özgür, E. M. (2018). Klasik kent kuramlarından eleştirel kent kuramlarına geçiş bağlamında kentleri yeniden okumak. *Ege Coğrafya Dergisi, 27*(1), 1–19.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integration of Green Jobs in Architectural Carpentry and Joinery Practices for a Sustainable Environment in Gombe State

Sale Nimrod KAMO [1*]

[1]School of Vocational and Technical Education Federal College of Education, Gıdan-Madı, Sokoto State
*nimrodsalek@gmail.com (Responsible Author)

Bala Japhet AMATIGA [2]

[2]Gombe State Ministry of Education

Yakubu Molta NITTE[3]

[3]Gombe State Ministry of Education

Abstract

This study investigated the integration of green job principles into architectural carpentry and joinery practices in Gombe State, Nigeria. The objectives were to identify existing practices, assess the level of awareness and application of green job principles among practitioners, and determine the relationship between existing practices and sustainable approaches. A descriptive survey and correlational design were employed, consisted of 117 carpentry and joinery practitioners selected from workshops, construction firms, and technical colleges. Data were collected using a validated questionnaire titled Integration of Green Jobs in Carpentry and Joinery Practices Questionnaire (IGJCJPQ), which recorded a reliability coefficient of 0.81. Results indicated that most existing practices remain conventional and environmentally unsustainable, with limited adoption of renewable materials and energy-efficient tools. Awareness of green principles was moderate, but practical application was hindered by inadequate training and institutional support. A weak relationship was found between existing practices and the application of green job principles. The study recommends curriculum reform in TVET programs, continuous professional training, and strengthened institutional collaboration to enhance sustainable carpentry and joinery practices in Nigeria.

Keywords: Green jobs, carpentry and joinery, sustainability, TVET, Gombe State

Introduction

Architectural joinery and carpentry are woodwork trades consisting of designing, creating, and assembling wooden artifact and fittings that contribute to functionality and building appearance. The trades cover various aspects of work from cutting, shaping, joining, and finishing wooden members for furniture, fittings, doors, windows, and other architectural components. As Sigha, Adewumi, and Ibitoye (2025) and Isemede (2024) noted, carpentry and joinery are imperative in today's construction because they ensure firm and accurate woodwork needed for today's architectural structures. The trade efficiency relies significantly on the technical ability of artisans and craftsmen, on knowledge of materials, and attitude, which all have an impact on the quality, safety, and sustainability of construction methods. A pivotal feature of the successful carpentry and joinery skill is access and use of right materials. Folorunso (2021) emphasized that the selection of working material either hardwood, softwood, plywood, or Medium Density Fiberboard (MDF) should be informed by durability, strength, grain direction, and resistance to moisture. Proper knowledge of wood properties is equivalent to optimal use of wood materials and its longevity in building structure. But traditional carpentry and joinery have placed functionality, cost-effectiveness, and productivity over environmental issues such as waste management, use of renewable materials, and carbon efficiency (Adewolu, Ademilua, & Imomoh, 2024). This failure is an indictment on the imperative to redirect carpentry and joinery practice to greener and more sustainable options.

Carpentry and Joinery is a skilled trade offered in Nigerian technical colleges under the Technical and Vocational Education and Training (TVET) system. The subject is skill-oriented to equip students with employable skills for self-employment and paid employment in the building industry. The curriculum is centered on gaining skills in designing, cutting, constructing, setting out, and finishing various permanent and temporary wooden structures (Oviawe & Anaele, 2020). It involves both theoretical and practical aspects with the motive of preparing trainees for skilled craftsmanship, entrepreneurship, and sustainable construction. Deba, Saulawa, and Hasan (2022), stated that the program goals of Carpentry and Joinery are to expose students to expertise and competence in designing, constructing, and preserving timber for architectural building structures; to develop competencies in the construction of joinery, and to transfer skills for furniture and fitting assembling for domestic and public structures. These objectives aimed to develop craftsmen who are capable of being able to contribute meaningfully towards national development through the delivery of competent manpower in Nigeria's construction sector. However, the integration, sustainability and green competence into the training modules of carpentry and joinery is limited, resulting in educational mismatch with future environmental demands in the industry (Munif, 2024).

Despite these objectives, Nigeria continues to experience unemployment, environmental degradation, and unsustainable construction practices. The traditional carpentry and joinery trade remains dominated by non-renewable products and processes that contribute to waste generation, deforestation, and energy inefficiency. As the world continues to demand attention towards sustainability, more green jobs that assist in environment restoration or conservation which are now required (Jacob & Umoh, 2025). The trend is a call for balance between carpentry and joinery activities and environmentally friendly employment strategies that promote environmental conservation as well as socio-economic resilience.

Green jobs represent a paradigm shift methodology which employ generation of idears that balances economic growth and sustainable environmental management. They encompass woodwork operations like cutting, planing, and the use of energy-efficient powered tools and machines that reduce the environmental impact, promote energy saving, and increase the sustainable consumption of building materials (Lawal, Jimoh, Abdullah, Bello, & Awoyemi, 2024). According to Oboro (2024), green jobs directly contribute to the preservation of ecosystems, enhancing the effectiveness of use of resources, and reducing carbon emissions in industries such as construction, manufacturing, and agriculture. In the built environment, green jobs involve the utilization of eco-friendly materials; hardwood, softwood, plywood, or medium Density Fiber (MDF) in construction practice. The implementation of green job principles to architectural carpentry and joinery works offers a window of opportunity to sustainable development by enhancing wood-based construction works to be environmentally sustainable as well as economically feasible. From this, the blending of carpentry and joinery with the green job offers a strategic opportunity to drive traditional craftsmanship to a sustainable industrial development in Nigeria.

The incorporation of green jobs into joinery and carpentry activities involves reorientation at training institutions and industrial sectors. Craftsmen, artisans, and technicians must be equipped with knowledge, attitude and technical proficiency required for sustainable material selection, low energy-efficient construction processes, and application of renewable technologies. Soji, Usman, Abdullahi, and Adaji (2024) noted that green building practices thrive where craftsmen are highly aware of environmental management and are able to utilize green innovations. Chukwu, Omeje, Ojo, Okekpa, Vershima, and Kechere (2024) further

contended that technical and vocational training holds the central position to facilitate the transition to green through the development of skilled manpower capable of integrating sustainability concepts into traditional carpentry and joinery trades. Hence, inclusion of green competencies in the Nigerian TVET curriculum for joinery and carpentry is essential in ensuring that graduates are capable of performing in the evolving green economy. Success in this trend is, however, dependent on the extent to which industry stakeholders adopt sustainability-driven reforms that harmonize technical competence with environmental mindset.

Sustainable carpentry and joinery architecture emphasizes the responsible use of construction materials, efficient energy equipment, and economic sustainability in building operations. Adeniran and Omoniyi (2024) emphasized utilizing production methods with reduced waste, recycling, and wood reuse, as well as reducing the carbon footprint of wood conversion and preparation. In carpentry and joinery, sustainability involves the judicious selection of sustainably grown timber, using non-toxic adhesives and finishes, and incorporating energy-efficient strategies in structural building and furniture design. Sustainable practices promote life-cycle evaluation of products to ensure each production phase from logging to end product leaves a beneficial impact on environmental quality, as pointed out by Sadar Din and Ishak (2024). Therefore, carpentry and joinery sustainability extends beyond the choice of material; it includes occupational safety, skill development, and ethical craftsmanship. Amasuomo (2021) highlighted that Education for Sustainable Development (ESD) is central in empowering craftsmen with the needed knowledge, values, and skills to promote environmental sustainability in architectural carpentry and joinery practices. The integration of green practices into training and in-the-work activity ensures that the carpentry and joinery craft aligns with international standards of green building requirements, hence contributing to Nigeria's environmental and economic sustainability goals. Similarly, wood waste recycling, support the reuse of sawdust and offcuts to relieves forest pressure and promotes circular economy (Udokpoh & Nnaji, 2023). As a result, the incorporation of green jobs in architectural carpentry and joinery activities in Gombe State offers a strategic path towards fulfilling sustainable development through ecological preservation, economic empowerment, and technological advancement.

Statement of the problem

Carpentry and joinery work need to embrace green building principles that emphasize environmental responsibility, material efficiency, and economic viability. Such practice involves promoting efficient use of timber and other materials used in construction, employing energy-efficient renewable tools and production techniques with minimal impact on the environment. Within the scope of a green economy, joinery and carpentry are not merely technical professions but key factors for sustainable development. They are also committed to integrating environmentally friendly design principles, employing low-emission adhesives and finishes, and incorporating mechanisms for recycling and waste recovery in the production process. Integrating sustainability in every stage of production can reduce deforestation and loss of materials. Moreover, they can produce decent and inclusive jobs through the creation of green jobs that enable environmental protection while enhancing productivity and innovation in the construction sector.

But notwithstanding this, the vast majority of Nigerian carpentry and joinery operations are still dominated by conventional practices that value production and cost over sustainability. Most

carpentry and joinery artisans still rely on unsustainably harvested timber, inefficient and antiquated tools, and poor waste disposal methods. In addition, the integration of green skills into vocational training is also inadequate, rendering the graduate's incapable of adopting environmentally friendly practices. Institutional and policy gap impose additional limitations on industry progression toward green innovation.

Therefore, this study seeks to examine existing carpentry and joinery practices, assess awareness and application of green job principles, into architectural carpentry and joinery for a sustainable environment in Gombe State.

Purpose of the Study

The purpose of this study is to examine the integration of green job principles in architectural carpentry and joinery practices for a sustainable environment in Gombe State. Specifically, the study seeks to:

1. Identify existing carpentry and joinery practices in Gombe State.
2. Examine the level of awareness and application of green job principles among carpentry and joinery practitioners in Gombe State.
3. Examine the relationship between existing carpentry and joinery practices and the application of green job principles in the industry in Gombe State.

Research Questions

1. What are the existing carpentry and joinery practices in Gombe State?
2. What is the level of awareness and application of green job principles among carpentry and joinery practitioners in Gombe State?
3. What is the relationship between existing carpentry and joinery practices and the application of green job principles in Gombe State?

Hypothesis

H_{o1}: There is no significant relationship between existing carpentry and joinery practices and the application of green job principles in Gombe State.

Methodology

This study adopted the descriptive survey and correlational research design. This design was considered appropriate because it enabled the researchers to collect existing conditions, opinions, and practices regarding the integration of green jobs in architectural carpentry and joinery for a sustainable environment in Gombe State. The population of the study comprised of 117 carpentry and joinery practitioners in Gombe State, including master craftsmen, artisans, and technical instructors working in construction firms, private workshops, and technical colleges. Given the manageable population size, all 117 practitioners were considered for inclusion in the study; hence, no sampling was required. However, respondents were purposively selected to ensure adequate representation of practitioners across Gombe Metropolis, Billiri, Kaltungo, and Deba. The instrument for data collection was a structured questionnaire using a four-pointLikert-scale and tagged "Integration of Green Jobs in Carpentry and Joinery Practices Questionnaire" (IGJCJPQ). The questionnaire was divided into three sections. Section A consisted of bio-data of the respondents while Section B contained 10 items to elicit information relating to existing carpentry and joinery practices and Section C also contained 10 items to elicit information on the level of awareness and application of green job principles. Items in Sections B to C were structured on a four-point Likert scale ranging from

Strongly Disagree (1) to Strongly Agree (4). To ensure the validity of the instrument, the draft questionnaire was subjected to face validation by three experts; two from the Department of Technical Education, Federal College of Education (Technical), Gombe and one from the Department of Environmental Science Gombe State University. The reliability of the (IGJCJPQ) was tested by administering the questionnaire on 20 carpentry/joinery practitioners in Bauchi state who were not included in the main study. The obtained data were processed using Cronbach Alpha, which resulted 0.81. Personal administration and return of copies of the questionnaire were done by the researchers themselves and collected the questionnaire on the spot. Mean, and standard deviation and correlation, were employed to answer the research questions. The criterion mean value of 2.50 and above were accepted while mean values below 2.50 were rejected.

Results

The result of the analysis of the data is presented below:

Research Question 1

What are the existing carpentry and joinery practices in Gombe State?

Table 1. Mean and Standard Deviation of Existing Carpentry and Joinery Practices

S/N	Items statement	Mean	SD	Remarks
1	Carpentry/joinery in my region is basically involved in meeting the customer's requirements rather than considering factors related to the environment.	1.97	.73	Rejected
2	Most artisans and craftsmen prefer traditional tools and methods over modern, energy-efficient equipment.	3.28	1.04	Accepted
3	Timber for construction purposes is commonly harvested without concerns for sustainability in forestry practices.	2.48	.84	Rejected
4	Sawdust, scraps, and other waste materials are just disposed of rather than being reused or even recycled.	2.40	1.01	Rejected
5	Carpentry/joinery skills teach more concern for efficiency rather than sustainability in construction.	3.29	.63	Accepted
6	Projects generally emphasize near-term function over long-term ecological concerns.	3.57	.59	Accepted
7	Application of chemically treated or toxic finishing materials is also prevalent in carpentry/joinery operations.	3.44	.49	Accepted
8	Very few carpenters/joiners undergo any kind of professional training in eco-friendly carpentry/joinery practices.	3.45	.60	Accepted
9	Most carpentry and joinery work is reliant on non-renewable forms of energy.	3.52	.57	Accepted
10	Safety standards in occupational health can be overlooked in the course of carpentry and joinery production practices.	2.45	.43	Rejected

Table 1 indicated that six items were accepted and four rejected. The accepted items (2, 5, 6, 7, 8, and 9) indicate that carpentry and joinery activities in Gombe State area still dominated by conventional methods and practice, with limited adoption of modern and sustainable approaches. Conversely, items 1, 3, 4, and 10 Meeting the customer's requirements rather than

considering factors related to the environment, timber for construction purposes is commonly harvested without concerns for sustainability in forestry practices, sawdust, scraps, and other waste materials are just disposed of rather than being reused or even recycled., and poor conformity with safety standards were rejected. This suggests that, while traditional practices persist, there is an emerging awareness and gradual shift among practitioners toward more responsible and environmentally carpentry and joinery practices.

Research Question 2

What is the level of awareness and application of green job principles among carpentry and joinery practitioners in Gombe State?

Table 2. Mean and Standard Deviation of Awareness and Application of Green Job Principles

S/N	Items statement	Mean	SD	Remarks
1	I am aware that carpentry practices can affect the environment in a significant manner.	3.59	.49	Accepted
2	I understand the concept of Green Jobs in relation to the construction industry.	3.44	.67	Accepted
3	I work with wood that is certified to be ecologically sustainable.	3.37	.60	Accepted
4	I consciously minimize wood waste through reuse or recycling during my work.	3.38	.48	Accepted
5	I consider energy efficiency when choosing tools and equipment for woodwork tasks.	3.48	.50	Accepted
6	I use eco-friendly finishes, adhesives, and paint to avoid polluting the environment.	3.06	1.00	Accepted
7	I have undergone training/sensitization in relation to sustainable construction practices.	2.29	.90	Rejected
8	I design furniture, fittings with durability, recyclability in mind.	2.89	.95	Accepted
9	I agree with the suggestion that principles from the green industry should be incorporated into carpentry courses.	3.09	.99	Accepted
10	I believe adopting green job principles enhances both environmental protection and business profitability.	2.87	.99	Accepted

Table 2 revealed that nine of the ten items were accepted, while only one was rejected. Accepted items (1, 2, 3, 4, 5, 6, 8, 9, and 10) indicate moderate level of awareness and modest application of green job principles among the carpentry and joinery practitioners. Respondents demonstrated awareness of the environmental effects of their operations, showed interest in sustainable materials use, and acknowledgment of energy efficiency and eco-friendly production. However, item 7 relates to training and sensitization in sustainable construction techniques was negated. This suggests that despite growing awareness, the lack of formal training and institutional support continues to hinder full integration of green job practices in carpentry and joinery operations.

Research Question 3

What is the relationship between existing carpentry and joinery practices and the application of green job principles in Gombe State?

Hypothesis 1

There is no significant relationship between existing carpentry and joinery practices and the application of green job principles in Gombe State.

Table 3. Pearson Product Moment Correlation of Existing Carpentry and Joinery Practices and the Application of Green Job Principles

Variables	Mean	SD	N	rppmc	Remarks	Sig.	Decision
existing C&J practices	31.20	2.37	177	.236	Weak Relationship	.002	S
Aw & Ap of Green Job	30.00	3.05					

Table 3 reveals a weak but statistically significant positive correlation ($r = 0.236$, $p = 0.002$) between existing carpentry and joinery practices and the application of green job principles in Gombe State. Since $p < 0.05$, the null hypothesis is rejected. This indicates that although the relationship is weak, improvements in carpentry and joinery practices are associated with increased application of green job principles among practitioners

Discussion of Findings

The findings revealed that carpentry and joinery practices in Gombe State remain largely dominated by conventional methods with limited sustainability awareness. This result is consistent with the finding of Sigha, Adewumi, and Ibitoye (2025), who observed that traditional craftsmanship techniques, though valuable for architectural identity, often neglect sustainable design considerations. Similarly, Oviawe and Anaele (2020) found that most technical college graduates in carpentry and joinery lacked the competencies required for sustainable development, confirming the continued prevalence of non-green practices in the field. In the same vein, Adeniran and Omoniyi (2024) reported low adoption of cleaner production practices among wood processing facilities in Nigeria, which aligns with the weak integration of sustainability seen in this study. To this end, the current study confirms that carpentry and joinery activities in Gombe State still follow conventional methods, emphasizing productivity over environmental protection.

The results also indicated that the level of awareness and application of green jobs among the practitioners was moderate. This result was consistent with that of Munif (2024), who stated that the integration of green competences into higher education programs was a key imperative for cultivating sustainability skills. Hasan et al. (2022) have also introduced a standard tool for assessing the actual skills of Carpentry and Joinery Students that highlighted the steady rise of environmental awareness due to institutional changes. Further studying by Oboro (2024) indicated that there was a steady rise in awareness of green jobs opportunities for workers at Delta State, Nigeria. Therefore, the current study further asserted the pre-existing evidence that while awareness of environmental issues was on a steady increase for artisans, the actualized level of green job training was still inadequate.

The result of the hypothesis test revealed a weak but significant relationship between existing carpentry and joinery practices and the application of green job principles. Although the correlation is weak, its significance indicates a gradual transition from conventional to more sustainable practices. This agrees with Jacob and Umoh (2025), who identified that the

integration of blue, green, and grey economic models in Nigeria requires incremental adaptation rather than immediate transformation. Likewise, Soji, Usman, Abdullahi, and Adaji (2024) noted that green innovation competencies in construction are emerging slowly due to barriers such as limited resources and inadequate institutional frameworks. Lawal et al. (2024) also stressed that while energy efficiency awareness is growing, its adoption among Nigerian households and small industries remains weak, mirroring the situation observed among carpenters and joiners in this study. To this end, it can be inferred that the weak correlation recorded signifies the beginning of behavioral change towards green practices, even though full integration has not yet been achieved. This finding can be likened to the discovery made by Udokpoh and Nnaji (2023), which found that the reuse and recycling of sawdust have received little recognition by artisans despite its significant contribution to sustainable development. Chukwu et al. (2024) can further clarify that many institutions offering TVET in Nigeria continue to place more value on conventional craftsmanship rather than green skills, contributing to a huge skills mismatch between industry requirements and the outcome of technical education. This could be the reasons that respondents received less exposure to environmentally friendly training. Adewolu et al. (2024) pointed out that while awareness of sustainable construction requirements prevails in the southwest of Nigeria, there remains a barrier against actual implementation that was impeded by expensive and technical limitations. This study may add credence to the information that sustainability integration of another conventional trade including but not limited to carpentry and joinery remains current but developing.

Conclusion

In conclusion, the findings from this research have provided a crucial area linking the practices of carpentry and joinery to the application of green job principles in Gombe State. The research showed that despite practitioners possessing moderate knowledge of sustainable construction practice, the complete integration of green principles remains limited due to inadequate training and institutional support. This implies that sustainability promotion in carpentry and joinery must be strengthened through industry-technical education partnership, green modules in vocational training, and capacity-building initiatives.

Recommendations

1. There should be periodic workshops, seminars, and certification programs for carpentry and joinery practitioners
2. There should be strong collaboration between technical institutions and industry to enable innovation, research, and adoption of sustainable technologies within the woodwork sector.
3. The TVET program curriculum needs to be examined in order to incorporate environmental sustainability, use of renewable material, and waste management modules in the practice of carpentry and joinery.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

References

Adeniran, D. A., & Omoniyi, T. E. (2024). Appraisal of cleaner production practices in selected wood processing facilities in Ibadan, Nigeria. *Adeleke University Journal of Engineering and Technology*, *7*(1), 059-072.

Adewolu, A. O., Ademilua, A. O., & Imomoh, I. E. (2024). Greening the tropics: An in-depth analysis of sustainable building ratings in South-West Nigeria. *Global Journal of Engineering and Technology*, 2583-3359.

Amasuomo, T. (2021). *Barriers to the adoption of environmentally sustainable design methods in residential buildings. The architects' and building owners' perspectives in four Nigerian states* (Doctoral dissertation, Open Access Te Herenga Waka-Victoria University of Wellington).

Chukwu, D. U., Omeje, H. O., Ojo, S. A., Okekpa, A. A., Vershima, M. N., & Kechere, I. C. (2024). Industry evolving needs and TVET institutional offerings: a qualitative response to the on-demand skill gap in Nigerian woodwork technology institution. *International Journal of Vocational Education and Training Research*, *10*(1), 1-7.

Folorunso, C. O. (2021). Analysis of effectiveness of wooden floor finishes in some residential buildings in Lagos, Nigeria. *International Journal of Building Pathology and Adaptation*, *39*(5), 756-765.

Hasan, S., Deba, A. A., & Saulawa, B. U. (2022). Development and standardization of an ınstrument for assessing carpentry and joinery students' practical skills in Nigerian Senior Secondary Schools. *Canadian Journal of Educational and Social Studies*, *2*(1), 73-85.

Isemede, E. (2024). Fostering woodwork technology in tertiary education: The role of computer numerical control (CNC). *International Journal of Functional Research in Science and Engineering (IJFRSE)*, *3*(1).

Jacob, A., & Umoh, O. (2025). Exploring the ıntersections of blue, green, and grey economies in Nigeria: Opportunities, challenges, and strategic pathways for sustainable development. *Journal of Sustainable Economics*, *3*(1), 1-26.

Lawal, O. A., Jimoh, A. A., Abdullah, K. A., Bello, B. A., & Awoyemi, E. D. (2024). Economic and environmental impact of energy audit and efficiency: A report from a Nigeria household. *Energy for Sustainable Development*, *79*, 101387.

Munif, A. R. (2024). Advancing sustainable skills: Integrating green competencies in higher education curriculums. *Green Environmental Technology*, *1*(1), 1-9.

Oboro, E. D. (2024). Green economy and green jobs: Evidence from Delta State, Nigeria. *Journal of Academic Research in Economics*, *16*(1).

Oviawe, Jane Itohan, and Anaele, E. O. (2020). Carpentry and Joinery skills required by technical college graduates for sustainable development in Edo and Delta States, Nigeria." *Vocational and Technical Education Journal* 2, no. 1.

Sadar Din, K. M., & Ishak, M. S. (2024). Sustainable building construction materials in the United Arab Emirates: A review. *Sustainability*, *16*(15), 6565.

Sigha, A., Adewumi, B., & Ibitoye, O. (2025). Examining Traditional craftsmanship techniques suitable for modern architectural design. *Journal of Built Environment and Geological Research*.

Soji, S. M., Usman, N. D., Abdullahi, U., & Adaji, A. A. (2024). Assessing green innovation competencies for sustainable construction practices in Nigeria: A Delphi Survey. *Environmental Technology and Science Journal*, *15*(2), 109-118.

Udokpoh, U., & Nnaji, C. (2023). Reuse of sawdust in developing countries in the light of sustainable development goals. *Recent Progress in Materials*, *5*(1), 1-33.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Problem of the Quality of Groundwater from Doucen Plain Intended for Irrigation and Its Assessment

GAAGAI Aissam [1*]

[1] Scientific and Technical Research Center on Arid Regions (CRSTRA), Biskra 07000, Algeria.
gaagaiaissam37@gmail.com (Responsible Author)

MALLEM Salah Eddine[2]

[2] Scientific and Technical Research Center on Arid Regions (CRSTRA), Biskra 07000, Algeria.
salaheddine.ma.7@gmail.com

Abstract

In order to assess the quality of groundwater used for irrigation in the Sahara aquifer in Algeria, this research used irrigation water quality indices (IWQI), to assess and predict the quality of groundwater used for irrigation. The physicochemical parameters obtained for the collected groundwater samples showed that Ca_2+ > Mg_2+ > Na+ > K+ and Cl- > $SO_4$2- > HCO_3- > NO_3-, due to the predominance of limestone, sandstone and clay minerals under the action of human activity. To assess the quality of irrigation water, IWQIs values such as irrigation water quality index (IWQI), sodium adsorption rate (SAR), Kelly index (KI), sodium percentage (Na%), permeability index (PI) and magnesium risk. (MH) showed mean values of 47.17, 1.88, 0.25, 19.96, 41.18, and 27.87, respectively. For example, IWQI values revealed that 33% of samples were severely restricted for irrigation, while 67% of samples ranged from moderate to high restriction for irrigation, indicating that moderately to highly salt-sensitive crops should be irrigated in loose soils without all compressed layers. Finally, the application of physicochemical parameters and water quality indices constitutes a useful and practical strategy for assessing groundwater quality and development.

Keywords: Geographic Information System (GIS), multivariate analysis, Sahara Aquifer, Algeria

1. Introduction

In recent years, the deterioration of groundwater quality has been exacerbated by uncontrolled leaching of leachate from landfills, excessive use of fertilizers, and other human activities that are significantly dangerous to human health (Egbueri et al.,2021; Noori et al., 2019; Maghrebi et al., 2021). Many studies have evaluated groundwater quality in the world (Ghodbane et al., 2022; Chorfi et al., 2022). Nevertheless, the majority of these studies primarily concentrated on single-parameter evaluation, in which the governing elements were assessed individually, and the most compromised factor had a significant influence on water quality (Sener et al., 2017). Hence, there is an increasing need for techniques that allow for better water quality interpretation to ensure effective groundwater quality control and management. Owing to their statistical ease of use and adaptability. Irrigation water quality indices (IWQIs) are among the best methods for monitoring groundwater quality for agricultural activities. IWQIs can help to interpret complex water quality data in simple terms (Elsayed et al., 2020; El Osta et al., 2022; Masoud et al., 2022). Several indices have been used to categorize groundwater quality for agricultural purposes. These indices include the irrigation water quality index (IWQI), permeability index (PI), sodium adsorption ratio (SAR), Kelly index (KI), magnesium hazard (MH), and sodium percentage (Na%).

• This study aims to:

(i) Identify the groundwater characteristics and geochemical controlling mechanisms using physicochemical parameters and multivariate statistical analysis.

(ii) Assessment and classify the groundwater quality for irrigation using IWQIs.

2. Materials and Methods

2.1. Geographic Location

- The region of Doucen is located in the Northwestern city of Ouled Djelal. For the area-wise, it's 247 km^2.
- It has administrative borders with the communes of Chaiba to the west, El-Ghrouss to the east and north, the town of Ouled Djalel to the south (Figure 1).

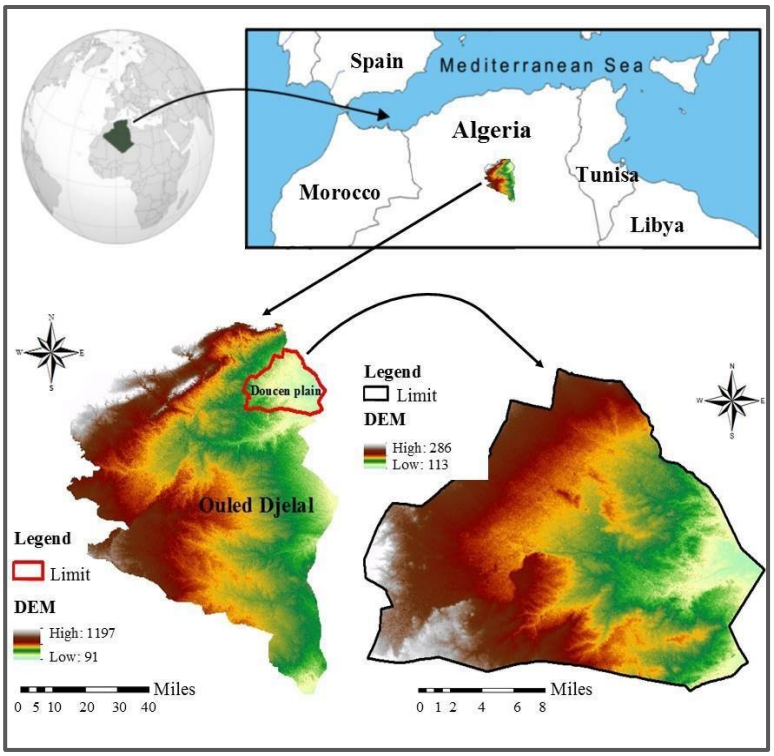


Figure 1. Map of the study area

Geologically, the formations ranging from the Secondary to the Quaternary periods are as follows:

i. Secondary formations (Cretaceous): consist of limestone, crystalline limestone, dolomite, sandstone, gypsum, anhydrite, clay, and marl.

ii. Tertiary formations (Paleogene and Neogene): consist of limestone, marls, gypsum, clays, gravel, and red sand.

iii. Quaternary Formations: These are made up of scree, pebbles, gravel, sand, gypsum, limestone, sandy alluvium, and clay alluvium (Figure 2).

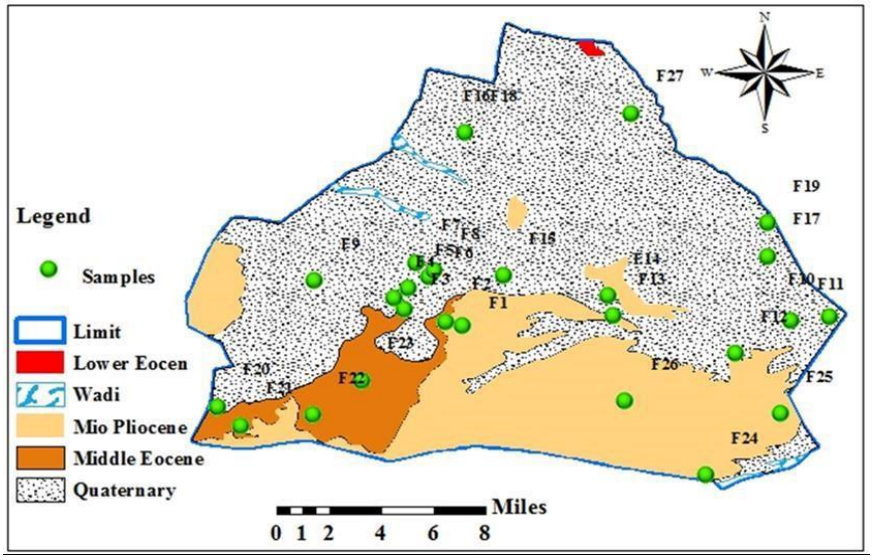


Figure 2. Geological map of the Doucen plain, Algeria

2.2. Methodology

1. Multivariate Statistical Analysis: two methods used:

• (i) Cluster analysis: The present study, Ward's clustering method and the Euclidean distance was used to apply CA.

• (ii) PCA method to extract the major elements related to the various causes of variance in hydrochemical data collected from the Doucen plain.

2. Irrigation Water Quality Indices (IWQIs)

• The IWQI, SAR, KI, Na%, MH, and PI% were all determined depended on the physicochemical parameters of the samples (Table1).

Table 1. The IWQIs, related formula

WQIs	Formula
IWQI	$\sum_{i=1}^{n} Q_i W_i$
SAR	$\frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$
KI	$\frac{Na^+}{Ca^{2+}+Mg^{2+}}$
Na%	$\frac{(Na^+ + K^+)}{(Ca^{2+}+Mg^{2+})+(Na^+ + K^+)} \times 100$
MH	$\left[Mg^{2+} / \left(Ca^{2+} + Mg^{2+}\right)\right] \times 100$
PI	$\left(\frac{Na^+ + \sqrt{HCO_3^-}}{(Ca^{2+}+Mg^{2+}+Na^+)}\right) \times 100$

Note(s): All IWQIs are calculated in meq/L.

Spatial Distribution Pattern

- Using ArcGIS software, to produce maps presenting the geographical distribution of groundwater quality indicators,
- Such as IWQI, SAR, KI, Na%, MH, and PI%, that are useful for irrigation.

3. Findings and Discussion

3.1. Analysis of Multivariate Statistics

Three groups has been determined.

- The (G1) revealed a close association between HCO3, SO4, Mg, and Ca due to the presence of the sulphates or anhydride and calcium sulphates.
- The (G2) revealed a close association between the Na, K, Cl, and TDS, indicating the participation of chlorides and salts in the EC.
- Both G1 and G2 demonstrated that the lithological component dominated the mineralization of the Plio-Quaternary aquifer's waters in Doucen.
- G3 showed the dissociation of nitrates from other chemical elements present in groundwater, which indicating an anthropogenic source (Figure 3).

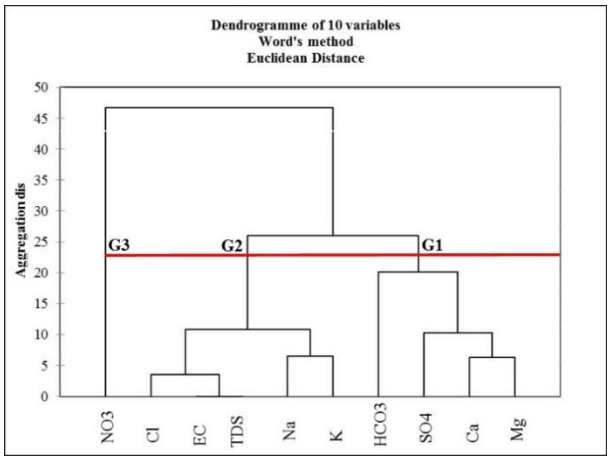


Figure 3. Cluster dendrogram for variables: G1 (group 1), G2 (group 2), G3 (group 3) and the groupscould be distinguished in terms of their hydrochemical variable at the red line.

3.2. Principal Component Analysis (PCA)

Three factors (F) were retained from the PCA analysis.

- F1 explained 59.86% of the dataset variability, while F2 and F3 explained respectively 11.35% and 10.35%.
- F1 has a robust positive relationship with TDS, Cl, Ca, Mg, K, and SO_4.
- The source of SO_4 may be coming from fertilizer and sulfur compounds.

- The Ca, Mg, and K could be due to anthropogenic sources, anhydride, and calcium sulphates.
- The presence of chloride could be due to weathering of soils.
- While F3 was highly correlated with NO_3 and moderate correlation with HCO_3, which indicating alkaline water passing through rocks and soil (Figure 4).

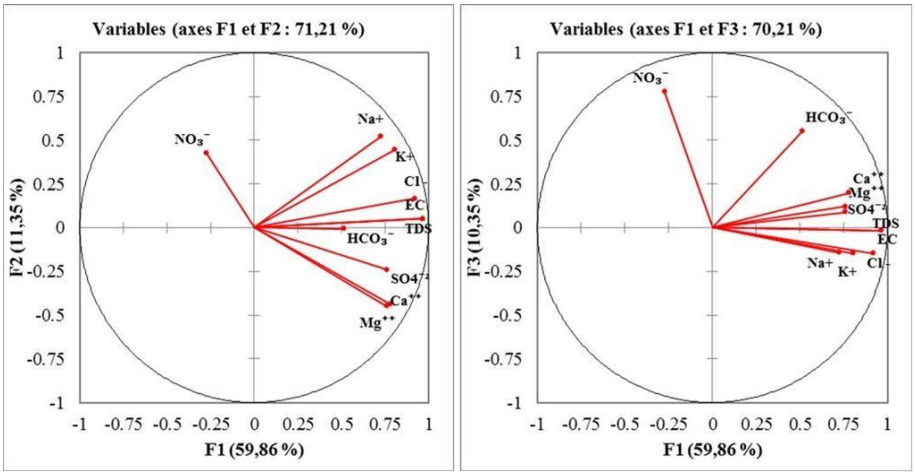


Figure 4. Plots of PCA scores for F2 vs. F1 (a) and F3 vs. F1 (b).

3.3. Irrigation water quality indices

3.3.1 Irrigation water quality index (IWQI)

✓ The resulting IWQI value ranging from 19 to 73 mg/L.

✓ The IWQI falls into three categories (moderate, high and severe restriction) with an equal 33.33%.

✓ According to IWQI values, the central of the region has a water quality degradation by the rock weathering, and the ion exchange process (Figure 5).

3.3.2. Sodium adsorption ratio (SAR)

- The calculated percent of SAR varied from 0.63% to 4.1%.
- 4 classes to identify the irrigation water, Unsuitable (>26%), Fair Poor (19-26%), good (10-18%), and excellent (<10%).
- The value of SAR indicated that all of the study site's water samples belongs to excellent category, which indicating its suitability for irrigation (Figure 5).

3.3.3. Kelley Index (KI)

- 02 classes here: If the KI value > 1, there is too much sodium. KI < 1 water is suitable for irrigation.

- In this study, the KI value diverse from 0.08 to 0.62. As regards the KI outcomes, the all samples were deemed irrigation-ready.
- The results indicated an overabundance of sodium ions in the water (Figure 5).

3.3.4. Sodium percentage (Na%)

✓ Na% ranged from 7.88% to 39.31%.

✓ There are 05 classes: excellent (< 20%), acceptable (20-40%), allowed (40-60%), dubious (60-80%), and inappropriate (> 80%).

✓ About 59.26% of the samples are in the excellent class, and these are positioned in the north, south east, and south west.

✓ However, about 40.74% of the samples are in the acceptable category for irrigation and are located in the geographic center of the region (Figure 5).

3.3.5. Magnesium Hazards (MH)

✓ The groundwater samples showed MH value varies from 25.38 to 56.22.

✓ Less than 50%, groundwater was appropriate for irrigation in 25 samples.

✓ More than 50%, it was not.

✓ These inappropriate samples are situated in the northern region (Figure 5).

3.3.6. Permeability index (PI)

- Three classes for PI were defined: unsuitable (PI<25), good (PI=25-75), and excellent (PI>75).
- The PI value was ranging from 13.95 to 46.68.
- Approximately 55.55% of the samples found in moderate class and the rest (44.44%) were unsuitable for irrigation, which located in the north, south east and south west of area (Figure 5).

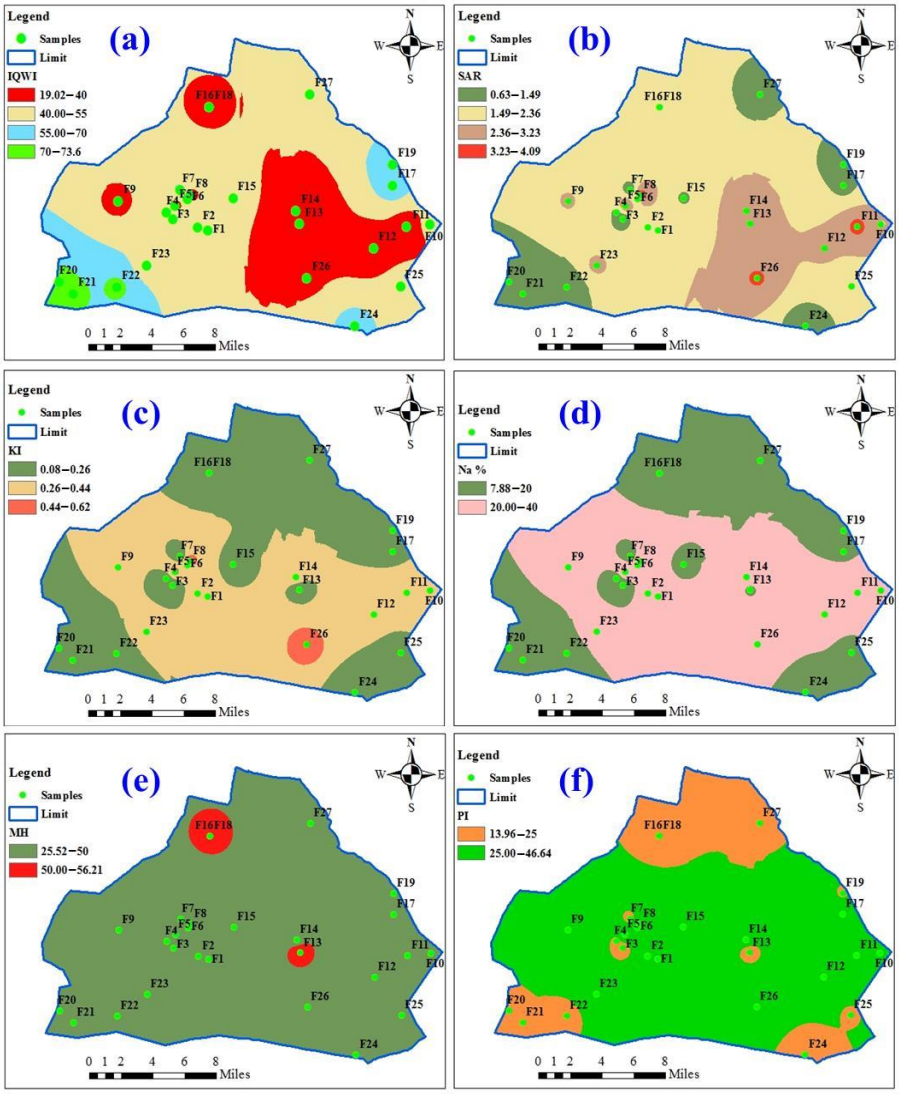


Figure 5. The spatial variation map of the Doucen plain: Irrigation water quality indices (IWQIs). (a) IQWI, (b) SAR, (c) KI, (d) Na%, (e) MH, (f) PI.

4. Conclusion and Recommendations

In this study, IWQIs, multivariate statistical analyses, were applied to determine groundwater quality for irrigation in the Doucen Plain.

- According to the physicochemical results, groundwater in the study area indicating Ca-Cl water type due to the dominance of sandstone, limestone, and clay minerals under the influence of anthropogenic activities, rock weathering, ion dissolution and exchange processes.
- The IWQI values revealed that 33% of our samples were severely restricted for irrigation, while 67% of the them diverse from moderate to high constraints for irrigation.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

References

Chorfi, A., Hafid, H., Baaloudj, A., Rizi, H., Aouissi, H.A., Chaib, S., Ababsa, M., Allaoua, N., Houhamdi, M. (2022). Characterization and Diversity of macroin-vertebrates in groundwater in the region of Souk-Ahras (North-East of Algeria). *Ekológia*. 2022, 41, 219–227.

Elsayed, S., Hussein, H., Moghanm, F.S., Khedher, K.M., Eid, E.M., Gad, M. (2020). Application of irrigation water quality indices and multivariate statistical techniques for surface water quality assessments in the Northern Nile Delta, Egypt. *Water*, 2020, 12, 3300.

El Osta, M., Masoud, M., Alqarawy, A., Elsayed, S., Gad, M. (2022). Groundwater suitability for drinking and irrigation using water quality indices and multivariate modeling in Makkah Al-Mukarramah Province, Saudi Arabia. *Water*, 2022, 14, 483.

Egbueri, J.C., Ezugwu, C.K., Unigwe, C.O., Onwuka, O.S., Onyemesili, O.C., Mgbenu, C.N. (2021). Multidimensional analysis of the contamination status, corrosivity and hydrogeochemistry of groundwater from parts of the Anambra Basin, Nigeria. *Anal. Lett.* 2021, 54, 2126–2156.

Ghodbane, M., Benaabidate, L., Boudoukha, A., Gaagai, A., Adjissi, O., Chaib, W., Aouissi, H.A. (2022). Analysis of groundwater quality in the lower Soummam Valley, North-East of Algeria. *J. Water Land Dev.* 2022, 54, 1–12.

Maghrebi, M., Noori, R., Partani, S., Araghi, A., Barati, R., Farnoush, H., Haghighi, A.T. (2021). Iran's groundwater hydrochemistry. *Earth Space Sci.* 2021, 8, e2021EA001793.

Masoud, M., El Osta, M., Alqarawy, A., Elsayed, S.,Gad, M. (2022). Evaluation of groundwater quality for agricultural under different conditions using water quality indices, partial least squares regression models, and GIS approaches. *Appl. Water Sci.* 2022, 12, 244.

Noori, R., Ghahremanzadeh, H.; Kløve, B., Adamowski, J. F., Baghvand, A. (2019). Modified-DRASTIC, modified-SINTACS and SI methods for groundwater vulnerability assessment in the southern Tehran aquifer. *J. Environ. Sci. Health* 2019, 54, 89–100.

Sener, S.¸ Sener, E. Davraz, A. (2017). Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey). *Sci. Total Environ.* 2017, 584–585, 131–144.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Dam failure mechanisms and risk assessment

GAAGAI Aissam [1*]

[1] Scientific and Technical Research Center on Arid Regions (CRSTRA), Biskra 07000, Algeria.
Gaagaiaissam37@gmail.com (Responsible Author)

MALLEM Salah Eddine[1]

[1] Scientific and Technical Research Center on Arid Regions (CRSTRA), Biskra 07000, Algeria.
salaheddine.ma.7@gmail.com

Abstract

The analysis of the Babar dam failure on Oued el Arab was carried out to show the impact of the flood wave and its speed on the four villages located downstream of the dam such as Hella, Kherenne, Chebla and El Oueldj. This model is dedicated to the description of floods during the dam failure following the formation of a breach in the dike. The main factors taken into account in this simulation are: the flood water level and the flood hydrograph. This flood risk analysis showed that the maximum flow of the flood wave recorded at the breach is 9253 m³/s), and that it begins to attenuate downstream of the dam along Oued El Arab where it arrives at the last village with a lower flow, of the order of 1110 m3/s. This simulation made it possible to create a risk map showing the areas threatened by the flood wave that would result from a complete failure of the structure. Consequently, a safety plan can be developed to mitigate the consequences of these floods as much as possible. A sensitivity analysis was conducted to determine the impact of the breach parameters on the "dam failure" scenario.

Keywords: Modeling, failure, sensitivity analysis, HEC-RAS.

1. Introduction

Many cities have been built alongside rivers all over the world, typically downstream of various hydraulic constructions like reservoirs and dams. As demonstrated in Japan (Swanson *et al*., 1986), canada (Clague *et al*., 1994), Malczyce (poland) (Chalfen *et al*., 2005), and algeria (Berghout *et al*., 2016; Bouchehed *et al*., 2017; Boussekıne *et al*., 2016; Derdous *et al*., 2015), such localization puts people and property at higher risk of flooding.

• This study was developed to address the impact of an earth dam failure on the downstream of the dam, as in the case of the Babar Dam.

• The failure simulation was performed using the one-dimensional HEC-RAS hydrodynamic model.

• This model can simulate the failure of a structure such as a dam or a lateral structure.

• In this work, we are looking for understand the impact of flood propagation downstream of the dam in the event of a failure using the HEC-RAS model.

2. Materials and Methods

Geographic Location

• The Babar Dam is located in southeastern Algeria in the eastern part of the Saharan Atlas in the Nememcha Mountains (Fig. 1).

• The lower part of the valley is situated between two mountain ranges, where the citys such as Hella, Kheranne, Chebla, and Ouelga are located.

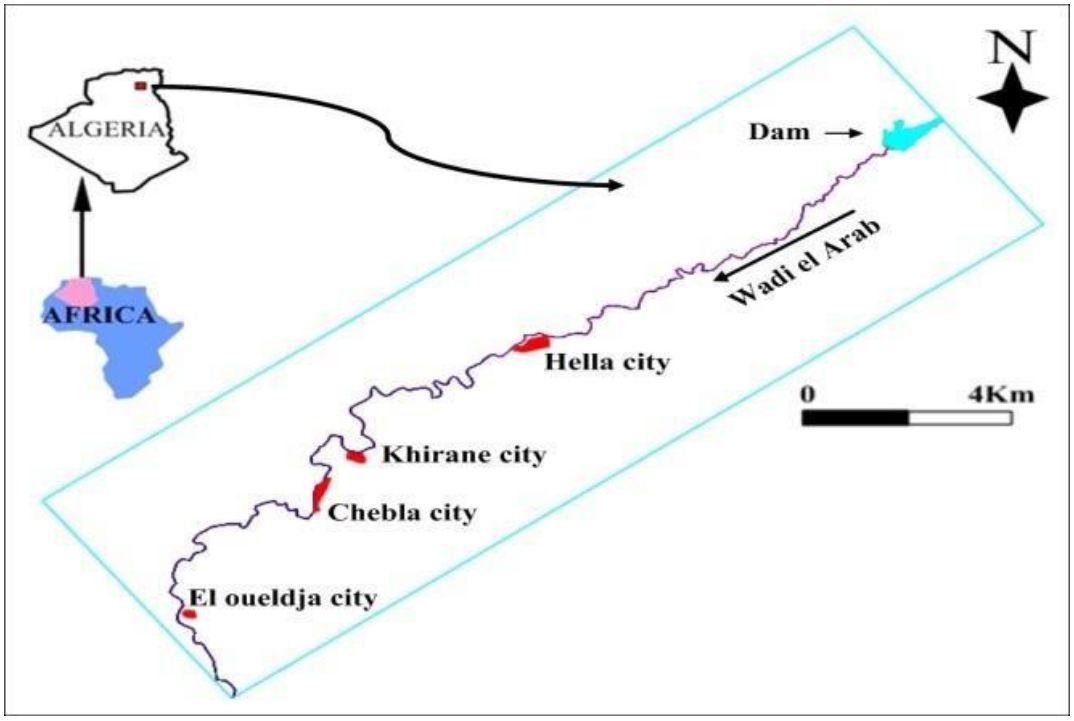


Figure 1. Map of the study area

3.1. HEC-RAS Model 4.1

HEC-RAS is a software program that allows simulations to be performed on four axes:

1- Calculations of the steady and unsteady flow of a river,
2- determination of sediment transport capacity,
3- analysis of water temperature.

3.2. Evaluation of Breach Parameters

In this case study, we chose two breach design formulas: 1- that of the (Trieste, D. J., 1988) 2- and that of (Froehlich, 1995) (Figure 2).

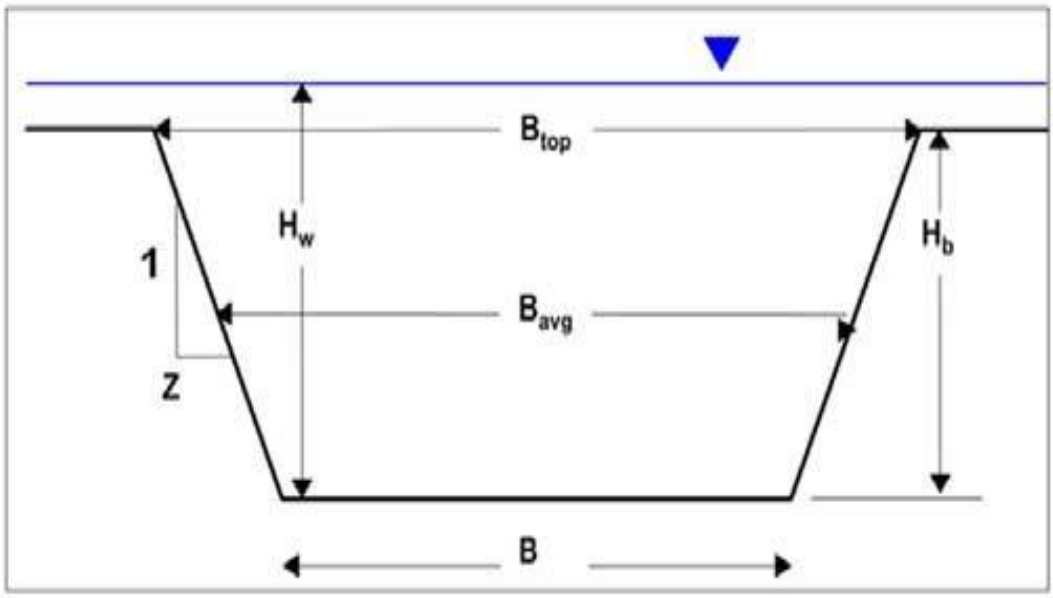


Figure 2. Breach profile type; source: own elaboration

3. Findings and Discussion

3.1. Dam Failure Scenario

The calculations of the breach parameters using the two methods are very similar, with the exception of the peak flow rate:

1- For Froehlich, D. C.: the peak flow rate is 9423.64 m³/s.

2- For Trieste, D. J., the peak flow rate is 8527.61 m³/s.

- The results of the Froehlich, D. C. method were considered the best estimate of the gap parameters,
- However, it can be adopted because the Froehlich, D. C. formula is:

1. The most suitable for earth dams,

2. The most recent

3. It is identified based on the study of real cases (63 cases).

3.2. Flood Wave Simulation (Discharge-Velocity)

Based on the results obtained by the HEC-RAS model using two parameters:

1- Qmax = 9423.64 m³/s,

2- The time taken to deplete the dam reservoir (t = 2:15 h) it can be concluded that dam failure can pose a real danger to all infrastructure as well as to the populations located downstream of the dam (Table 1).

Table 1. Simulated propagation of flood waves downstream of the dam

Station	station	Profile	Qtotal (m3/s)	Time (hour e)	Depth (m)	Min Ch El(m)	W.S. Elev(m)	E.G. Elev(m)	E.G. slope (m/m)	velosity (m/s)	flow Area (m2)	width(m)	Froude
Bredg 1	138	Max WS	9181,03	05 :00	11.14	900	911,16	913,36	0,00806	12,07	2507,77	402,35	1,17
Bredg 2	91	Max WS	1845,05	06 :40	5.8	760,71	766,81	767,33	0,004349	5,43	1029,37	325,18	0,75
village hella	90	Max WS	1844,2	06 :45	7.7	757	762,12	762,71	0,007299	5,71	957,03	400,19	0,93
village Khérenne	26	Max WS	1252,28	07 :45	7.7	392,73	401,75	402,21	0,001407	3,96	745,11	155,38	0,45
village Chebla	20	Max WS	1356,99	08 :00	5.5	357,22	363,53	363,84	0,002039	3,54	918,05	262,11	0,51
Village Oueldja	10	Max WS	1217,47	08 :45	5	305,23	310,53	311,75	0,010047	6,13	574,44	480,23	1,06

3.3. Flood Risk Analysis

- This analysis revealed that the first three villages (Hella, Khérenne, and Chebla) are the most exposed to this flood.
- This requires us to provide the authorities with a series of measures to attempt to mitigate the risk of flooding in the villages in the event of a dam failure.
- It will be essential to maintain the proper functioning of the dam and provide a warning system, as well as establish a population evacuation plan before the flood wave reaches them.
- This flood risk analysis using this model helps us determine the time it will take for this flood wave to reach these villages.
- Seen at the time of breach formation (1:054 h), the first village will be hit by the flood after 6:45 h and the last village at 8:45 h, which makes it easier to execute the alert plan.
- According to the risk map, we can implement:
- an integrated flood management strategy for the river downstream of the dam in the event of a dam failure that can save as many villages located on the riverbed as possible (Figure 3).

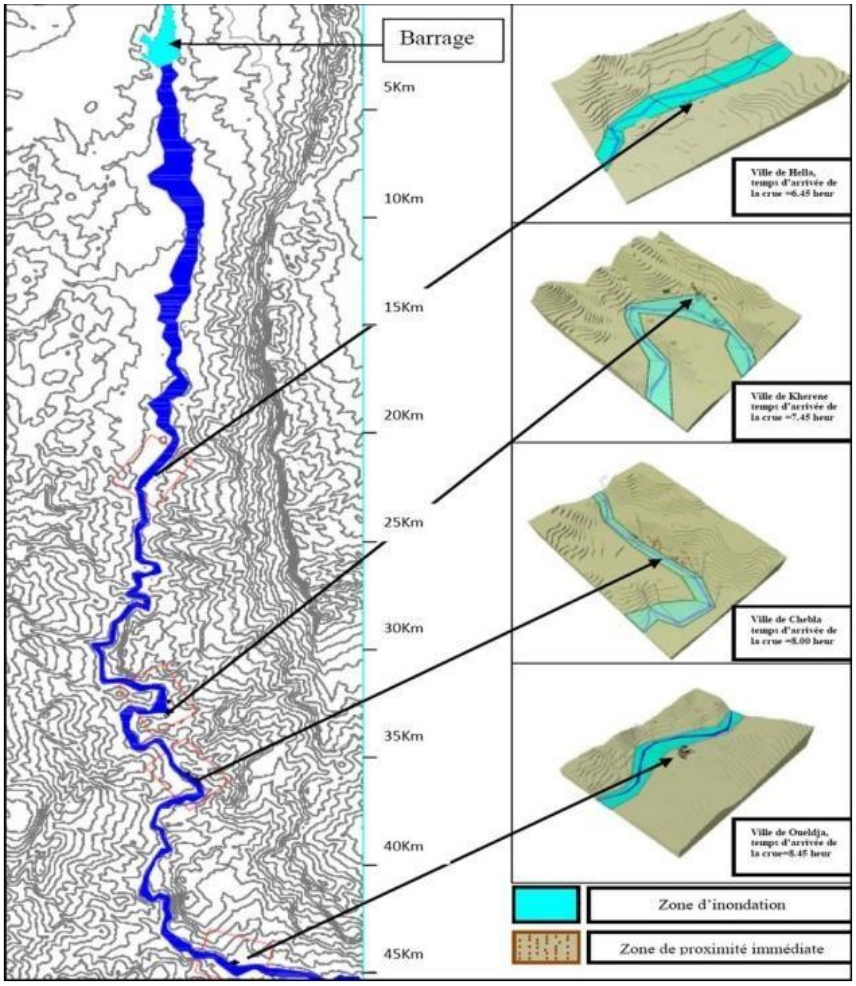


Figure 3. Babar Dam Break Flood Map

i. Conclusion and Recommendations

- The HEC-RAS model is well-suited to facilitate dam failure analysis.
- Proper analysis of dam failure risks will help in the development of contingency plans to mitigate the increased loss of life and property.
- Model stability issues are also addressed, and solutions have been provided to some typical problems.
- Using the HEC-RAS model, users can perform dam failure analyses and breach investigations.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. There is no conflict of interest.

References

Berghout A. & Meddi M. (2016). Sediment transport modelling in Wadi Chemora during flood flow events. Journal of Water and Land Development. No. 31 p. 23–31. DOI 10.1515/jwld-2016-0033.

Chalfen M., Kowalski J. & Molski T. (2005). Skuteczność rozwiązań technicznych chroniących tereny przyległe do stopni wodnych na przykładzie rejonu Malczyc [The efficiency of technical solutions for the protection of areas adjacent to a river dam – an example of the Malczyce region]. *Woda- Środowisko-Obszary Wiejskie.* T. 5. Z. 1 (13) p. 41–56.

Clague, J.J. & Evans S.G. (1994). Formation and failure of natural dams in the Canadian Cordillera. Bulletin / Geological Survey of Canada. 464. Ottawa. Geological Survey of Canada. ISBN 978-0660154961 pp. 35.

Froehlich, D. C. (1995). Peak Outflow from Breached Embankment Dam, Journal of Water Resources. *Planning and Management*, vol. 121(1), 90-97.

Swanson, F.J., Oyagı, N. & Tomınaga, M. (1986*). Landslide dams in Japan. In: Landslide dams: Process, risk, and mitigation.* Ed. R.L. Schuster. New York. American Society of Civil Engineers Special Publication. (3), 273–378.

Trieste, D. J. (1988). Downstream Hazard Classification Guidelines. (ACER Technical Memorandum No. 11, 56 pages). U.S. Department of the Interior, Bureau of Reclamation (USBR).

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Azərbaycan Respublikasında Maliyyə İnfrastrukturunun Sahibkarlığa Təsiri Formaları

Vüqar NƏZƏROV

ORCID 1: 0000 - 0001 - 9856 - 7184
[1]Dos., i.ü.f.d. Azərbaycan Turizm və Menecment Universiteti, İqtisadiyyat.
vuqar_74@mail.ru **(**Responsible Author)

Xülasə

Maliyyə infrastrukturu maliyyə sisteminin fəaliyyətini təmin edən və sahibkarlıq fəaliyyətinin inkişafı üçün əlverişli şərait yaradan institutlar, mexanizmlər və alətlər toplusudur. "Azərbaycan Respublikasında maliyyə infrastrukturunun sahibkarlığa təsiri formaları" məqaləsində bank sektoru, kapital bazarı, mikromaliyyə institutları, zəmanət sistemləri və dövlət dəstək proqramları kimi maliyyə infrastrukturunun əsas elementlərinin sahibkarlıq fəaliyyətinə təsiri araşdırılmışdır. Təhlillər göstərir ki, ölkəmizdə maliyyə mənbələrinin mövcudluğu, maliyyə əməliyyatlarının şəffaflığı, kredit və investisiya institutlarının inkişaf səviyyəsi kiçik və orta sahibkarlığın yaradılması və davamlılığı dinamikası ilə birbaşa əlaqəlidir. Əməliyyat xərclərini azaldan və sahibkarların maliyyə məhsullarına çıxışını genişləndirən maliyyə xidmətlərinin rəqəmsallaşdırılmasının roluna xüsusi diqqət yetirilməlidir. Həmçinin məqalədə: sahibkarlıq subyektlərinin maliyyə vasitəçiləri ilə səmərəli qarşılıqlı əlaqəsini məhdudlaşdıran institusional, struktur maneələr müəyyən edilmişdir; sahibkarlığın stimullaşdırılmasında, davamlı iqtisadi artımda əsas amil kimi balanslaşdırılmış maliyyə infrastrukturunun formalaşdırılmasının zəruriliyi barədə nəticə çıxarılmışdı; ədəbiyyat təhlili, müqayisəli və institutsional yanaşma, empirik təhlil (kəmiyyət metodları), keyfiyyət metodları, zəif və güclü tərəflərin diqanostikası aparılmışdır.

Açar sözlər: Maliyyə infrastrukturu; sahibkarlıq fəaliyyəti; mikro, kiçik və orta sahibkarlıq subyektləri

Forms of Influence of Financial Infrastructure on Entrepreneurship in the Republic of Azerbaijan

Abstract

Financial infrastructure is a set of institutions, mechanisms and tools that ensure the functioning of the financial system and create favorable conditions for the development of entrepreneurial activity. The article "Forms of influence of financial infrastructure on entrepreneurship in the Republic of Azerbaijan" examines the impact of key elements of financial infrastructure on entrepreneurial activity, such as banking sector, capital market, microfinance institutions, guarantee systems and state support programs. The analysis shows that the availability of financial resources in our country, the transparency of financial transactions, the level of development of credit and investment institutions are directly related to the dynamics of the creation and sustainability of small and medium-sized businesses. Particular attention should be paid to the role of digitalization of financial services, which reduces operating costs and expands entrepreneurs ' access to financial products. Also in the article: institutional, structural barriers have been identified that limit the effective interaction of business entities with financial intermediaries; it was concluded that it is necessary to form a balanced financial infrastructure as a key factor in the stimulation of entrepreneurship and sustainable economic growth; literature analysis, comparative and institutional approach, empirical analysis (quantitative methods), qualitative methods, diganostics of weaknesses and strengths were carried out.

Keywords: Financial infrastructure; entrepreneurial activity; Micro, small and medium-sized businesses

1. Introduction

Sahibkarlıq iqtisadi artımın, innovasiyaların və sosial dayanıqlığın əsas "mühərriklərindən" biri hesab edilir. Sahibkarlıq təşəbbüslərinin uğurlu fəaliyyət göstərməsi və inkişafı üçün maliyyə mənbələrinə çıxış, etibarlı hesablaşma mexanizmləri, mülkiyyət hüquqlarının qorunması və qərar qəbul etmək üçün məlumat verən maliyyə infrastrukturu mühüm rol oynayır. Dövlət, regional və yerli qurumlar - banklar, bank olmayan maliyyə-kredit təşkilatları, kapital bazarları, sığorta və zəmanət sistemləri - maliyyə infrastrukturunun əsasını təşkil edir.

Qloballaşma, maliyyə bazarlarının qeyri-sabitliyi, sürətlə dəyişən texnoloji şərait şəraitində maliyyə infrastrukturu təkcə dəstək elementi deyil, həm də rəqabətqabiliyyətlilik amilinə çevrilir. Sahibkarlar, xüsusən də kiçik və orta sahibkarlar birbaşa borc kapitalının alınma imkanlarından, maliyyə institutlarının şəffaflığından, risklərin qiymətləndirilməsi və idarə edilməsi mexanizmlərinin mövcudluğundan, maliyyə əməliyyatlarının əməliyyat xərclərindən asılıdır.

İnkişaf etməmiş maliyyə infrastrukturu ilə sahibkarlıq müxtəlif problemlərlə üzləşir və bunlara aşağıdakıları aid edə bilərik:

- maliyyələşmə prosesinə məhdud giriş;

- kreditlərin yüksək dəyəri;

- investisiyaların zəif səviyyədə qorunması;

- zəmanət sistemlərinin beynəlxalq standartlara cavab verməməsi;

- investorların etibarının olmaması və s.

Bu məqalənin məqsədi maliyyə infrastrukturunun sahibkarlığa necə təsir etdiyini, bu cür təsiri qiymətləndirmək üçün hansı metodlardan istifadə edilə biləcəyini araşdırmaq, habelə sahibkarlıq fəaliyyətini stimullaşdırmaq istiqamətində maliyyə infrastrukturunun yaxşılaşdırılması üçün təkliflər hazırlamaqdır. Bundan əlavə, maliyyə infrastrukturunun sahibkarlığa təsirinin əsas formalarını sistemləşdirmək və təhlil etmək, həm müsbət, həm də məhdudlaşdırıcı təsirləri müəyyənləşdirmək və ən təsirli olduğu şərtləri göstərmək lazımdır.

Azərbaycanda maliyyə infrastrukturunun tətbiqi və inkişafının təhlili göstərir ki, bu, sahibkarlıq fəaliyyətinin stimullaşdırılmasında, xüsusilə kiçik və orta sahibkarlığın seqmentlərində, eləcə də qeyri-neft sektorunda getdikcə daha əhəmiyyətli rol oynayır. Azərbaycan iqtisadiyyatı şaxələndirmək, rəqabət qabiliyyətini artırmaq, neft sənayesindən kənarda iş yerləri yaratmaq vəzifəsi ilə üzləşir və maliyyə infrastrukturu bu prosesdə zəruri vasitə kimi çıxış edir.

2. Tədqiqat Metodları

Azərbaycan Respublikasında maliyyə infrastrukturunun sahibkarliğa təsiri formalarını araşdırarkən müxtəlif tədqiqat metodlarının istifadəsi məqsədəuyğundur. Bunların bəzilərini nəzərdən keçirək.

Ədəbiyyat üzrə təhlil maliyyə infrastrukturu və sahibkarlıq mövzusunda yerli və xarici işlərin, o cümlədən məqalələr, beynəlxalq təşkilatların hesabatları, dövlət və regional tədqiqatların öyrənilməsini nəzərdə tutur. Bu, anlayışları sistemləşdirməyə, maliyyə infrastrukturunun əsas

komponentlərini müəyyən etməyə və maliyyə institutları ilə sahibkarlıq arasında qarşılıqlı əlaqənin mövcud nəzəri modellərini müəyyən etməyə imkan verir. Məsələn, innovativ sahibkarlığın maliyyə infrastrukturunun tədqiqi vençur və büdcə fondlarının, sığorta mexanizmlərinin və zəmanət institutlarının innovativ fəaliyyətə necə töhfə verdiyini göstərir.

Müqayisəli və institutsional yanaşma maliyyə institutlarının inkişaf səviyyəsinə, qanunvericilik bazasına, sahibkarlığa dəstək mexanizmlərinə (zəmanət institutları, mikromaliyyə, investisiya vasitəçiləri) görə müxtəlif ölkələrin və bölgələrin müqayisəsini əhtə edir. Hüquqi və institutsional amillərin maliyyə infrastrukturunun səmərəliliyinə təsirinin təhlili olduqca vacib məsələdir. Məsələn, kiçik və orta sahibkarlığın inkişafına həsr olunmuş əsərlərdə institusional yanaşma hüquqi tənzimləmə, maliyyə institutlarının şəffaflıq dərəcəsi və etimad səviyyəsindəki fərqlərin sahibkarların maliyyə imkanlarına necə təsir etdiyini müəyyənləşdirməyə imkan verir.

Keyfiyyət metodları sahibkarlarla, maliyyə institutlarının, dövlət orqanlarının mütəxəssisləri ilə müsahibələri; maliyyə infrastrukturunun əhəmiyyətli dərəcədə yaxşılaşdırıldığı və sahibkarlığın artdığını göstərdiyi uğurlu bölgələrin/ölkələrin işlərinin təhlilini nəzərdə tutur. Bu, yalnız kəmiyyət nöqteyi-nəzərdən əlaqələrini deyil, həm də infrastrukturun sahibkarlıq fəaliyyətinə təsir etdiyi mexanizmləri müəyyənləşdirməyə kömək edir.

Güclü və zəif tərəflərin diaqnostikası toplanan məlumatlar əsasında maliyyə infrastrukturunun aşağıdakı istiqamətlərdə təhlilinin aparılmasını nəzərdə tutur:

*** güclü tərəflər** (məsələn, inkişaf etmiş bankların olması, hüquqi cəhətdən müdafiə, zəmanət sistemləri);

*** zəif tərəflər** (tənzimləmə problemləri, yüksək əməliyyat (tranzaksiya xərcləri), kiçik sahibkarlar üçün maliyyələşdirmə mənbələrinin əlçatmazlığı);

*** imkanlar** (rəqəmsallaşma, sistemə daxi olmanın genişləndirilməsi, dövlət dəstəyi);

*** təhdidlər** (maliyyə cəhətdən qeyri-sabitlik, inamsızlıq riski, korrupsiya və s.).

Empirik təhlil/kəmiyyət metodları ölkəmizdə maliyyə infrastrukturu və sahibkarlıq arasında qarşılıqlı əlaqələri daha geniş, aydın şəkildə izah etməyə şərait yaradır. İlk öncə Azərbaycan Respublikasında sahibkarlıq fəaliyyətini nəzərdən keçirək.

Göstəricilər/İllər	2019	2020	2021	2022	2023
Sahibkarlıq subyektlərinin ümumi sayı, o cümlədən:	**271304**	**316370**	**355906**	**377842**	**401149**
Mikro sahibkarlıq subyektlərinin sayı	262622	307717	346171	366944	389133
Kiçik sahibkarlıq subyekti olan müəssisələrin sayı	5956	5943	6856	7760	8610
Orta sahibkarlıq subyekti olan müəssisələrin sayı	2726	2710	2879	3138	3406

Cədvəl 1. 2019-2023-cü illərdə Azərbaycan Respublikasında fəaliyyətdə olan mikro, kiçik və orta sahibkarlıq subyektlərinin sayı **[7]**

Cədvəl 1-də 2019-2023-cü illərdə Azərbaycan Respublikasında fəaliyyətdə olan mikro, kiçik və orta sahibkarlıq subyektlərinin sayı təqdim olunub. Bu cədvəldən belə nəticəyə gələ bilərik ki,

2019-cu il ilə müqayisədə 2023-cü ildə sahibkarlıq subyektlərinin ümumi sayı 129845 vahid, yaxud 47.9% artmışdır. Müqayisə olunan dövrdə həm mikro, həm kiçik və orta sahibkarlıq subyektləri üzrə artım müşahidə edilirdi [7].

İllər/Göstəricilər	Yaradılmış əlavə dəyər, mln. manat	İşçilərin sayı, min nəfər	Orta aylıq nominal əmək haqqı, manat	Əsas kapitala investisiyalar, mln. manat
2019 - cəmi, o cümlədən:	**11071.7**	**332.2**	**531.0**	**3422.2**
Mikro	4900.8	40.2	332.5	515.5
Kiçik	1423.2	85.1	437.0	494.2
Orta	4747.7	206.9	624.6	2412.5
2020 - cəmi, o cümlədən:	**10941.0**	**348.7**	**612.3**	**2674.1**
Mikro	4455.2	40.9	359.4	970.2
Kiçik	1617.9	92.1	533.8	380.4
Orta	4867.9	215.7	714.4	1323.5
2021 - cəmi, o cümlədən:	**13956.1**	**357.8**	**632.2**	**3387.7**
Mikro	5790.8	40.9	382.5	1706.2
Kiçik	2384.3	102.2	528.2	892.7
Orta	5781.0	214.8	748.3	788.8
2022 - cəmi, o cümlədən:	**17170.4**	**370.1**	**707.9**	**2827.1**
Mikro	7091.9	42.4	450.8	857.1
Kiçik	2796.1	104.8	575.6	955.1
Orta	7282.4	222.9	843.0	1014.9
2023 - cəmi, o cümlədən:	**20087.1**	**390.8**	**765.8**	**2366.1**
Mikro	7653.2	49.9	501.5	303.5
Kiçik	3200.8	110.3	642.8	794.0
Orta	9233.1	230.6	899.4	1268.6

Cədvəl 2. 2019-2023-cü illərdə Azərbaycan Respublikasında mikro, kiçik və orta sahibkarlıq subyektlərinin əsas makroiqtisadi gostəricilər **[7]**

Cədvəl 2-də 2019-2023-cü illərdə Azərbaycan Respublikasında mikro, kiçik və orta sahibkarlıq subyektlərinin əsas makroiqtisadi gostəricilər təqdim olunub. Bu cədvəl əsasında qeyd etmək lazımdır ki, 2019-cu il ilə müqayisədə 2023-cü ildə ölkəmizdə yaradılmış əlavə dəyər, işçilərin

sayı və orta aylıq nominal əmək haqqı artmışdır. Lakin 2019-cu il ilə müqayisədə 2023-cü ildə əsas kapitala investisiyalar 1056.1 mln. manat, yaxud 30.9 azalmışdır [7].

Cədvəl 3-də 2019-2023-cü illərdə ölkə iqtisadiyyatında mikro, kiçik və orta sahibkarlıq subyektlərinin payı təqdim olunub. Bu cədəvldən belə nəticəyə gəlmək olar ki, 2019-cu il ilə müqayisədə 2023-cü ildə ölkə iqtisadiyyatında yaradılmış əlavə dəyərdə (həmçinin qeyri neft-qaz sektoru üzrə) artım; müəssisələrdə muzdla işləyənlərin ümumi sayında cüzi artım, lakin həmin göstəricidə qeyri neft-qaz sektoru üzrə azalma; sahibkarlıq subyektləri tərəfindən əsas kapitala yönəldilmiş investisiyalarda (həmçinin qeyri neft-qaz sektoru üzrə) azalma müşahidə edilirdi [7].

İllər/Göstəricilər	**Ölkə iqtisadiyyatında yaradılmış əlavə dəyərdə (həmçinin qeyri neft-qaz sektoru üzrə)**	**Müəssisələrdə muzdla işləyənlərin ümumi sayında (həmçinin qeyri neft-qaz sektoru üzrə)**	**Sahibkarlıq subyektləri tərəfindən əsas kapitala yönəldilmiş investisiyalarda (həmçinin qeyri neft-qaz sektoru üzrə)**
2019 - cəmi, o cümlədən:	**14.9 (24.6)**	**43.7 (53.6)**	**21.0 (27.0)**
Mikro	6.6 (11.0)	5.3 (6.7)	3.2 (4.1)
Kiçik	1.9 (3.2)	11.2 (16.7)	3.0 (3.9)
Orta	6.4 (10.4)	27.2 (30.2)	14.8 (19.0)
2020 - cəmi, o cümlədən:	**16.7 (23.7)**	**42.1 (43.8)**	**23.2 (11.5)**
Mikro	6.8 (9.9)	4.9 (6.1)	8.4 (3.4)
Kiçik	2.5 (3.5)	11.1 (12.9)	3.3 (7.7)
Orta	7.4 (10.3)	26.1 (24.8)	11.5 (0.4)
2021 - cəmi, o cümlədən:	**16.4 (26.6)**	**41.8 (43.2)**	**31.1 (30.8)**
Mikro	6.8 (11.3)	4.8 (5.0)	15.7 (15.5)
Kiçik	2.8 (4.6)	11.9 (12.3)	8.2 (8.1)
Orta	6.8 (10.7)	25.1 (25.9)	7.2 (7.2)
2022 - cəmi, o cümlədən:	**13.9 (27.2)**	**41.8 (43.1)**	**29.1 (22.8)**
Mikro	5.7 (11.5)	4.8 (5.0)	8.8 (6.9)
Kiçik	2.3 (4.5)	11.8 (12.2)	9.8 (7.7)
Orta	5.9 (11.2)	25.2 (25.9)	10.5 (8.2)
2023 - cəmi, o cümlədən:	**18.0 (27.2)**	**44.0 (45.3)**	**19.0 (15.8)**
Mikro	6.8 (11.3)	5.6 (5.8)	2.4 (2.0)

Kiçik	2.9 (4.6)	12.4 (12.8)	6.4 (5.3)
Orta	8.3 (11.3)	26.0 (26.7)	10.2 (8.5)

Cədvəl 3. 2019-2023-cü illərdə ölkə iqtisadiyyatında mikro, kiçik və orta sahibkarlıq subyektlərinin payı, faizlə **[7]**

İllər	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Kredit portfeli, o cümlədən:	**14900.9**	**14157.0**	**16659.1**	**19594.4**	**23183.0**	**27477.7**
biznes kreditləri	9031.6	8478.3	9740.0	10855.1	12616.8	14787.2
istehlak kreditləri	4075.3	3661.2	4518.4	5754.1	6937.0	8445.0
ipoteka kreditləri	1794.0	2017.5	2400.7	2985.2	3629.2	4245.5

Cədvəl 4. 2019-2024-cü illərdə Azərbaycan Respublikasında bankların kredit portfelinin strukturu barədə məlumat, mln. manat **[8]**

Cədvəl 4-də 2019-2024-cü illərdə Azərbaycan Respublikasında bankların kredit portfelinin strukturu barədə məlumat təqdim olunub. Bu cədvəldən aşağıdakı vacib məqamları xüsusi qeyd etməliyik:

* 2019-cu il ilə müqayisədə 2024-cü ildə Azərbaycan Respublikasında bankların kredit portfelində canlanma müşahidə edilir, belə ki, təhlil olunan dövrdə kredit portfeli 12576.8 mln. manat, yaxud 84.4% artmışdır;

* kredit portfelində ən böyük artım ipoteka kreditlərin payına düşür:

- 2019-cu il ilə müqayisədə 2024-cü ildə kredit portfelində biznes kreditləri 5755.6 mln. manat, yaxud 63.7% artmışdır;

- 2019-cu il ilə müqayisədə 2024-cü ildə kredit portfelində istehlak kreditləri 4369.7 mln. manat, yaxud 107.2% artmışdır;

- 2019-cu il ilə müqayisədə 2024-cü ildə kredit portfelində ipoteka kreditləri 2451.5 mln. manat, yaxud 136.6% artmışdır.

İllər	**2021**	**2022**	**2023**	**2024**
Qeyri-işlək kredit (QİK), o cümlədən:	**748.0**	**735.3**	**614.2**	**655.1**
biznes kreditləri	498.3	507.3	378.0	374.8
istehlak kreditləri	183.4	184.9	196.8	246.3
ipoteka kreditləri	66.2	43.0	39.4	34.0
QİK/Kredit portfeli, o cümlədən	**4.5%**	**4.6%**	**2.6%**	**2.4%**
biznes (QİK)/biznes kreditləri	5.1%	4.7%	3.0%	2.5%
istehlak (QİK)/istehlak kreditləri	4.1%	0.7%	2.8%	2.9%
ipoteka (QİK)/ipoteka kreditləri	2.8%	6.2%	1.1%	0.8%

Cədvəl 5. Bankların qeyri-işlək kreditlərinin strukturu barədə məlumat (mln. manat) **[8]**

Cədvəl 5-də 2021-2024-cü illərdə Azərbaycan Respublikasında bankların qeyri-işlək kreditlərinin strukturu barədə məlumat təqdim olunub. Sevindirici hal ondan ibarətdir ki, 2021-ci il ilə müqayisədə 2024-cü ildə bankların qeyri-işlək kreditlərinin məbləği 92.9 mln. manat, yaxud 12.4% azalmışdır. Kredit portfelində növləri üzrə qeyri-işlək kreditlərin payında vəziyyət aşağıdakı kimidir:

- 2021-ci il ilə müqayisədə 2024-cü ildə biznes kreditləri üzrə qeyri-işlək kreditlərin məbləği 2.6% azalmışdır;

- 2021-ci il ilə müqayisədə 2024-cü ildə istehlak kreditləri üzrə qeyri-işlək kreditlərin məbləği 1.2% azalmışdır;

- 2021-ci il ilə müqayisədə 2024-cü ildə ipoteka kreditləri üzrə qeyri-işlək kreditlərin məbləği 2.0% azalmışdır.

Maliyyə ifrastrukturunun sahibkarlığa təsiri formaları arasında dövlət dəstək mexanizmləri xüsusi qeyd olunmalıdır. "Sahibkarlığın inkişafı fondu" güzəştli kredit mexanizmlərini, subsidiyaları, kredit zəmanətlərini fəal şəkildə tətbiq edir. 2024-cü ildə bu fond vasitəsilə güzəştli kredit alan sahibkarlıq subyektlərinin sayı əvvəlki ilə nisbətən 74.7% artmışdır və belə kreditlərin məbləği təxminən 248.1 milyon manat təşkil etmişdir. Dövlət zəmanəti və subsidiya mexanizmi də fəaliyyət göstərir: 2024-cü ildə 12 layihə üçün 19.2 milyon manat kredit üzrə 23.4 milyon manat məbləğində dövlət zəmanəti verilmişdir ki, bunun da bir hissəsi subsidiyalaşdırılmışdır (təxminən 6.2 milyon manat) [13].

Cədvəl 6, 7 və 8-də maliyyə ifrastrukturunun sahibkarlığa təsiri forması kimi maliyyə texnologiyaların istifadəsi dərəcəsi təqdim olunub.

İllər	AZİPS (Real Vaxt Rejimində Hesablaşmalar Sistemi)			XÖHKS (Xırda Ödənişlər üzrə Hesablaşma Klirinq Sistemi)			AÖS (Ani Ödənişlər Sistemi)		
	Sayı, min ədəd	Məbləği, mln. manat	Bir ödənişin məbləği, min manat	Sayı, min ədəd	Məbləği, mln. manat	Bir ödənişin məbləği, min manat	Sayı, min ədəd	Məbləği, mln. manat	Bir ödənişin məbləği, min manat
2015	489.0	121624.0	248.7	29858.0	15033.0	503.5	-	-	-
2016	574.0	131962.0	229.9	32628.0	16103.0	493.5	-	-	-
2017	747.0	191293.0	256.1	37228.0	18883.0	507.2	-	-	-
2018	820.0	252563.0	308.0	39115.0	21848.0	558.6	-	-	-
2019	894.0	232236.0	259.8	55721.0	26482.0	475.3	-	-	-
2020	908.0	195570.0	215.4	58917.0	27831.0	472.4	-	-	-
2021	1113.0	183756.0	165.1	69639.0	33906.0	486.9	117.0	280.0	2.4
2022	1358.6	300066.3	220.9	95896.6	41939.1	437.3	337.3	549.6	1.6

2023	2119.4	716310.9	338.0	145036.7	49012.0	337.9	587.6	1054.4	1.8
2024	2226.8	705835.6	317.0	165537.5	52952.1	319.9	800.7	1372.6	1.7

Cədvəl 6. 2015-2024-cü illərdə Azərbaycan Respublikasında Milli Ödəniş Sistemləri üzrə əməliyyatlar **[8, 9, 10, 11, 12]**

Cədvəl 6-dan aşağıdakı nəticələrə gələ bilərik:

- 2015-ci il ilə müqayisədə 2024-cü ildə Real Vaxt Rejimində Hesablaşmalar Sistemi üzrə əməliyyatların məbləği 584211.6 mln. manat, yaxud 480.3% artmışdır;

- 2015-ci il ilə müqayisədə 2024-cü ildə Xırda Ödənişlər üzrə Hesablaşma Klirinq Sistemi üzrə əməliyyatların məbləği 37919.1 mln. manat, yaxud 252.2% artmışdır;

- 2021-ci il ilə müqayisədə 2024-cü ildə Ani Ödənişlər Sistemi üzrə əməliyyatların məbləği 1092.6 mln. manat, yaxud 390.2% artmışdır.

İllər	**Bir terminala düşən əhalinin sayı, min nəfər**			**1000 ödəniş kartına düşən əməliyyatlar, orta aylıq**		**Bir bankomata düşən əməliyyatlar, orta aylıq**		**Bankomat üzrə bir əməliyyatın orta aylıq həcmi, manat**
	Bankomatlar	POS-terminallar	POS-terminallar ticarətdə və xidmətdə	sayı, əməliyyat	həcmi, manat	sayı, əməliyyat	həcmi, manat	
2013	3.9	0.28	0.29	1268.5	202625.2	2167.6	394833.0	182.1
2014	3.7	0.13	0.13	1346.2	208749.5	2121.8	395792.8	186.5
2015	3.6	0.12	0.12	1380.1	220837.6	2009.3	377509.9	187.9
2016	3.8	0.13	0.14	1296.2	198606.2	1834.1	334941.7	182.3
2017	3.9	0.14	0.15	1444.2	220371.1	2053.6	389502.8	189.3
2018	3.9	0.15	0.15	1573.8	240445.4	2237.7	440648.2	196.6
2019	3.8	0.15	0.16	1887.2	274370.3	2415.3	525391.0	216.5
2020	3.7	0.17	0.17	2134.8	276308.8	2616.1	627675.8	239.3
2021	3.5	0.17	0.17	2795.5	298005.1	2889.8	680506.6	235.7
2022	3.4	0.14	0.15	4192.2	384286.3	3551.9	842997.4	237.0
2023	3.3	0.12	0.13	6532.4	496061.5	4377.1	1003396.6	229.1
2024	3.2	0.10	0.11	8605.5	572129.7	4630.5	1092008.2	235.6

Cədvəl 7. 2013-2024-cü illərdə Azərbaycan Respublikasında ödəniş kartları və terminallardan istifadə göstəriciləri **[8, 9, 10, 11, 12]**

Cədvəl 7-dən aşağıdakıları xüsusilə qeyd etməliyik:

- 2013-cü il ilə müqayisədə 2024-cü ildə bankomatlar, POS-terminallar, o cümlədən ticarətdə və xidmətdə POS-terminallar üzrə bir terminala düşən əhalinin sayında azalmalar müşahidə edilir, bu isə müsbət hal kimi qəbul edilməlidir (ölkəmizdə FinTech-in infrastruktur bazasının yaxşılaşdırılması);

- 2013-cü il ilə müqayisədə 2024-cü ildə 1000 ödəniş kartına düşən əməliyyatların orta aylıq həcmi 369504.5 manat, yaxud 182.4% artmışdır;

- 2013-cü il ilə müqayisədə 2024-cü ildə bir bankomata düşən əməliyyatların orta aylıq həcmi 697175.2 manat, yaxud 176.6% artmışdır;

- 2013-cü il ilə müqayisədə 2024-cü ildə bankomat üzrə bir əməliyyatın orta aylıq həcmi 53.5 manat, yaxud 29.4% artmışdır.

İllər	Bank müştərilərinin sayı	Müştəri hesablarının sayı
2015	5716385	16229206
2016	5352456	15161312
2017	5772040	16120944
2018	6466071	18083747
2019	8478075	21265993
2020	10490089	24983255
2021	12323105	26729371
2022	13535655	32131951
2023	14654384	39590672
2024	15999555	47278994

Cədvəl 8. 2015-2024-cü illərdə Azərbaycan Respublikasında bank müştərilərinin və müştəri hesablarının sayı **[8, 9, 10, 11, 12]**

Cədvəl 8-dən aşağıdakı nəticələrə gələ bilərik:

- 2015-ci il ilə müqayisədə 2024-cü ildə Azərbaycan Respublikasında bank müştərilərinin sayı 10283170 nəfər, yaxud 179.9% artmışdır;

- 2015-ci il ilə müqayisədə 2024-cü ildə Azərbaycan Respublikasında müştəri hesablarının sayı 31049788 vahid, yaxud 191.3% artmışdır.

İllər	Elektron bankçılıq			
	internet bankçılıq		mobil bankçılıq	
	sayı, min əməliyyat	həcmi, mln. manat	sayı, min əməliyyat	həcmi, mln. manat
2022	24832	203369	121488	22688
2023	21208	227679	290799	46249
2024	21232	274744	627905	63906

Cədvəl 9. 2022-2024-cü illərdə Azərbaycan Respublikasında elektron bankçılıq **[8, 9, 10, 11, 12]**

Cədvəl 9-dan aşağıdakı məqamların qeyd olunması vacibdir:

- 2022-ci il ilə müqayisədə 2024-cü ildə internet bankçılıq üzrə əməliyyatların sayı 3600 min əməliyyat, yaxud 14.5% azalmışdır;

- 2022-ci il ilə müqayisədə 2024-cü ildə internet bankçılıq üzrə əməliyyatların həcmi 71375 mln. manat, yaxud 35.1% artmışdır;

- 2022-ci il ilə müqayisədə 2024-cü ildə mobil bankçılıq üzrə əməliyyatların sayı 506417 min əməliyyat, yaxud 416.8% artmışdır;

- 2022-ci il ilə müqayisədə 2024-cü ildə mobil bankçılıq üzrə əməliyyatların həcmi 41218 mln. manat, yaxud 181.7% artmışdır.

3. Nəticə və Təkliflər

Azərbaycanda maliyyə infrastrukturu sahibkarlıq mühitinə əhəmiyyətli və müxtəlif təsir göstərir: kiçik və orta müəssisələrinin kreditləşməsinin artırılmasından tutmuş rəqəmsal ödənişlərin genişləndirilməsinə və dövlət elektron sistemlərinin tətbiqinə qədər. Bu təsiri gücləndirmək üçün aşağıdakı nəticə və təklifləri qeyd etmək lazımdır:

Nəticələr:

1. Maliyyə infrastrukturu sahibkarlığa çoxölçülü təsir göstərir. Əsas komponentlər-kredit resurslarına giriş, investisiyaların cəlb etmək bacarığı, zəmanət sistemləri, sığorta və maliyyə cəhətdən qorunma - biznesin artımı və davamlılığı üçün zəmin yaradır. Adekvat infrastruktur olmadan sahibkarlar yeniliyə və miqyaslanmaya qarşı maneələrlə üzləşirlər.

2. İnstitutsional amillər vacibdir. Qanunvericilik, mülkiyyət hüquqlarının qorunması, maliyyə qurumlarının şəffaflığı, məhkəmə sistemi və hüquqi məsələlərin tətbiqi sahibkarlar, investorlar və maliyyə vasitəçiləri arasındakı etimada əhəmiyyətli dərəcədə təsir göstərir.

3. Mikromaliyyələşdirmə kiçik sahibkarlığa dəstək mexanizmi kimi önəmli təsir göstərir. Bir çox kiçik sahibkarlar və startaplar üçün ənənəvi bank kreditləri ya mövcud deyil, ya da çox bahalıdır. Mikromaliyyə təşkilatları bu boşluğu doldurur, lakin onlar tez-tez miqyas, tənzimləmə mühiti və davamlılıq problemləri ilə qarşılaşırlar.

4. Maliyyə xidmətlərinin rəqəmsallaşdırılması vacib drayverdir. Elektron ödənişlər, məsafədən xidmət, maliyyə texnologiyaları (FinTech) əməliyyat xərclərini azaldır, onun sürətini artırır, uzaq bölgələrə girişi yaxşılaşdırır və sahibkarların giriş maneələrini azaldır.

5. Regional fərqlər və zəif infrastruktur bağlantısı sahibkarlığın ümumi artımını məhdudlaşdıra bilər. Nisbətən inkişaf etmiş maliyyə sistemi olan ölkələrdə belə, maliyyə infrastrukturunun zəif olduğu bölgələr və ya sektorlar mövcuddur - məsələn, zəif kapital bazarı, zəmanət sisteminin və maliyyə vasitəçiləri arasında kifayət qədər rəqabətin olmaması.

Təkliflər:

1. Qanunvericilik və institutsional bazanın təkmilləşdirilməsi:

* Mülkiyyət hüququnu, maliyyə institutlarının şəffaflığını, investorların qorunmasını təmin edən standartların hazırlanması və tətbiqi;

* Mikromaliyyə təşkilatları, startaplar və kiçik müəssisələr üçün tənzimləmə prosedurlarının sadələşdirilməsi.

2. Zəmanət və sığorta institutlarının inkişafı:

* Kiçik müəssisələr və fəaliyyətə başlayan sahibkarlar üçün dövlət və ya yarı dövlət zəmanət fondlarının yaradılması;

* İnnovativ və aşağı riskli layihələrdə maliyyə risklərini əhatə edən sığorta məhsullarının inkişafı.

3. Mikromaliyyələşdirmə və alternativ maliyyə mənbələrinə dəstək:

* Mikromaliyyə təşkilatlarının kapitallaşmasını və dayanıqlığını artırılması, onların maliyyə bazarlarına və investisiyalarına çıxışının təmin olunması;

* Vençur kapitalı, kraudfandinq, biznes-mələklər kimi maliyyə mənbələrinin inkişaf etdirilməsi.

4. Maliyyə infrastrukturunun rəqəmsal transformasiyasının stimullaşdırılması:

* Uyğun olduğu yerlərdə elektron ödəmələr, mobil bankçılıq, blok-çeyn-həlləri infrastrukturlarının inkişaf etdirilməsi;

* Əməliyyat və tranzaksiya xərclərinin azaldılmasını, kreditlərin təsdiqlənməsi prosedurlarının sürətləndirilməsini, daha çox şəffaflığı təmin edən texnologiyaların tətbiqi.

5. Maliyyə savadlılığının və informasiya infrastrukturunun inkişafı:

* Sahibkarlara maliyyə uçotunun aparılması, pul vəsaitlərinin hərəkətinin idarə edilməsi, maliyyə alətlərinin anlaşılması bacarıqlarının öyrədilməsi;

* Maliyyə məhsulları, hüquq və vəzifələr, müxtəlif maliyyə mənbələrinin riskləri və faydaları haqqında məlumatların əldə olunması.

6. Regional siyasət və infrastrukturun yerli şəraitə uyğunlaşdırılması:

* Bölgələrin xüsusiyyətlərinin nəzərə alınması: urbanizasiyanın səviyyəsi, iqtisadi ixtisaslaşma, texnologiyaların mövcudluğu, nəqliyyat infrastrukturu;

* Dəstək tədbirlərinin sınağı, yerli ehtiyaclara uyğunlaşdırılması üçün daha az inkişaf etmiş bölgələrdə pilot layihələrin həyata keçirilməsi.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. There is no conflict of interest.

Ədəbiyyat

Sahibkarlıq fəaliyyəti haqqında Azərbaycan Respublikasının Qanunu, Bakı, 15.12.92

Azərbaycan Respublikası regionlarının 2019-2023-cü illərdə sosial-iqtisadi inkişafı Dövlət Proqramı, 29.01.19

"Azərbaycan (2020): gələcəyə baxış" İnkişaf Konsepsiyası. Bakı, 29.12.2012

Azərbaycan (2030). sosial-iqtisadi inkişafa dair Milli Prioritetlər. Bakı, 02.02.2021

“Azərbaycan Respublikasının 2022-2026-cı illərdə sosial-iqtisadi inkişaf Strategiyası”, Bakı şəhəri, 22.07.22

Internet-mənbə: https://economy.gov.az/az/page/nazirlik/haqqinda

Internet-mənbə: https://www.stat.gov.az/

Internet-mənbə: https://www.cbar.az/

Internet-mənbə: https://uploads.cbar.az/assets/dc60ec901d1b89cf89d443444.pdf

Internet-mənbə: https://uploads.cbar.az/assets/c6426af9cd2368b44eb7ca4c6.pdf

Internet-mənbə: https://uploads.cbar.az/assets/c6426af9cd2368b44eb7ca4c6.pdf

Internet-mənbə: https://uploads.cbar.az/assets/4a6a6939aa9516234c3cdedbe.pdf

Internet-mənbə: https://economy.gov.az/az/post/2500/sahibkarlar-dovletin-guzestli-maliyye-mexanizmleri-ile-bizneslerini-inkisaf-etdirirler

Internet-mənbə: https://www.smb.gov.az/az

Internet-mənbə: https://cyberleninka.ru/article/n/infrastruktura-predprinimatelstva-suschnost-i-vidy

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Rural Displacement and Livelihoods: A Study of Farmer-Herder Conflicts in Benue State, Nigeria and Its Impact on Agricultural Development

Adoga Peter ADOGA[1*]

ORCID 1: 0009-0004-7388-1280
[1]Department of Geography, Faculty of Earth and Environmental Sciences, Bayero University Kano, Kano State, Nigeria.
adoga4u@gmail.com **(**Responsible Author)

Ikyapa Tertese PETER[2]

ORCID 2: 0000-0002-8623-3934
Department of Environmental Management, Faculty of Earth and Environmental Sciences, Bayero University Kano, Kano State, Nigeria.
ikyapapeter@gmail.com

Abstract

The escalating farmer-herder conflicts in Benue State, Nigeria, have triggered widespread rural displacement, disrupted agricultural activities, and destabilized local economies. Drawing from Focus Group Discussions and Key Informant Interviews across selected conflict-affected communities, the study investigates the socio-economic consequences of displacement and the broader implications for food production and rural resilience. The research employed a qualitative methodology, using random, purposive and snowball sampling techniques to select participants with direct experience of displacement. Data analysis reveals that sudden violent attacks often characterized by burning of properties, bloodshed and rape led to widespread displacement of rural farmers. Displaced farmers face significant livelihood disruptions, including loss of farmland, reduced income, food insecurity, family separation and social disintegration. Despite adopting coping strategies such as informal labour and temporal migration, they remain economically vulnerable and socially marginalized depending on stipends from family members and donations from individuals and organizations for those in IDPs camps. The findings underscore the long-term threat that rural displacement poses to agricultural development in Nigeria's north central, particularly in regions central to national food security. The study calls for multi-level policy responses, including improved land governance, community-based peacebuilding, livelihood rehabilitation programs, and early warning systems to prevent further displacement.

Keywords: Farmer-Herder Conflict, Rural Displacement, Livelihood Disruption, Agricultural Development, Climate-Induced Conflict, Benue State.

1. Introduction

1.1. Background and Context

In Nigeria's Middle Belt, farmer–herder conflicts have increasingly become a pervasive and destructive phenomenon, especially in states like Benue that are agriculturally rich yet socially vulnerable. Historically, pastoral mobility and settled farming coexisted through negotiated access to grazing and farmland, but mounting pressures have eroded this balance. These pressures include demographic growth, land conversion, agricultural expansion, and environmental stress; particularly those associated with climate change, variability and resource depletion (Adoga, Umeh & Idris, 2024; Ogunbode, Ajayi & Omisore., 2020). More recently, violent clashes, cattle

intrusion, crop destruction, and retaliatory attacks have led to displacement, livelihood loss, and food insecurity in affected rural zones (Nwankwo, Onuigbo & Chukwuma 2024; ACCORD, 2022).

Benue State is especially significant in this discourse because it is often referred to as Nigeria's "food basket." Its fertile soils and favorable agro-ecological conditions support diverse cropping systems and livestock production. However, the escalation of conflicts over land, water, and grazing access has disrupted agricultural timelines, displaced farm families, and undermined local food systems. The conflict in Benue is not merely local in scale but carries broader implications for national agricultural development and stability (Ijirshar, Udaah, Mile, Vershima, & Adaudu 2025). Indeed, recent studies show that insecurity in Benue state correlates with reductions in crop and livestock outputs (Ijirshar *et al*., 2025).

1.2. Problem Statement

While much of the existing scholars addresses the causes, nature, and security dimensions of farmer–herder conflicts, less attention has been given to the processes and consequences of rural displacement triggered by those conflicts; and how displacement, in turn, affects agricultural development. Rural populations forced to abandon farmland often lose critical assets, face social disintegration, and struggle to re-establish livelihoods under challenging conditions. In Benue State, where agricultural productivity is key to rural incomes and food security, such disruptions may have deeply negative ripple effects on local economies and communal stability.

Hence, a focused inquiry is needed to understand how conflict-induced displacement reshapes agricultural landscapes, constrains rural livelihood options, and potentially stunts growth in agrarian sectors. Without such knowledge, policies designed to reduce conflict or rehabilitate displaced populations may fail to address the structural economic consequences.

1.3. Research Questions and Objectives

In response, this study is guided by the following research questions:

a. How does farmer–herder conflicts in Benue State contribute to rural displacement?
b. What challenges do they face in rebuilding their livelihoods?
c. What are the short-term and long-term impacts of rural displacement on agricultural development in Benue State?

The objectives of this study are thus: To interrogate how the farmer–herder conflicts in Benue State precipitate rural displacement, to characterize the obstacles they encounter in re-establishing their livelihoods and to assess both immediate and enduring impacts of displacement on agricultural productivity, land use, and rural economies.

1.4. Significance of the Study

This research contributes in multiple ways. First, by centering displacement as a focal outcome of conflict, it opens a lens on livelihood disruptions that is less represented in existing studies. Second, by paying particular attention to agricultural development, it bridges peace/security research with agrarian economics and rural development discourse. Third, by combining lived

experiences from conflict-affected communities with policy-oriented inquiry, the study offers grounded insights to policymakers, development agencies, and local stakeholders striving to design interventions with real impacts. Finally, in the context of climate change and growing resource stress across West Africa, the findings from Benue may serve as a case from which lessons can be drawn for other conflict-prone agrarian regions.

1.5. Scope and Limitations

This study is geographically focused on selected rural communities in Benue State that have recently experienced farmer–herder conflicts and consequent displacement. Data is drawn through Focus Group Discussions and Key Informant Interviews with displaced farmers, host community members, and local leaders. The temporal scope centers on conflict and displacement events occurring approximately between 2018 and 2025, aligning with heightened conflict waves in the north central Nigeria. While the qualitative methodology limits broad generalizability, the depth of insight gained will illuminate displacement dynamics and agricultural consequences that may resonate in comparable agrarian settings.

1.6. Literature Review

1.6.1. Theoretical perspectives on displacement

Displacement, whether due to conflict, disaster, or development; has been studied through multiple theoretical lenses. A promising conceptual framework is offered by Hirsch, Eizenberg, & Jabareen (2020), who defines key dimensions of displacement: power, positionality, eligibility, temporality, and resistance. These concepts emphasize that displacement is not merely physical relocation but involves shifts in rights, identities, and agency. Hirsch's framework helps in analyzing how rural households displaced by conflict transform their social and economic interactions.

In the domain of resilience and sustainability, Kochskämper, Glass, Haupt, Malekpour. & Grainger-Brown (2025) explore the interplay between resilience-building and advancing the SDGs. They argue that resilience interventions tailored for cities and communities can accelerate SDG progress, but only when they consider local vulnerabilities and equity (Kochskämper *et al*., 2025). This work suggests that in contexts of displacement, resilience frameworks must be integrated with SDG objectives to ensure displaced populations are not left further behind.

Other theoretical perspectives include structural violence theory, which views displacement as an outcome of entrenched inequalities and systemic exclusion (Galtung, 1969 cited in broader conflict literatures such as Henderson, 2019; Disabil, 2017). Also relevant is political ecology, which emphasizes how resource access, power relations, and environmental stressors intersect to force relocation and livelihood change. These theories help situate displacement within broader structural forces rather than treating it as isolated crises.

From a development planning vantage, rights-based theory of development frames displacement as a violation of human rights, demanding redress in terms of restitution, compensation, and participation in rebuilding (often invoked in UN and humanitarian literature). This aligns with the ethos of SDG principles of "leaving no one behind."

1.6.2. Displacement and the sustainable development goals

Since the adoption of the 2030 Agenda, scholars have interrogated how displaced populations are integrated into or excluded from SDG monitoring and implementation. Le Voir (2023) critically examines how displaced persons are often invisible in key SDG indicators, especially those related to sexual and reproductive health, showing that data systems rarely disaggregate by displacement status. This invisibility undermines accountability and equity under the SDG framework.

More broadly, Le Voir (2023) links forced displacement as a barrier to SDG attainment. The paper highlights how conflict-driven internal displacement directly affects goals related to poverty (SDG 1), food security and hunger (SDG 2), and decent work (SDG 8) by disrupting productivity, access to resources, and labor markets. The argument is that displacement both results from unsustainable development paths and inhibits progress toward sustainable outcomes.

1.6.3. Empirical studies: displacement, conflict, and rural livelihoods

Empirical studies from Nigeria and Sub-Saharan Africa reveal rich insights into displacement caused by agrarian conflict. A case study in the Middle Belt of Nigeria found that herder incursions forced farm families to migrate seasonally or permanently, losing land capital and community support systems (e.g. Mbah, Jiriko, & Amah, 2020). Those displaced often adopt secondary occupations, wage labor, or petty trade, though with significantly reduced income stability.

In the Sahel, forced migration due to conflict and environmental stress is well documented. For instance, scholars show that displaced farming households suffer lower food consumption, reduced crop diversity, and loss of social capital (Su & Amrit, 2024; Olanrewaju & Balana, 2023). Even after resettlement, returnees often struggle with reclaimed land, poor fertility, or conflict over new plots.

In Nigeria's Niger Delta, conflict-induced displacement from oil pollution and resource contests has been linked with declines in agricultural output and increased poverty. Some of studies showed that displaced rural producers had lower access to credit, inputs, and extension services, reducing yields relative to non-displaced communities (Odozi & Uwaifo, 2021; Ofuoko & Evwierhurhoma, 2018; Obi, 2010).

Another study in Northern Nigeria examined the displacement from Boko Haram conflict and found that displaced farmers had truncated crop cycles, limited market access, and adoption of short-term survival farming strategies (Tafida *et al*., 2023; George, & Adelaja, 2022). The authors argued that displacement contributes to a downward spiral in agrarian productivity, reinforcing economic fragility. Figure 1 shows some of the effects of displacement on communities and the people.

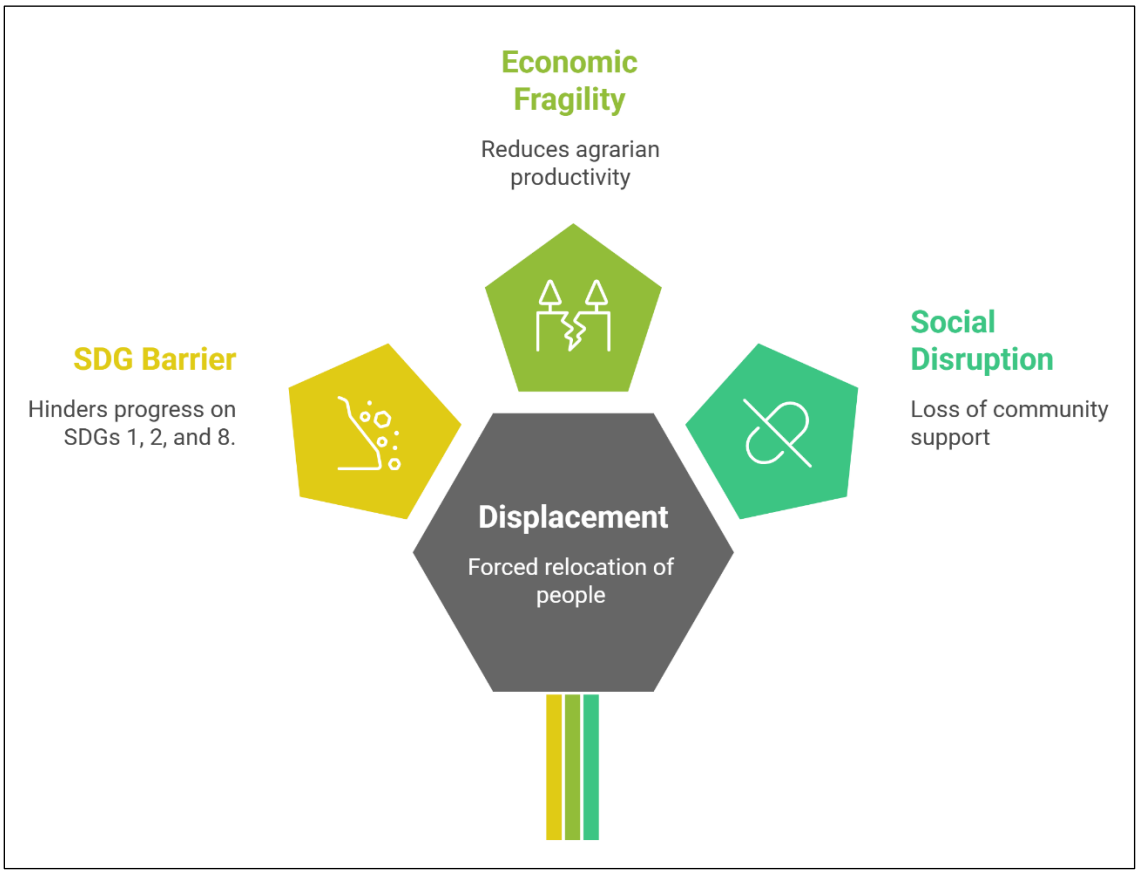


Figure 1. Effects of displacement

2. Materials and Methods

2.1. Study Area

Benue State lies in Nigeria's north central, occupying a landmass of about 34,059 km². It is geographically bounded between latitudes 6° 25′ and 8° 08′ N and longitudes 7° 47′ and 10° 00′ E, and shares boundaries with Nasarawa (north), Taraba (east), Cross River, Ebonyi and Enugu (south), and Kogi (west) (Figure 2). The name is derived from River Benue which runs through.

Benue is characterized by a tropical savanna climate (Köppen's AW), with distinct rainy (April–October) and dry (November–March) seasons. Annual rainfall typically ranges from 1,000 mm to about 2,000 mm in many parts; the state also experiences a mono-peak rainfall pattern in some areas. Mean temperatures range from 23 °C to 37 °C, with relative humidity averaging 70 % (Ologunorisa, Obioma & Eludoyin, 2021). Vegetation & Soils

Vegetation transitions across the state from forest to savanna in the south to woodland/Guinea savanna in the north; reflecting soil fertility gradients and rainfall differences. Much of the land is cultivated, and natural vegetation has been altered by agricultural expansion. Soils are predominantly loamy, alluvial in floodplains, and basement complex-derived in upland areas,

forming a basis for mixed agriculture and suitability for many cash and food crops (Ujoh, Igbawua, Ogidi, 2019).

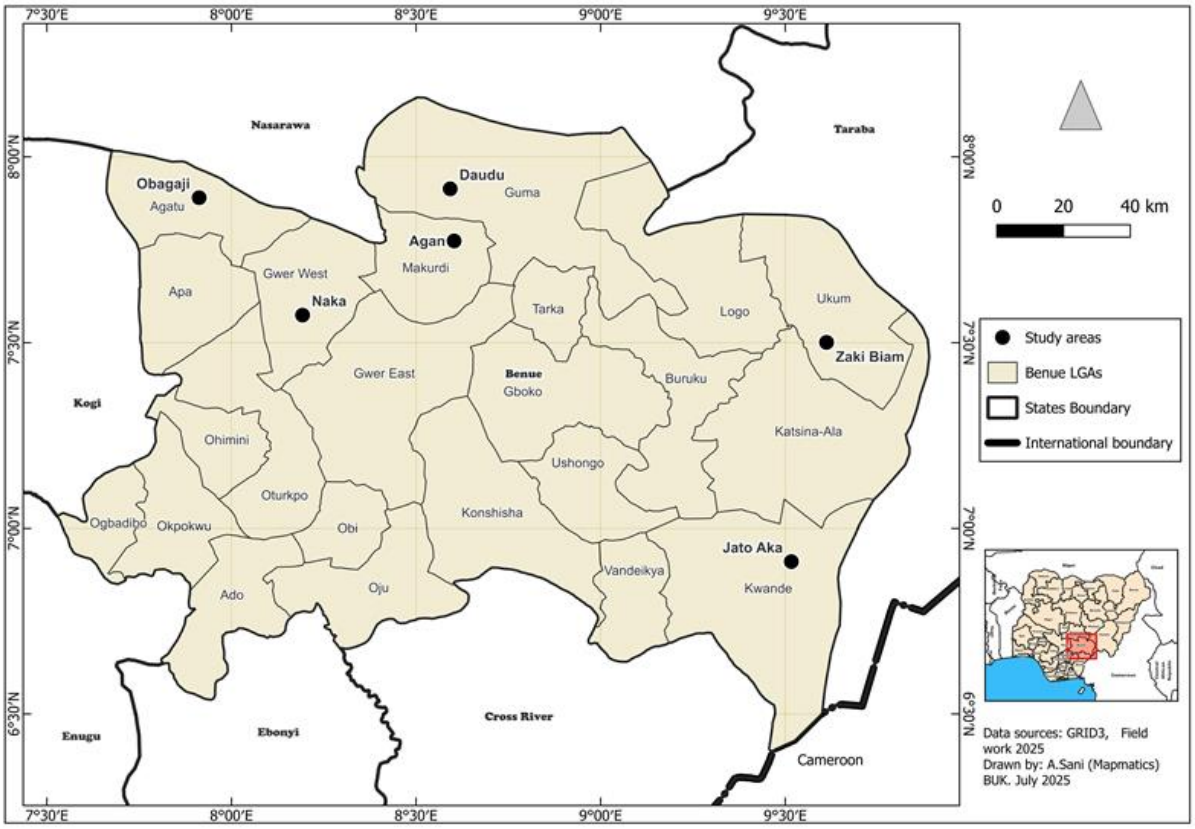


Figure 2. Map of Benue State showing the Six Sample Area

Agriculture is the mainstay of Benue's economy: over 70 % of the population is engaged in farming. Prominent crops include yam, maize, cassava, rice, soybeans, beans, sorghum, millet, and others. Livestock rearing (cattle, goats, sheep) is widespread, especially in fringe zones. Fishing is also important along water bodies like the River Benue. The state is often dubbed Nigeria's "Food Basket" because of its significant contribution to national staples (Ukpoju & Oue, 2024).

2.2. Research Design

This study adopted a qualitative research design, focusing exclusively on the experiences and perspectives of farmers who have been directly affected by the perennial violent farmer–herder conflict and displacement. Focus Group Discussions (FGD's) and Key Informant Interviews (KII) were used as tools for data collections. The aim is to elicit rich, contextually grounded data rather than produce large-scale statistical generalizations.

2.3. Sampling Methods

Simple random, purposive and snowball sampling were used, simple random sampling was used to select six local government areas of Agatu, Guma, Gwer West, Kwande, Makurdi and Ukum out of the 23 in the state; purposive sampling approach was used to select six rural communities within each of the local government known for recurrent farmer–herder conflicts and the resultant rural displacement. The six communities are: Obagaji in Agatu LGA, Daudu in Guma LGA, Naka in Gwer West LGA, Jato Aka in Kwande LGA, Agan in Makurdi LGA and Zaki Biam in Ukum LGA

Within each community, farmers who had experienced displacement or disruption of their farmland were selected via snowball sampling (to reach those affected) and random sampling (among the eligible pool) to diversify voices.

2.4. Data Collection Methods

2.4.1. Focus Group Discussions (FGDs)

12 Focus Group Discussions (FGDs) were conducted with two (male and female) FGDs in each community, as the focus is on agricultural impacts and livelihood disruption. Each FGD had 10 participants in attendance making a total of 120 participants.

The FGDs were semi-structured and guided by a discussion protocol focusing on: Drivers of conflict and how its effects on displacement, experiences of displacement and livelihood disruption, adaptation or recovery strategies, perceived impacts on agriculture and future prospects. Each FGD lasted between 60 and 90 minutes, audio-recorded (with permission), and transcribed verbatim.

2.4.2. Key Informant Interviews (KIIs)

Additionally, 12 Key Informant Interviews (KIIs) were conducted across the communities (2 per community), with local agricultural extension workers and community leaders.

Semi-structured interviews were used with the local experts, extension agents, or community leaders to complement and triangulate FGD data; especially regarding institutional responses, historical trends, and policy perspectives.

All interviews and FGDs were conducted in local languages (e.g., Tiv, Idoma) where necessary, with translation to English during transcription.

2.5. Data Analysis

Benue has often been a hotspot of contestation over land and grazing rights, because of its central location and agricultural potential, making it a relevant site for studying farmer-herder conflicts and displacement. Data was analyzed using thematic content analysis, transcripts were read repeatedly and coded into thematic nodes (e.g., “violent attacks,” “family separation,” “temporary shelter” “land abandonment”). Codes were grouped into broader themes following an inductive-deductive approach; inductive to capture emergent themes and deductive based on research questions.

NVivo was used to manage and organize codes and transcripts, facilitating pattern identification, cross-community comparison, and theme interrelations. Findings from FGDs and KIIs were triangulated to validate consistency.

2.6. Limitations

Because the study relies on qualitative data from farmers only, the perspectives of herders, non-farmers, or government actors are excluded. The purposive and snowball sampling limit statistical generalizability; the results however, provide depth and insight rather than population-wide representativeness. Recall bias may affect participants' estimates of losses or timelines in displacement and agricultural impacts.

3. Findings and Discussions

3.1 Findings

The data were organized into three major themes, reflecting the core research questions:

3.1.1. Conflict induced displacement

Participants across all six communities identified key reasons why the conflict led to widespread displacements:

A female FGD participant in Obagaji expressed that:

"The attacks are extremely violent and led to the deaths of many people, several missing even years after attacks. When you do not hear or see someone again after such an attack, you assume they died in the attack, with such magnitude of bloodshed, fleeing to new locations is the safer option"

Another female FGD participant in Naka added that:

"One terrible evil these herdsmen have been doing is the raping of women and young girls on the farms; sometimes they will kill them after raping them and sometimes, they will leave them to go. These trauma is difficult to live with; this is why we fled our own land"

A male FGD participant in Daudu further stated that:

"We are sedentary and have permanent residences while the herders are migrants with temporary makeshift structures, when they attacked our community, they burnt many houses and farms, even if we are to return back there, we will be rebuilding everything afresh"

A KII participant in Zaki Ibiam collaborating these statements stated that:

"These herdsmen attacks are sudden, persistent and can happen at any time of the day; whether while people are asleep in the night or in places of worship on Sunday. Given the magnitude of the violence and the fear of being killed by these heartless men, the displacement we are seeing the option for the farmers".



Plate 1. Part of Yelewata community in Guma local government area after armed herdsmen attack on June 14, 2025 that claimed over 100 lives and displaced over 3000 people.

3.1.2. Displacement experiences and adaptation challenges

Participants expressed their displacement experiences which were both sudden and prolonged:

A male FGD participant in Daudu narrated that:

"My entire village had to flee overnight due to violent attack that happened that night, it was when we got to Daudu that we actually knew all those that were killed, we could not go back until after a week only to meet decomposing bodies of our loved ones and our burnt properties. I personally lost all my credentials because I could not carry it as I ran for my life".

A female FGD participant in Makurdi stated that:

"as we fled our community, I got separated with my eldest son who is 12 years old. I thought he was with my husband who was much more behind us but when we got to Agan and he caught up with us, he was not with him. We kept searching for him and did not see him for over three months before he was brought to us from another IDP camp in Guma. In our case, we were very lucky, some people here are still looking for their loved ones. The sad thing is that, it is sometimes better to know that someone is dead than to just keep searching endlessly without ever finding them yet hoping you will see them one day. When fleeing, the most difficult people to carry are the elderly, some of them are sick, some blind even the children are easier because we can back them and others can run".

A KII participant in Jato Aka said that:

"there are several people in this place that have not gone back home since they fled during the time Fulani herdsmen attacked their communities, some have been here for 5 to 6 years, staying in temporal makeshift shelters"

Another KII participant in Obagaji added that:

"one painful angle to the effect of displacement is the increase in dependency burden, many of those displaced have lost their means of livelihoods and have no choice but run to either IDP camps

or to their relatives. In such conditions, they depend on the relatives for food and other stipends. So you can imagine, how pathetic for an able bodied man becoming dependent".

3.1.3. Rural displacement and agricultural decline

An FGD participant in Zaki Ibiam reported that:

"The displacement has cost us severely in terms of crop productivity and yield, those who are to cultivate are displaced resulting in low production of crops, either due to conflict-time abandonment or loss of access to farms".

Another FGD participant in Naka expressed that:

"displacement has led to farmland abandonment; some formerly productive areas remain uncultivated due to insecurity. The farmers are afraid of getting killed if they attempt to cultivate some areas"

"Apart from crops, we also lost farming tools, stored grains, and livestock during attacks. Before the crisis, I had six hectares of rice, five hectares of maize, three hectares of cassava. Now, I am squatting with my brother, some of our people are in IDP camps depending on donations from well-meaning individuals and non-governmental organizations" added another FGD participant in Makurdi.

A KII participant in Makurdi while collaborating the effects of rural displacement on agricultural development in the state stated that:

"as a result of the displacement, some of those displaced survive by becoming hired helps to cultivate farmlands for others, some shifting to peri-urban agriculture by growing short-cycle crops on rented lands near towns. However, this has not really boosted agricultural productivity in the state because many of them are still working below their normal capacity".

3.2. Discussion

The thematic results presented earlier illuminate how farmers in conflict-affected communities in Benue State experience displacement and agricultural disruption. In this discussion, we interpret those findings in light of existing literature and theory, reflecting on their broader meaning for policy and sustainability.

3.2.1. Displacement, livelihood losses, and agricultural decline

The experiences of displaced persons such as dependency on relatives, living in temporary makeshift shelters are consistent with Adoga, Akumaga & Mohammed (2025) who reported that most displaced persons stay in Internally Displaced Persons (IDPs) camps which are either schools or makeshift structures, exposed to poverty and hunger; depending largely on donations from non-governmental organizations and wealthy individuals. The more fortunate ones stay with their relatives as dependents.

The scale of yield loss, land abandonment, and asset depletion recorded in this study echoes findings from Nnaji, Ratna, Renwick & Ma (2022) who established that the incidence and severity of farmer-herder conflict increase food insecurity for rural households. In their survey, the severity

of conflict had a larger negative effect than mere incidence; paralleling your observations that more intense or repeated displacements lead to deeper and more lasting agricultural disruption.

The finding that farmland is left uncultivated under insecurity is consistent with broader patterns in conflict zones: Omotayo et al. (2025) documents declines in farm investment in conflict-affected areas, and participant reports of asset loss and abandonment substantiate the qualitative dimension of that trend. In sum, displacement becomes not only a geopolitical issue but a structural drain on agricultural productivity.

3.2.2. Implications for food security and sustainable development

The results underscore that rural displacement in Benue State is not simply a local social or security issue; it has profound implications for food security, agricultural development, and the realization of sustainable development goals (SDGs). The reduction in cultivated land, loss of crop yield, and displacement-induced failure to invest in agriculture directly undermine SDG 2 (Zero Hunger) and SDG 1 (No Poverty).

Moreover, as conflicts intensify and farmers abandon farmland, national food baskets shrink and supply chains tighten, compounding vulnerabilities. The linkage between insecurity and declining productivity observed in the recent study on insecurity in Benue (Ijirshar et al., 2025) reinforces that conflict-related displacement has quantifiable negative impacts on agricultural output locally.

3.2.3. Contributions and future directions

This study's qualitative depth, centering on farmers' voices, contributes to a more grounded understanding of how conflict-driven displacement impacts agriculture at community scale; complementing macro-level quantitative studies.

Future work should incorporate mixed methods: combining FGDs with household surveys and remote sensing of land use change; to triangulate qualitative reports with observable environmental and yield data. Also, exploring displacement from the perspective of herders, host communities, and institutional actors would enrich the multi-actor dynamics of conflict and displacement.

4. Conclusion, Policy Implications, and Recommendations

This study has explored the complex relationship between farmer-herder conflicts, rural displacement, and agricultural development in Benue State, Nigeria. Drawing on 12 focus group discussions and twelve key informant interviews, the findings reveal that conflict-driven displacement is both a humanitarian and developmental crisis. Farmers face recurring violence, land abandonment, loss of livelihoods, and disruptions to food production systems. Displacement not only weakens rural resilience but also undermines Nigeria's broader food security goals. The findings reaffirm that beyond ethnic or cultural tensions, the root causes lie in resource competition, land governance failures, climate stress, and weak institutional responses. Resolving this crisis requires multi-dimensional interventions that address both immediate relief and long-term agricultural recovery.

The study has implication for food security risk; displacement from farming communities reduces cultivated land and threatens local and national food production; challenging Nigeria's progress

toward SDG 2 (Zero Hunger) and SDG 1 (No Poverty). Institutional gaps through inadequate enforcement of land-use policies, poor coordination among security agencies, and lack of effective early warning systems worsen the cycle of violence and displacement. In addition, weak conflict resolution systems between traditional and state mechanisms remain fragmented or reactive, failing to address systemic grievances and recurring clashes.

Recommendations

The following are recommended:

1. The federal government should establish clear, participatory land tenure systems that reduce overlapping claims between farmers and pastoralists.

2. The government should invest in agricultural recovery and support by providing displaced farmers with access to inputs, extension services, and climate-smart technologies to rebuild their livelihoods.

3. The government should also support the resource users with climate-resilient infrastructure such as expansion of irrigation systems, water points, and storage facilities in conflict-prone areas to reduce dependence on rain-fed agriculture and seasonal migrations.

4. The government should establish a national conflict-monitoring system that integrates satellite data, community reporting, and socio-economic indicators for proactive interventions.

By translating findings into action, this study calls on policymakers, development actors, and local stakeholders to treat conflict-induced displacement as both a development emergency and an opportunity to rebuild more resilient agricultural systems in Benue State.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethical Approval from the state Ministry of Agriculture as well as the farmers' association was gotten before heading to the field. Additionally, community leaders were consulted to facilitate access and ensure culturally appropriate engagement. Before each FGD or interview, participants were briefed about the study's purpose, assured of confidentiality, and asked for voluntary informed consent. Anonymity was preserved by using anonymized identifiers. Participants could decline to answer questions or withdraw at any time without penalty.

Author 1 conceived the idea, collected the data and wrote the initial manuscript, author 2 also helped with data collection and edited the manuscript. There is no conflict of interest.

References

ACCORD. (2022). Analysing the patterns and dominant narratives of Nigeria's farmer–herder conflicts. African Centre for the Constructive Resolution of Disputes (ACCORD). Retrieved: September 15, 2025 from https://www.accord.org.za/publication/analysing-the-patterns-and-dominant-narratives-of-nigerias-farmer-herder-conflicts/

Adoga, P. A., Akumaga, U., and Mohammed, U. K. (2025). Understanding farmer-pastoralist conflicts in Nigeria's Benue valley: nature, causes, and impacts. *Journal of Ecopolitics,*

Peace, and Sustainable Development (JEPSD). 1(1), 97-110. https://doi.org/10.69798/85324665

Adoga, P. A., Umeh, P. P., and Idris, H. A (2024). Climate induced tensions: exploring the intersection of climate variability, livelihood disruptions and farmer pastoralist violence in parts of central Nigeria. *Ife Research Publications in Geography (IRGP)*, 24(2) 91-105

Disabi, A. J. (2017). Exploring Structural Violence in the Context of Disability and Poverty in Zimbabwe. *US National Library of Medicine*. Doi: 10.4102/aj.iod.v6io.274

George, J., & Adelaja, A. (2022). Armed conflicts, forced displacement and food security in host communities. *World Development.* 158. 105991. https://doi.org/10.1016/j.worlddev.2022.105991

Henderson, S. (2019). State Sanctioned Structural Violence: Women Migrant Domestic Workers in the Philippines and Sri Lanker. *Violence Against Women*. *26*(12-13): 1598-615

Hirsch, H., Eizenberg, E., & Jabareen, Y. (2020). A new conceptual framework for understanding displacement: Bridging the gaps in displacement literature between the global South and the Global North. *Journal of Planning Literature*, 35(4), 391 - 407. https://doi.org/10.1177/0885412220921514

Ijirshar, V. U., Udaah, I. I., Mile, B. N., Vershima, J. S., & Adaudu, A. (2025). Effect of insecurity on agricultural output in Benue State, Nigeria. arXiv Preprint. arXiv:2506.01525. Retrieved from https://arxiv.org/abs/2506.01525

Kochskämper, E., Glass, L. M., Haupt, W., Malekpour. S. & Grainger-Brown, J. (2025). Resilience and the Sustainable Development Goals: A scrutiny of urban strategies in the 100 resilient cities initiative. *Journal of Environmental Planning and Management*, 68(7), 1691-1717. https://doi.org/10.1080/09640568.2023.2297648

Le Voir, R. (2023). Leaving no One Behind: Displaced Persons and Sustainable Development Goal indicators on Sexual and Reproductive Health. *Population Research and Policy Review*, 42, article 77.

Mbah, E. N., Jiriko, R. K., & Amah, N. E. (2020). Socio-economic impacts of conflicts between farmers and cattle herdsmen in rural households of Benue State, Nigeria. *Journal of Agriculture and Sustainability* 13(13), 1-12. https://doi.org/10.289243/jp/jas.1967

Nwankwo, C. F., Onuigbo, R. A., & Chukwuma, L. O. (2024). Farmer–herder conflict and criminality in ungoverned forests: Implications in the Benue–Nasarawa region. *Environmental Challenges*, 9, Article 100133. https://doi.org/10.1016/j.envc.2024.100133

Nnaji, A., Ratna, N., Renwick, A. & Ma, W. (2023). Risk perception, farmer–herder conflicts and production decisions: Evidence from Nigeria. *European Review of Agricultural Economics*. 50(2), 683-716. https://doi.org/10.1093/erae/jbac012.

Obi, C. 1. (2010). Oil extraction, dispossession, resistance and conflict in Nigeria's oil-rich Niger Delta. Canadaian *Journal of Development Studies*, 30 (2), 219-236. https://doi.org/10.1080/02255189.2010/9669253

Odozi, J. C., & Uwaifo, O. R., (2021). Does violent conflict affect the labour supply of farm households? The Nigerian experience. Agricultural & Resource Economics Review, 50 (Special Issue 3: *Social Justice in Agricultural and Environmental Economics*). 401-435. https://doi.org/10.1017/age.2021.14

Ofuoku, A. U., & Evwierrhurhoma, F. (2018). Effect of land conflict on arable crop production in Delta State, Nigeria. Ege Universitesi Ziraat Fakultesi Dergisi. 55(3), 141-150. https://doi.org/10.20289/zfdergi.385905

Ogunbode, T. O., Ajayi, O. G., & Omisore, E. O. (2020). A review of farmers/herders clashes in Nigerian environment. *Journal of African Counselling and Allied Professions*, 2(1), 28–43. Retrieved from https://digitalcommons.usf.edu/jacaps/vol2/iss1/3/

Olarenwaju, O., & Balena, B. B. (2023) Conflict-induced shocks and household food secutrity in Nigreria. *Sustainability*, 15(6), Article 5057. https://doi.org/10.3390/su15065057

Ologunorisa, T., Obioma, O., & Eludoyin O. (2021) Urban *Flood Event and Associated Damage* in the Benue Valley, Nigeria. *Environmental Science*. DOI: 10.1007/s11069.021-05052-6

Omotayo, A. O., Adeoye, A., Omotosho, A. B., & Ogunniyi, A I. (2025). Impact of conflicts on agricultural crop investment in rural areas: Policy insight from a nationally representative survey dataset. *Land Use Policy*, 159, 107793.

Tafida, A . A., Tukur, A. L., Adebayo, E. F., Ndaghu, A . A., Onu, J. I., & Momodu, J. A. (2023). Boko haram insurgency and livelihood vulnerability of rural households in northern Adamawa State, Nigeria. *Resarch in Globalization*. 6, 100116. https://doi.org/10.1016/j.resglo.2023.100116

Su, Y. & Amrit, C. (2024). Literature review of food insecurity in the Sahel from an interdisciplinary perspective. *Journal of Decision Systems*, 33, 400-412. https://doi.org/10.1080/12460125.2024.2354640

Ukpoju, A., & Oue, H. (2024). Estimating the water balance of irrigated rice fields dry season, Makurdi, Nigeria. *Journal of Natural Resources and Environmental Management.* 14(3). https://doi.org/10.29244/jpsl.14.3.611

Ujoh, F., Igbawua, T., & Ogidi, P. M. (2019). Suitability mapping for rice cultivation in Benue State, Nigeria using satellite data. *Geo-Spatial Information Science*. 22, 332-344. Doi:10.1080/10095020.2019.1637075

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

On the Influence of the Number and Location of Elliptical Inclusions on the Deformation Process of a Cylindrical Shell With a Circular Hole

Eteri HART [1*]

ORCID 1: 0000-0002-6075-2269
[1]Prof. Dr. Sci. (Phys.-Math.), Professor of the Department of Theoretical and Computer Mechanics, Oles Honchar Dnipro National University, Dnipro, Ukraine.
hart@ua.fm (Responsible Author)

Oleksandr SHEBANOV [2]

ORCID 2: 0009-0006-0517-9654
[2]PhD Student, Oles Honchar Dnipro National University, Dnipro, Ukraine.
alexander.shebanov@gmail.com

Abstract

This study investigates the stress-strain state of a thin-walled cylindrical shell containing a small circular hole surrounded by several elliptical inclusions of different materials. Three configurations of inclusion arrangement relative to the hole are considered: vertical, horizontal, and diagonal. A finite element analysis was performed to evaluate the influence of the distance between the hole and the inclusions, their spatial arrangement, and material properties on the stress concentration factor (SCF). The results were compared with corresponding data for plates. The analysis of the conducted studies shows that for inclusions harder than the shell material, a horizontal arrangement reduces the SCF by approximately 36%, while for softer inclusions, a vertical arrangement reduces the SCF by approximately 20%. Furthermore, decreasing the distance between the hole and the inclusions leads to a decrease in stress concentration, with the most favorable configuration observed at the closest distance for horizontally positioned hard inclusions.

Keywords: Cylindrical shell, circular hole, elliptical inclusions, stress concentration factor, finite element method.

1. Introduction

Thin-walled structural elements such as shells and plates are widely used in aerospace, aviation, energy and civil engineering, architecture, and construction. Structural and technological requirements often result in structural inhomogeneities in the form of holes and inclusions, which inevitably disrupt the material's continuity (Avdonin, 1969). Such inhomogeneities lead to stress concentrations and influence the deformation and failure processes of the system (Savin, 1968). Therefore, accounting for the influence of local stress concentrators and finding ways to reduce stress concentrations in thin-walled structures remain important problems in solid mechanics and architectural sciences (Gudramovich et al., 2017). Numerical methods, particularly the finite element method, provide effective tools for solving such problems (Zienkiewicz et al., 2014).

Numerous studies have been devoted to the study of the stress-strain state of thin-walled shells with openings, among which the seminal work (Guz et al., 1980) deserves special mention. The problem of reducing stress concentration is extremely pressing. Among modern studies in this area, we note the work (Hart & Hudramovich, 2021), which proposes an effective scheme of variational-grid methods for solving a wide class of problems with structural inhomogeneities.

This scheme makes it possible to significantly accelerate the convergence of the numerical finite element method. In the work (Hudramovich et al., 2024), the possibility of using a radially inhomogeneous inclusion made of a functionally graded material around a hole is considered, which significantly (by 56%) reduces the local stress concentration. In the work of the authors (Hart & Shebanov, 2024), the idea of using hard elliptical inclusions at a certain distance from the hole was proposed, which led to the effect of reducing the stress concentration. This work is a continuation of the authors' research on the selection of rational parameters of inclusions in a thin-walled cylindrical shell with a small hole.

2. Materials and Methods

Let us consider the stress-strain state of thin-walled elastic homogeneous cylindrical shells of thickness h, radius R, and length H. The shells contain a small through circular hole of radius r, around which two (or four) identical elliptical inclusions are symmetrically located, each with a major semiaxis a and a minor semiaxis b. The centers of the inclusions are located at a distance l from the center of the hole ((Figure 1). The shell is subjected to a uniaxial uniform tensile load p.

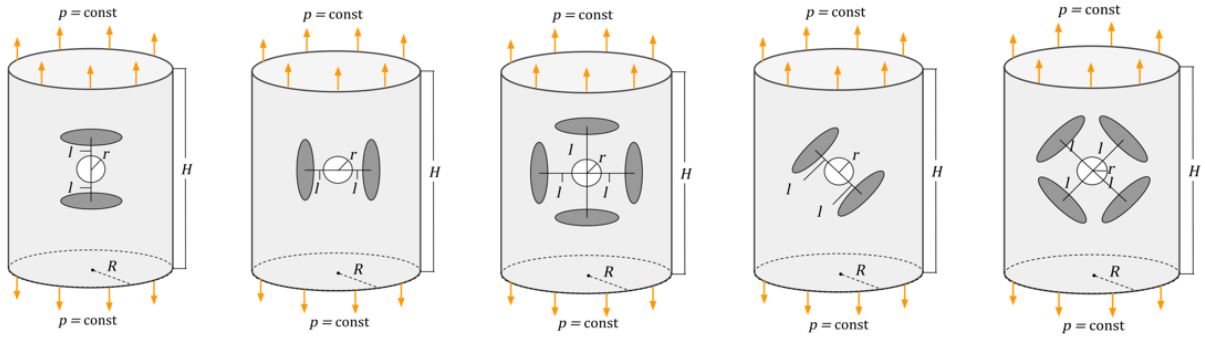


Figure 1. Geometry and loading schemas

The proposed configurations allow us to study the influence of the orientation and number of inclusions on the stress distribution around a circular hole in the shell.

In the variational formulation, the problem of studying the stress-strain state of a thin-walled, non-uniform cylindrical shell is reduced to minimizing the functional of the system's total potential energy. In the current study, this problem will be solved using the finite element method.

The results are obtained for the cylindrical shell with the following parameters: R=0.3m, H=0.8m, h=0.005m, r=0.02m. The half-axes of the elliptical inclusions are a=0.04m, b=0.02m. Two types of the materials with such moduli of elasticity E_i and Poisson's ratio μ_i were used: E_1=70 GPa, μ_1=0.3, E_2=210 GPa, and μ_2=0.33 with corresponding strength limit and offset yield limit: σ_u=470 MPa, $\sigma_{0.2}$=415 MPa and σ_u=720 MPa, $\sigma_{0.2}$=620 MPa. The choice of materials is conditional. The external tensile load at the ends of the shell is p=10 MPa.

To simplify the analysis, the relative inclusion stiffness factor is introduced: $k = E_{inc} / E_{shell}$, where E_{inc} is the modulus of elasticity of the inclusion and E_{shell} is the modulus of elasticity of the shell material. We consider the cases when $k > 1$ ("hard" inclusion) and $k < 1$ ("soft" inclusion).

The calculations were carried out for a shell containing two and four identical inclusions, symmetrically located at different distances l from the center of the circular hole to the geometric center of the elliptical inclusion (l = 8r; 5r; 3r; 2.5r).

3. Findings and Discussion

For all studied inclusion arrangements (Figure 1), stress and strain intensity fields were found, and the magnitude of the SCF was determined. Figures 2–6 show the results of the studies for hard and soft inclusions.

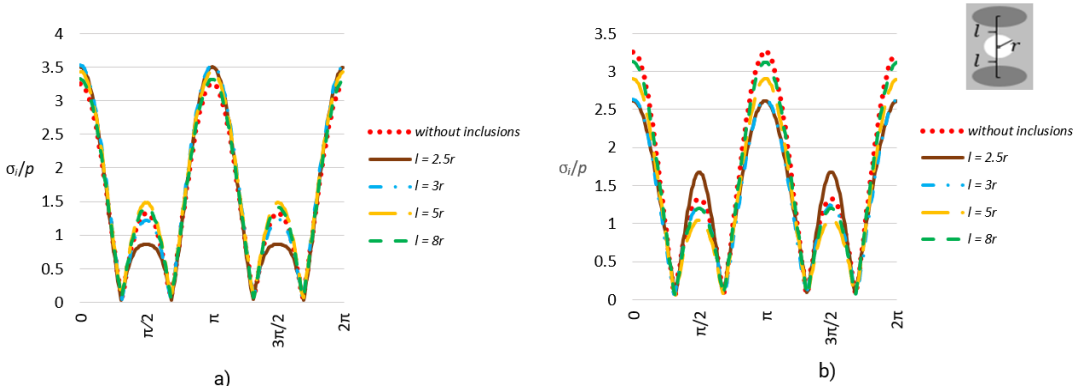


Figure 2. Distribution of the relative stress intensity σ_i/p along the contour of the hole for the case of two vertically located elliptical inclusions: k > 1 (a); k < 1 (b)

Figure 2 shows the variation of the normalized circumferential stress σ_i/p along the contour of a circular hole. Figure 2a corresponds to the case with two hard, vertically positioned inclusions (k > 1), while Figure 2b corresponds to the case with softer inclusions (k < 1). According to the figure, the use of hard inclusions does not reduce the stress concentration factor (SCF), but in the case of soft inclusions, it decreases when the inclusions are located sufficiently close to the hole.

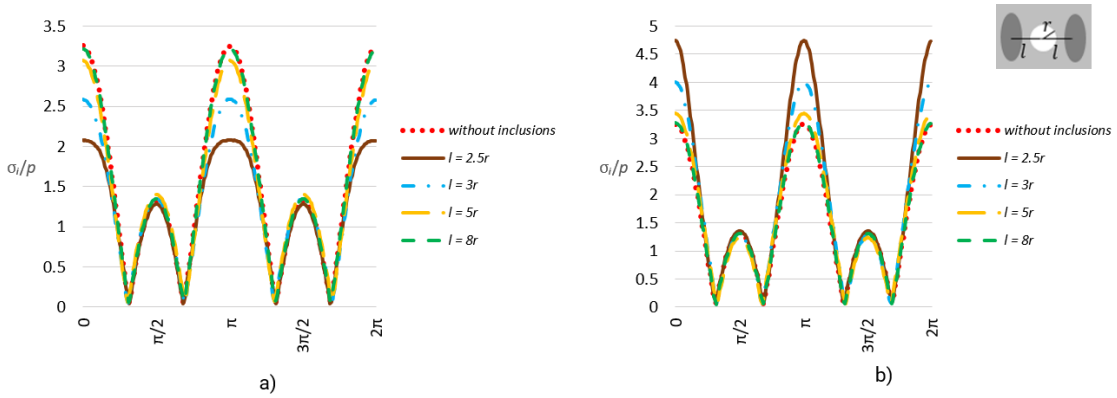


Figure 3. Distribution of the relative stress intensity σ_i/p along the contour of the hole for the case of two horizontally located elliptical inclusions: k > 1 (a); k < 1 (b)

Figure 3 presents the σ_i/p distribution in the circumferential direction along the hole contour for two horizontal inclusions. In the case of hard inclusions, the SCF decreases significantly at relatively close distances from the hole, whereas the use of soft inclusions does not lead to a decrease in the SCF.

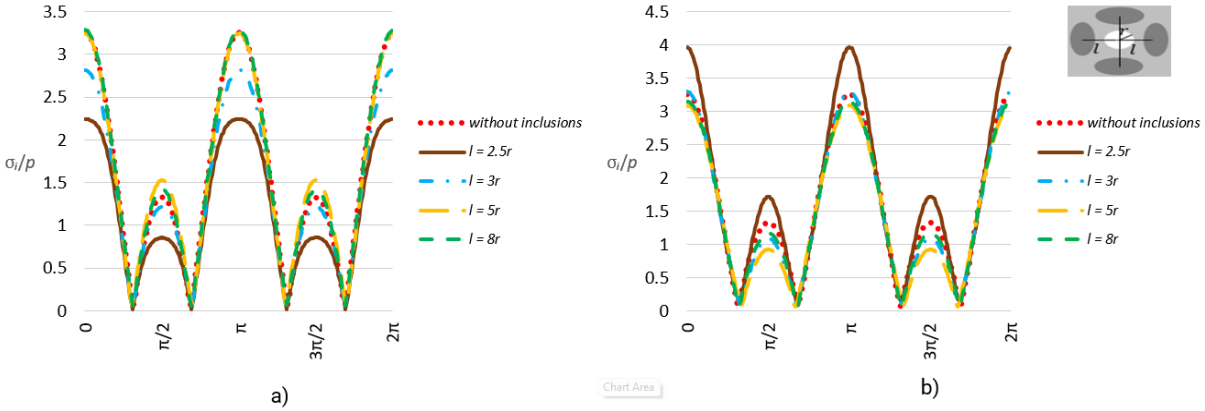


Figure 4. Distribution of the relative stress intensity σ_i/p along the contour of the hole for the case of four inclusions located along *Ox* and *Oy* axes: k > 1 (a); k < 1 (b)

Figure 4 presents stress distribution σ_i/p along the hole contour for the case of four inclusions positioned around the hole, symmetrically relative to the x- and y-coordinate axes. As in the previous configuration, placing hard inclusions closer to the hole significantly reduces the stress concentration. Using soft inclusions, however, does not significantly reduce the SCF.

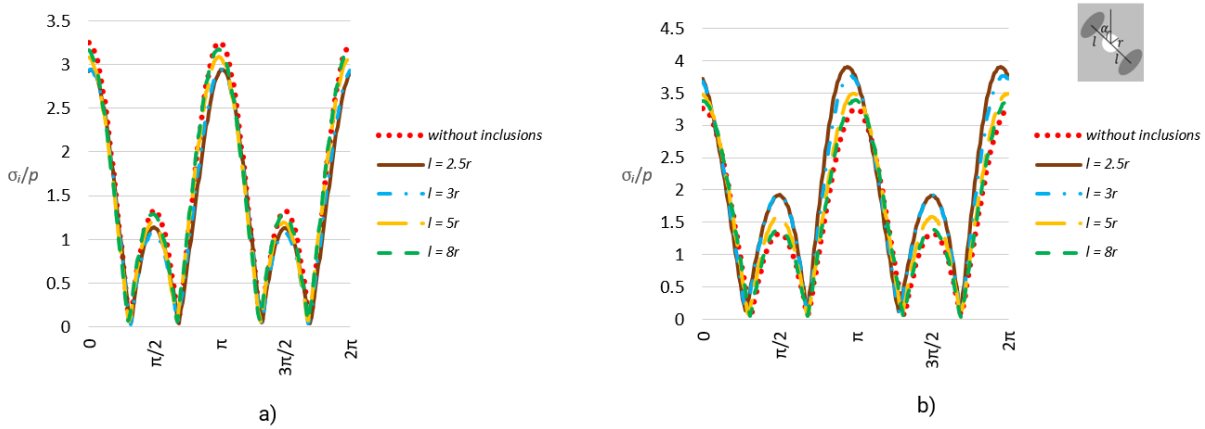


Figure 5. Distribution of the relative stress intensity σ_i/p along the contour of the hole for the case of two diagonally located elliptical inclusions: k > 1 (a); k < 1 (b)

Figure 5 shows the stress distribution σ_i/p along the hole contour for two diagonal inclusions. Here, too, a decrease in SCF is observed for hard inclusions and an increase for soft inclusions. However, a mechanical effect is also observed: as two hard diagonal inclusions approach the hole, the stress concentration zones shift in the direction opposite to the inclusion's location (to the right in the

figure). When using soft inclusions, a mechanical "shear effect" is also observed, but the stress concentration zones shift in the opposite direction (to the left in the figure).

Figure 6 shows the stress distribution σ_i/p along the hole contour for four diagonal inclusions. In this case, it is also observed that the use of hard inclusions reduces the SCF, while the use of soft inclusions increases the SCF.

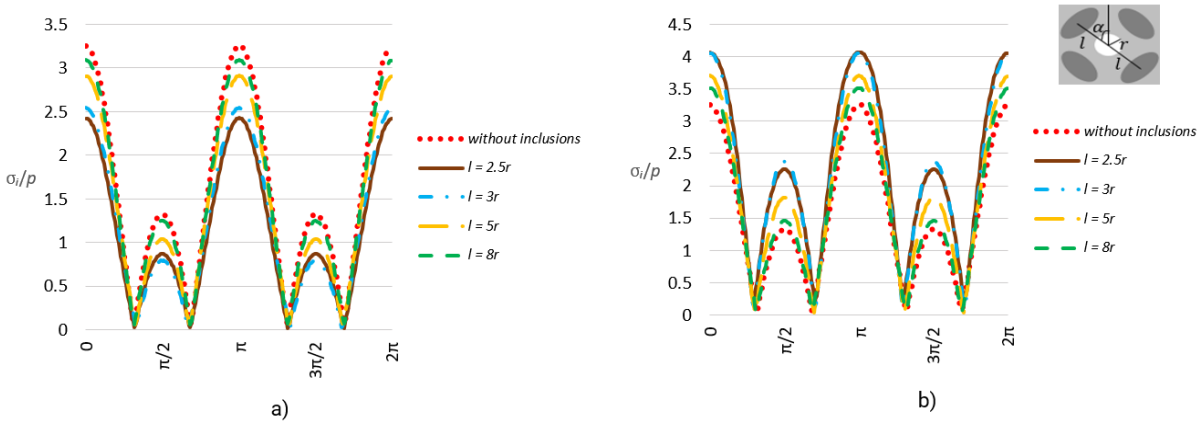


Figure 6. Distribution of the relative stress intensity σ_i/p along the contour of the hole for the case of four diagonally inclusions : k > 1 (a); k < 1 (b)

As an illustration of the best result from the options considered, we present the data in the Table 1.

Table 1. Stress concentration factor in a cylindrical shell with two horizontally located "hard" and "soft" inclusions

Problem / Distance, *l*	*k* > 1		*k* < 1	
	SCF	**δ, %**	**SCF**	**δ, %**
8*r*	3,22	-1,1	3,28	+0,8
5*r*	3,07	-5,5	3,45	+6,1
3*r*	2,59	-20,4	4,01	+23,2
2,5*r*	**2,08**	-36,1	4,74	+45,8

Here, δ is the deviation of the SCF from the corresponding value for the shell without inclusions (SCF=3.25 (Guz et al., 1980)).

The best result here is observed in the case of two "hard" inclusions at l=2.5r. The reduction in SCF the compared to the shell without inclusions is observed here by 36%.

ii. Conclusion and Recommendations

Among the studied configurations of elliptical inclusions surrounding a circular hole in a cylindrical shell, the horizontal arrangement of "hard" inclusions (k > 1) proved to be the most effective in reducing the stress concentration factor (SCF), resulting in a reduction of approximately 36% compared to a shell without inclusions. For "soft" inclusions, the vertical arrangement proved to be the most effective, providing a SCF reduction of approximately 20%. The analysis revealed a pronounced mechanical effect: as two "hard" diagonal inclusions approach the hole, the stress concentration zones shift in the direction opposite to the inclusion position (i.e., clockwise). A similar "shear effect" was also observed when using "soft" inclusions; however, in this case, the shift in the stress concentration zones occurs in the opposite direction (counterclockwise). This mechanical effect is qualitatively consistent with a similar phenomenon observed for a plate.

A promising direction for further research is to determine rational inclusion parameters for other hole configurations, taking into account their impact on reducing the SCF. This approach has significant practical implications for improving the design processes and optimizing components of modern engineering structures, ensuring increased strength, durability, and operational efficiency.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. This work was supported by ongoing institutional funding. No additional grants to carry out or direct this particular research were obtained. All authors contributed equally to the article. The authors declare that they have no conflicts of interest.

References

Avdonin, A. S. (1969). *Applied Methods for Calculating Shells and Thin-Walled Structures.* Moscow: Mashinostroenie (in Russian).

Gudramovich, V. S., Gart, E. L. & Strunin, K. A. (2017). Modeling of the behavior of plane-deformable elastic media with elongated elliptic and rectangular inclusions. *Materials Science*, 52(6), 768–774. https://doi.org/10.1007/s11003-017-0020-z

Guz, A. N., Chernyshenko, I. S., Chekhov, Val. N., Chekhov, Vik. N. & Shnerenko, K. I. (1980). *Theory of Thin Shells Weakened by Holes*. Kyiv: Naukova dumka (in Russian).

Hart, E. L. & Hudramovich, V. S. (2021). Projection-iterative schemes for the implementation of variational-grid methods in the problems of elastoplastic deformation of inhomogeneous thin-walled structures. *Journal of Mathematical Sciences*, 254(1), 21–38. https://doi.org/10.1007/s10958-021-05285-7

Hart, E. L. & Shebanov, O. D. (2024). Stress concentration around a circular hole in a cylindrical shell in the presence of surrounding elliptical inclusions. *Problems in Computational*

Mechanics and Strength of Structures, 38, 36–50. https://doi.org/10.15421/4224103 (in Ukrainian).

Hudramovich, V. S., Hart, E. L. & Terokhin, B. I. (2024). Stress concentration around a circular hole in thin plates and cylindrical shells with a radially inhomogeneous inclusion. *In Selected Problems of Solid Mechanics and Solving Methods. Advanced Structured Materials.* Collected work, Chapter 18, 204, 249–264. Cham: Springer. https://doi.org/10.1007/978-3-031-54063-9_18

Savin, G. N. (1968). *Distribution of Stresses Around the Holes.* Kyiv: Naukova dumka (in Russian).

Zienkiewicz, O. C., Taylor, R. L. & Fox, D. D. (2014). *The Finite Element Method for Solid and Structural Mechanics.* Amsterdam: Elsevier. Access Address: https://www.sciencedirect.com/book/9781856176347/the-finite-element-method-for-solid-and-structural-mechanics

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Emerging AI Regimes and Contemporary Filmmaking in Nigeria: Governance, Practice, and Creative Futures

Rotimi-Williams BELLO [1*]

ORCID 1: 0000-0002-8121-2712
[1] Dr., Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
Dr., Department of Mathematics and Computer Science, University of Africa, Toru-Orua, Nigeria
sirbrw@yahoo.com **(**Responsible Author)

Roseline Oluwaseun OGUNDOKUN[2]

ORCID 2: 0000-0002-2592-2824
[2] Dr., Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
ogundokunroseline1@gmail.com

Pius A. OWOLAWI [3]

ORCID 3: 0000-0002-5781-5054
[3] Prof., Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
owolawipa@tut.ac.za

Etienne A. van WYK[4]

ORCID: 0000-0002-0436-2741
[4] Dr., Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
vanwykea@tut.ac.za

Chunling TU[5]

ORCID 5: 0000-0003-2791-020X
[5] Prof., Department of Computer Systems Engineering, Tshwane University of Technology, South Africa
duc@tut.ac.za

Odunayo IMORU[6]

ORCID 6: 0000-0002-6412-4905
[6] Dr., School for Continuing Education, Red River College Polytechnic, Winnipeg, Manitoba, Canada
aymorus@gmail.com

Abstract

Filmmaking is rapidly transforming by Artificial Intelligence (AI) across the globe, with Nigeria's vibrant film industry (i.e. Nollywood) emerging as an adopter and a contested site for technological experimentation. How technological, institutional, and regulatory frameworks as emerging AI regimes are reforming creative practices and industry structures in Nigeria is examined in this paper. Also, the integration of AI tools was explored in this paper across pre-production, production, post-production, and distribution by situating Nollywood within global discourses of platform capitalism and algorithmic governance. The paper highlights several case studies such as AI-enabled editing, subtitling, visual effects, and distribution on digital platforms. It addresses the challenges in governance related to intellectual property, labour, and cultural representation. The paper, by drawing on a multi-level framework of AI regimes, emphasizes that in time to come, Nigerian filmmaking will depend on innovation that is balanced with protections for creative labour and cultural integrity. The paper concludes by recommending policies and practices for building a comprehensive, sustainable AI-enabled film ecosystem in Nigeria and Africa in general.

Keywords: Artificial intelligence, filmmaking**,** Nigeria, Nollywood, regime

1. Introduction

Nollywood, as condensed in global discourse is a contemporary filmmaking industry in Nigeria, and the second largest film industry in the world by output, contributing to the world film industry with over 2,000 films produced annually [1, 2]. Known for its resourcefulness, cultural vibrancy, and speed, Nollywood operation for a long time has been within informal economies and decentralized production networks [3, 4]. Be that as it may, in the past decade, film industry in Nigeria has gradually embroiled with global digital infrastructures, particularly as international streaming platforms, such as Netflix, Showmax, Amazon Prime, and regional operators, such as iROKOtv, and Africa Magic incorporate Nigerian content into global circuits [5-7].

Artificial Intelligence (AI) plays vital roles in this transformation [8]. AI encompasses a wide range of technologies that enable automated or semi-automated decision-making, creative augmentation, and pattern recognition [9]. Recommendation algorithms are now underpinned by AI on streaming platforms, moreover, post-production tools (noise reduction and automated rotoscoping) are powered by AI, and multilingual subtitling is supported by AI for linguistically diverse Nigerian audiences [10]. Beyond tools, AI is gradually building business models and audience engagement strategies.

This study explores emerging AI regime in Nigerian filmmaking. By AI regime, we refer not only to the technologies but also to the market logics, social practices, and governance structures that mediate the means for deploying AI. This framing underscores AI as not only a neutral tool but also as part of a sociotechnical assemblage that redistributes labor, power, and cultural expression. We based the study on three interrelated research questions:

(1) What method is used for integration of AI tools into filmmaking practices in Nigeria?
(2) What governance challenges, labor dynamics, and power relations accompany these integrations?
(3) What industry, community, and policy strategies could allow inclusive and culture-driven AI adoption in Nigerian film?

The study combines conceptual frameworks and analysis, literature review, methodology, and empirical illustrations drawn from trade publications, industry reports, and case studies. The study further situates experience of Nigerians within global shifts, while foregrounding the local dynamics of multilingualism, informality, and regulatory uncertainty. The bone of contention is the advantages and the disadvantages in adopting AI, where advantages bring creative opportunities, and disadvantages bring serious risks. The trajectory of AI adoption by Nollywood will depend on context-specific practices and proactive governance.

1.1. Conceptual Framework: AI Regimes and Film Ecologies

The work in science and technology studies, and political economy were extended by the notion of AI regimes, this is because they both view technologies as tools embedded in several aspects of governance, labor, and purpose driven, and not as isolated tools [11-13]. According to [14], components of the AI Regimes in Film are (1) Technological affordances, which are the actual AI capabilities, such as script generation, automated subtitling, and GAN-based visual effects. (2)

Institutional actors, which include filmmakers, professional associations, post-production companies, global platforms, and government regulators. (3) Regulatory frameworks, which involve film policy initiatives, data protection regimes, and copyright law. (4) Market logics, which also involve subscription-driven models, recommendation systems, and monetization incentives that influence storytelling choices. (5) Cultural contexts, which include the multilingual, multicultural, and diasporic nature of Nigerian audiences.

Filmmaking in Nigeria can be referred to as an ecology, where there is an intertwinement of production, distribution, and reception [15]. The interventions of AI ripple across this ecology, in that, linguistic representation is affected by the automated subtitling; distribution visibility is shaped by recommendation algorithms; and labor hierarchies are altered by AI-driven editing. The application of AI regime lens enables people to see the adoption of AI as not only about technical efficiency but also about governance, who decides the way and manner the tools are deployed, who benefits, and who do not benefit [16].

1.2. Strands of Literature on Film and AI

There are three strands into which literature on film and AI can be grouped; they are (1) Global perspectives on AI in creative industries. (2) AI in film and media. (3) African and Nigerian contexts.

(1) Global perspectives on AI in creative industries: These include (a) automation versus augmentation, which involves the debate among scholars whether creative labor is displaced by AI or human creativity is enhanced, (b) platform capitalism, this is evident in the work of researchers like Srnicek [17], where it was showed the influence of platforms on centralizing control and monetizing data, thereby raising concerns about cultural homogenization, (c) algorithmic governance, which is evident in studies that underscore the importance of recommendation systems in shaping cultural consumption and audience exposure.

(2) AI in Film and Media: How AI is used in audience analytics, script analysis, editing, dubbing, and CGI is documented by research [18]. Hollywood has used AI for box office performance prediction and trailer generation [19]. Asians are taking advantage of AI-assisted dubbing and translation for cross-border circulation [20].

(3) African and Nigerian Contexts: Informality, rapid production, and local-global dynamics are emphasized by literature on Nollywood [21]. AI in Nigeria is directly addressed by few studies; however, emerging reports such as UNESCO and local press show that AI-based editing, automated subtitling, and low-cost VFX are gradually adopted by filmmakers. A gap is showed through policy analyses that film and tech policies in Nigeria rarely address AI explicitly, leaving regulation ad hoc [22, 23].

Global optimism is revealed by the literature about potential of AI and concerns about cultural homogenization and labor precarity [24]. For Nollywood, there is an intersection of these debates and longstanding issues of linguistic diversity, resource constraints, and global marginalization.

2. Methodology

To analyze the intersection of emerging AI regimes and contemporary filmmaking in Nigeria, a designed qualitative review and interpretive methodology are adopted by this study. To capture both governance perspectives and creative practices, the framework of the study combines systematic literature analysis, industry mapping, and case study evaluation. Fig. 1 shows a conceptual framework diagram illustrating governance, practice, and creative futures.

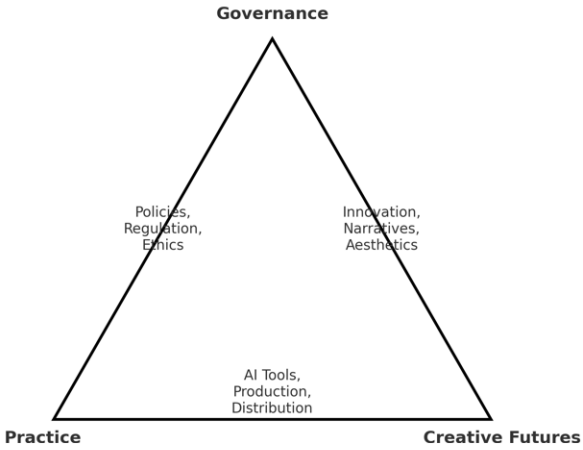


Figure 1. A conceptual framework diagram showing governance, practice, and creative futures

2.1. Research Design

The research employs a multi-layered qualitative approach founded upon policy and governance analysis, such as government policy analysis, regulatory discourse analysis, and institutional document analysis shaping AI adoption in Nigeria. Industry practice analysis, such as examining how AI is incorporated into filmmaking practice by creative practitioners, studios, and filmmakers, forms part of the research design. Furthermore, the research design takes a future orientation, which is by combining insights on how stories, aesthetics, and future practice are redrawn by AI in Nollywood and surrounding creative industries.

2.2. Data Sources

The data used in this study is got from the following sources:

(a) Academic literature on AI in African film studies, creative industries, and digital governance in peer-reviewed journal articles and conference papers.
(b) Policy and institutional reports like National Film and Video Censors Board (NFVCB) guidelines, Nigerian National Artificial Intelligence Policy (2023 draft), and UNESCO/UNCTAD digital economies reports.
(c) Industry journalism and newspaper coverage, including interviews with Nigerian producers, trade publications (Variety, The Africa Report), and press releases from Nollywood production companies adopting AI technology.

(d) Case studies, a number of which are selected films and production processes in which AI tools, including deepfake technology, Computer-Generated Imagery (CGI), scriptwriting, and AI-driven editing have been utilized or discussed within the Nigerian context.

2.3. Sampling and Selection

Key texts and cases most relevant to AI and filmmaking in Nigeria were selected by using purposive sampling. Selection criteria included evidence of Nigerian or African contextual relevance, direct focus on creative technologies enabled by AI, and representation of both practitioner voices and governance frameworks.

2.4. Analytical Framework

A comparative thematic analysis structured around three dimensions was employed by the study:

(a) Governance, including ethics, regulation, intellectual property, and labor implications of AI in Nigeria.
(b) Practice, including actual use of AI in Nollywood for production, distribution, and audience engagement.
(c) Creative futures, including speculative and innovative scenarios for cinema in Nigeria, considering global AI transformations.

2.5. Validity and Limitations

For enhancing validity, results were compared across practitioner interviews, policy documents, and secondary texts. Nevertheless, there had been certain limitations which the research was aware of, specifically lack or shortage of peer-reviewed Nigerian case studies on AI filmmaking. Promotional discourses, as potentially witnessed through dependence on media accounts and industry reports. The currency of published sources may be outpaced by rapid technological change. By combining creative foresight, industry practice mapping, and governance analysis, a comprehensive lens was offered by this methodology for understanding how contemporary filmmaking in Nigeria is being reshaped by emerging AI regimes.

3. Case Studies

In this section, four case studies were conducted, including Case A: AI in post-production and VFX workflows, Case B: Algorithmic distribution and platform economies, Case C: AI-assisted subtitling and localization, and Case D: AI in scriptwriting and pre-production.

3.1. Case A: AI in Post-Production and VFX Workflows

Post-production houses in Nigeria are exploring AI-based tools such as Topaz Video Enhance AI (for upscaling) and DaVinci Resolve's AI-driven noise reduction. Both time and labor costs are reduced by these tools, allowing more refined visuals at lower budgets. However, the need for entry-level assistants (who once handled manual frame cleaning) is also reduced by these tools. Fig. 2 shows AI in post-production and VFX workflows.

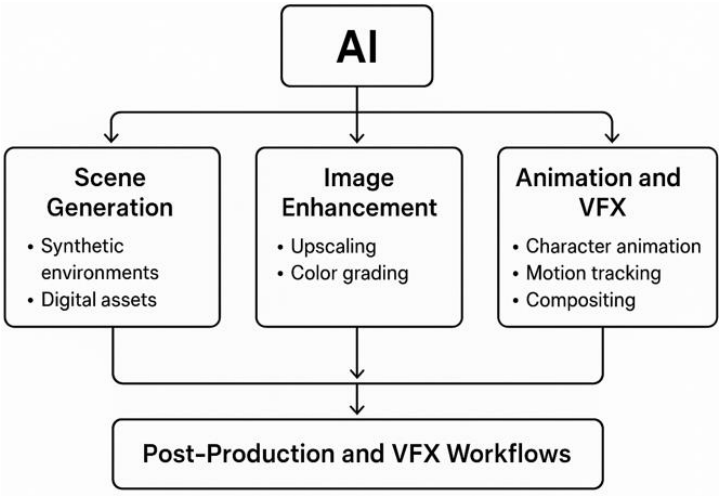


Figure 2. AI in post-production and VFX workflows

3.2 Case B: Algorithmic Distribution and Platform Economies

AI-driven recommendation systems are used by streaming platforms like Showmax and Netflix. This raises visibility challenges for Nigerian films, such as local films being relegated behind global blockbuster by algorithmic bias. Moreover, diasporic audiences who are seeking African content are depending on AI for targeted recommendations. While some voices are amplified by the platform regime, others are marginalized. Fig. 3 shows algorithmic distribution and platform economies.

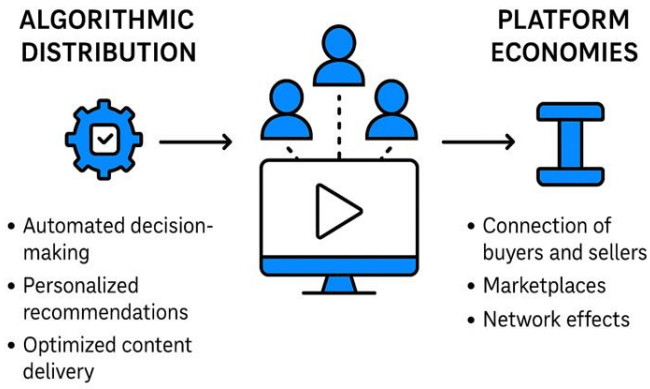


Figure 3. Algorithmic distribution and platform economies

3.3 Case C: AI-Assisted Subtitling and Localization

Multilingual reality in Nigeria, which include English, Pidgin, Hausa, Yoruba, and Igbo makes subtitling important. Multilingual versions are generated by increasingly use of AI-based speech-to-text and translation tools, such as Google AutoML, and YouTube subtitles. While the use of AI for subtitling expands reach, reception is undermined by quality issues, such as mistranslation, and loss of cultural nuance. This limitation makes traditional, human-in-the-loop subtitling essential. Fig. 4 shows AI-assisted subtitling and localization.

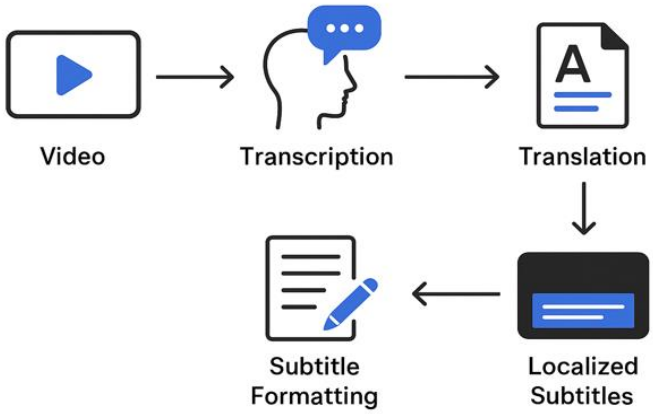


Figure 4. AI-assisted subtitling and localization

3.4. Case D: AI in Scriptwriting and Pre-production

AI text generators, such as ChatGPT-like tools are beginning to be explored by some Nigerian writers for various assignments such as brainstorming dialogue or story arcs. This practice raises questions about authorship, novelty, and intellectual property. While homogenization is an issue to writers, they acknowledge utility of AI for speeding up drafts. Fig. 5 shows AI in scriptwriting and pre-production.

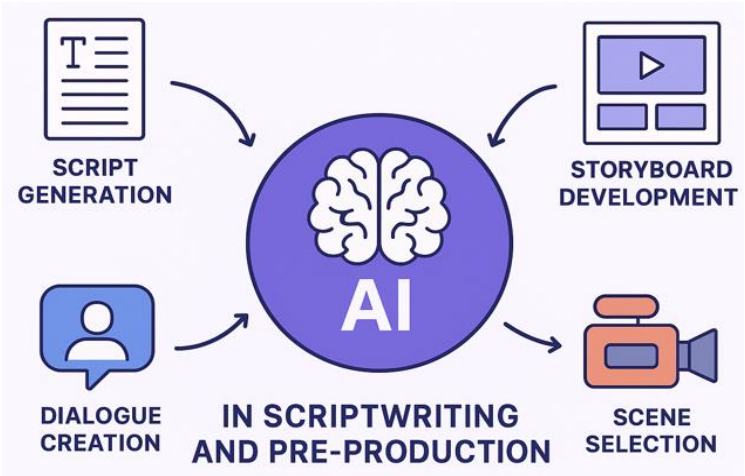


Figure 5. AI in scriptwriting and pre-production

4. Analysis: Themes and Tensions

4.1. Labor Reconfiguration

While certain manual roles such as assistant editors, and translators are displaced by AI tools, new oversight roles such as quality controllers, and AI tool specialists are also created. The risk is that new opportunities are outpaced by job losses, especially for young entrants.

4.2. Creative Affordances

Ambitious projects like CGI, and high-quality editing are attempted by resource-constrained filmmakers using AI. Aesthetic horizons may be expanded by this, but also risk overreliance on pre-trained, globally oriented models that may not reflect local textures.

4.3. Platform Power and Algorithmic Gatekeeping

Visibility is controlled by streaming platforms through algorithms, privileging content optimized for engagement. The pressure faced by filmmakers in Nigeria to adapt to global genres, thumbnails, and metadata strategies undermines experimental or culturally specific storytelling.

4.4. Governance Gaps

There are no clear policies on AI in Nigerian creative industries. There is silence on AI generated content by the intellectual property laws. Filmmakers are exposed to exploitation by global tech firms due to weakness of data protection.

4.5. Cultural Integrity vs. Marketization

Globally, Nigerian cinema is expanded through localization enabled by AI but risks flattening linguistic and cultural subtlety. Hybrid workflows that combine AI speed with human oversight are required by cultural pluralism.

5. Recommendations

For policymakers, it is recommended that AI is explicitly integrated into film policy frameworks in Nigeria. Developing guidelines for copyright and IP attribution in works assisted by AI is also recommended. Moreover, it is recommended to the policymakers to support training programs and capacity building for AI in creative industries. For industry, adoption of hybrid workflows such as AI + human oversight is recommended to balance efficiency with quality. In addition, negotiation of the contracts underpinning the platforms to provide fair visibility for Nigerian films is recommended. In addition, establishment of collective bargaining instruments for safeguarding creative labor is recommended. For practitioners, testing of AI as an augmentative tool, but not a replacement, is recommended. In addition, practitioners are encouraged to establish provenance and lock in intellectual rights by documenting workflows. Finally, for ethical AI adoption, they should share communal knowledge about best practices.

6. Conclusion

The governance, practice, and creative futures of emerging AI regimes and contemporary filmmaking in Nigeria have been presented in this study. AI integration into filmmaking in Nigeria

is inevitable but uneven. While creative possibilities are opened by AI, it also puts labor, cultural nuance, and sovereignty at risk. By AI regime concept, it is obvious that adoption of AI is not only a technical issue but a governance challenge that requires coordinated action from those who make policies, industry leaders, and practitioners (creative communities). For Nollywood, the task is to harness the potential of AI while preserving cultural identity and equitable labor practices. If handled effectively, AI could help cinema in Nigeria expand its global influence while deepening its cultural roots. However, if left unregulated, it risks aggravating inequalities and cultural homogenization. Governance as much as innovation will determine the future of Nigerian film in the era of AI.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. The authors declare that they have no conflicts of interest.

References

Agina, A. (2022). Nigerian Film Audiences on the Internet: Influences, Preferences and Contentions. *In Routledge Handbook of African Popular Culture*. 237-259. Taylor & Francis.

Arrojo, M. J. (2024, September). Impact of Artificial Intelligence in the Audiovisual Industry. A Taxonomy of Uses and Applications. *In International Conference on Communication and Applied Technologies* (pp. 183-194). Singapore: Springer Nature Singapore.

Anantrasirichai, N., & Bull, D. (2022). Artificial intelligence in the creative industries: a review. *Artificial intelligence review*, 55(1), 589-656.

Bello, R. W., & Mohamed, A. S. A. (2018). Impact of technology on traditional museum collection storage and management. *International Journal of Computer Science and Mobile Computing*, 7(11), 46-51.

Bassey, B. E. (2025). Popular Culture and the Nigerian Filmic Space: The Efficacy-Entertainment Braid. *Creative Saplings*, 4(8), 48-70.

Baños, R., & Díaz-Cintas, J. (2024). Exploring new forms of audiovisual translation in the age of digital media: cybersubtitling and cyberdubbing. *The Translator*, 30(1), 129-144.

Chauhan, M., & Perera, I. M. (2024). Artificial intelligence: promises, perils—and political economy. *French Politics*, 22(2), 152-163.

Dixon, R. B. L. (2023). A principled governance for emerging AI regimes: lessons from China, the European Union, and the United States. *AI and Ethics*, 3(3), 793-810.

Ernest-Samuel, G. C., & Uduma, N. E. (2019). From informality to New Nollywood: Implications for the audience. *In Nollywood in glocal perspective* (pp. 45-66). Cham: Springer International Publishing.

Fagbile, Y. A. (2025). Nollywood, Film Streaming, and Ethical Practices. *Integral Research*, 2(3), 177-189.

Julius-Adeoye, R. J., Omoruyi, A. E., Babarinde, D. M., & Akpor-Robaro, M. O. (2024). Nigerian Film Industry's Socio-Economic Context: Different Waves of Feature Film Making in Nigeria From 1970 to 2024. *Journal of African Film & Diaspora Studies* (JAFDIS), 7(2).

Kang, J. Y. (2024). Generative AI in film production: Analyzing the active role of AI in creative and decision-making processes. *Journal of Digital Contents Society*, *25*(10), 3041-3052.

Madongo, C. T., Tang, Z., & Hassan, J. (2024). Movie box-office revenue prediction model by mining deep features from trailers using recurrent neural networks. *J. Adv. Inf. Technol*, 15(6), 764-783.

Mellouli, S., Janssen, M., & Ojo, A. (2024). Introduction to the issue on artificial intelligence in the public sector: risks and benefits of AI for governments. *Digital Government: Research and Practice*, 5(1), 1-6.

Madichie, N. O., Ajakaiye, B. O., & Ratten, V. (2019). The impact of new media (digital) and globalisation on Nollywood. *In Digital Entrepreneurship in Sub-Saharan Africa: Challenges, Opportunities and Prospects* (pp. 89-121). Cham: Springer International Publishing.

Oguamanam, C. (2020). Nollywood phenomenon: The Nollywood phenomenon: Innovation, openness, and technological opportunism in the modeling of successful African entrepreneurship. *The Journal of World Intellectual Property*, 23(3-4), 518-545.

Obiora, A. V., & Adikuru, C. C. (2024). Emerging Artificial Intelligence Techniques in the Production of Jagun Jagun Movie. *Social Science Research*, 10(3), 13-30.

Simon, G. I. (2024). 'They are now pocket videos, not home videos': Streaming and reconfiguration of video consumption in Nigeria. *International Journal of Cultural Studies*, 27(1), 82-98.

Srnicek, N. (2017). *Platform Capitalism*. Polity Press, Cambridge Malden, MA. 1-92.

Tsika, N. (2024). Nollywood internationalism: Filmic entanglements on Nigerian terrain. *Journal of African Cinemas*, 16(2-3), 169-186.

Thomas, S. (2024). AI and actors: Ethical challenges, cultural narratives and industry pathways in synthetic media performance. *Emerging Media*, 2(3), 523-546.

Verdegem, P. (2023). Critical AI studies meet critical political economy. *In Handbook of Critical Studies of Artificial Intelligence* (pp. 302-311). Edward Elgar Publishing.

Veale, M., Matus, K., & Gorwa, R. (2023). AI and global governance: Modalities, rationales, tensions. *Annual Review of Law and Social Science*, 19(1), 255-275.

Yuan, S., Huang, W. L., Chen, Z., & Yin, H. (2024). Unveiling the mediating role of cultural trade and domestic identity in Chinese consumer engagement with foreign films and TV series. *PLoS One*, 19(12), e0314416.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Examining the Sustainable Development of Shopping Malls

Chinedu OLUIGBO[1*]

ORCID 1: 0000-0001-7427-6833
[1]Arc., Niger Delta University, Faculty of Environmental Sciences, Department of Architecture, Wilberforce Island - Nigeria
chineduoluigbo@ndu.edu.ng (Responsible Author)

Uchenna EBERENDU[2]

ORCID 2: 0009-0007-6761-2262
[2]Arc., Federal Polytechnic Ekowe, School of Environmental Design and Technology, Department of Architecture, Bayelsa State - Nigeria
ueberendu@yahoo.com

Rotimi-Williams BELLO[3]

ORCID 3: 0000-0002-8121
[3]Dr., University of Africa, Faculty of Basic and Applied Sciences, Department of Mathematics and Computer Science, Toru-Orua - Nigeria
sirbrw@yahoo.com

Chidiebere MARSHALL[4]

ORCID 4: 0009-0004-8374-241X
[4]Mr., Drexel University, School of Engineering, Department of Construction Management, Pennsylvania, United States of America
chidi.marshall@drexel.edu

Abstract

The growing demand for sustainable practices in the built environment has led to the need for energy-efficient, environmentally responsive, and socially inclusive designs in commercial developments. Thereto, this study explores sustainable design features in shopping malls through a qualitative case study approach, examining four malls across diverse climatic zones: Noke Mall (Taipei, Taiwan – Humid subtropical climate), Sarit Centre (Nairobi, Kenya – Subtropical highlands climate), SPAR Port Harcourt Mall (Rivers State, Nigeria – Tropical wet climate), and Palms Shopping Mall (Lagos State, Nigeria - Tropical wet and dry climate). Data were collected through physical observations, existing architectural documentations, and synthesized based on the following themes; sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design process, and regional priority as adopted from Leadership in Energy and Environmental Design [LEED] green building rating categories. Hence, the study findings reveal a range of sustainability practices, including natural ventilation, daylighting, and flexible circulation spaces, as well as gaps such as high dependency on mechanical systems and limited water reuse strategies. The study provides evidence-based recommendations for architects, developers, and built environment professionals to enhance sustainability in mall design, balancing user experience with environmental responsibility.

Keywords: Building systems, Design features, green building, shopping malls, sustainability

1. Introduction

Shopping malls are central to modern urban life, serving as hubs for commerce, social interaction, and leisure. Beyond their commercial function, malls increasingly reflect broader societal

priorities, including sustainability, user experience, and architectural innovation. In recent years, urbanization, climate change, and environmental degradation have underscored the need for malls to integrate sustainable building systems that minimize energy and water consumption, promote waste management, and optimize indoor and outdoor environmental quality. Mall design has evolved from simple retail clusters to complex mixed-use developments that combine shopping, leisure, office, and sometimes residential spaces. These multifunctional centres aim to attract diverse users while optimizing space, energy use, and operational efficiency. The sustainability of shoping malls is influenced not only by materials and technologies but also by planning strategies, circulation design, and climate-responsive features. For instance, building orientation, natural ventilation, and daylighting strategies can reduce energy demand for lighting, heating, and cooling, while green spaces enhance the aesthetic and ecological quality of the environment (Han et al., 2019; Aktas, 2012). Despite the theoretical understanding of sustainable mall design, there remains a lack of empirical studies documenting real-life implementations across different geographic and climatic contexts. Most existing studies rely heavily on secondary data, and historical descriptions, leaving uncertainty about how sustainability principles translate into practice.

1.1. Aim of the study

This study examines four shopping malls in distinct regions — Humid subtropical climate, Subtropical highlands climate, Tropical wet, and dry climates in view to extrapolate sustainable design features.

1.2. Objectives of the study

The objectives of this study are to:

i. Identify sustainable features of each case study.

ii. Explore the design and operational features of selected shopping malls with respect to key sustainable systems.

iii. Provide recommendations for future malls that balance environmental responsibility with user experience and commercial viability.

Thus, this study contributes to the innovative sustainable solutions in the built environment sub-theme, offering practical insights for architects, developers, engineers, and urban planners.

2. Literature Review

2.1. Mall patterns and functional design

Shopping malls have historically followed several functional patterns, including dumbbell, strip, high-rise, and cluster types (Ali, 2015; Tiwari & Abraham, 2010). Cluster-type layouts are particularly suited to community-centered malls, where multiple units are organized around a shared open space. Contemporary design trends often combine these patterns to maximize circulation, accessibility, and multifunctionality. For example, modern malls integrate retail, leisure, food courts, and office spaces, creating mixed-use environments that enhance visitor experience and generate diversified revenue streams (Heffner & Twardzik, 2015).

2.2. Sustainability in Mall Design

Sustainability has emerged as a key consideration in mall designs with strategies such as:

i. Energy-efficient systems: LED lighting, automated lighting controls, and HVAC systems optimized for local climate conditions (Aktas, 2012; Han et al., 2019).

ii. Passive environmental strategies: Natural ventilation through atria, wide corridors, and large fenestrations; daylighting via skylights and roof openings; and strategic building orientation to reduce solar gain.

iii. Water and waste management: Water-efficient plumbing, rainwater harvesting, greywater reuse, and proper waste segregation and recycling.

iv. Materials selection: Use of locally sourced, recycled, or low-embodied-energy materials to reduce carbon footprint and enhance indoor environmental quality.

Despite these recommendations in literature, empirical studies evaluating actual implementation in operational malls remain limited. Most previous work has focused on design guidelines or theoretical modeling rather than assessing real-life performance (Lorek & Spangenberg, 2014; El-Hedhli et al., 2013).

2.3. User experience and functional planning

The architectural and operational design of malls influences both shopper behavior and satisfaction. Elements such as spacious atria, clear circulation, landscape integration, and accessible amenities contribute to a positive shopping experience (Farrag et al., 2010; Teik et al., 2015). In addition, mixed-use layouts can improve dwell time and enhance commercial viability. However, emerging digital retail trends and e-commerce have challenged traditional mall formats, requiring innovative responses such as integrated entertainment zones, interactive displays, and adaptive reuse of spaces (Çakmak, 2012; Kumar & Thakur, 2014).

2.4. Green Building Certification

For buildings to be certified sustainable there are key criteria they must meet. Hence, green building certifications are used to ascertain a project's ability to showcase commitment in being environmentally responsible. Notably, Leadership in Energy and Environmental Design [LEED], and Building Research Establishment Environmental Assessment Method [BREEAM] are predominant certification systems in the world.

2.4.1. Leadership in Energy and Environmental Design (LEED)

LEED is a global sustainable building certification program developed by the non-profit U.S. Green Building Council (USGBC). It covers rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods, which is tailored towards helping building owners / operators be environmentally responsible, and ensure efficient use of resources, thereof (Green Building Facts, Retrieved 24 November 2015).

However, this study adopts LEED green buildings rating categories (themes) to explore the sustainable development of selected malls which include; sustainable sites, water efficiency,

energy and atmosphere, materials and resources, indoor environmental quality, locations and linkages, awareness and education, innovation in design, and regional priority (Green Building Facts, Retrieved 24 November 2015).

2.4.2. Categories for earning LEED credits

i. Sustainable Sites: This category takes cognizance of site selection deliverables, site analysis, development density, heat island effects, drainage systems, and efforts in managing run-offs.

ii. Water Efficiency: Keen on reducing potable water use within the building, through low-flow fixtures, water-efficient landscaping, and systems.

iii. *Energy & Atmosphere:* Awards credits for energy efficiency, use of renewable energy, and clean commissioning systems.

iv. *Materials & Resources:* Examines the use of recycled building materials / elements, green building materials, and waste management during construction and operation of buildings.

v. *Indoor Environmental Quality:* Focuses on occupant health and comfort by addressing ventilation, air quality, daylighting, views, and the use of thermal efficient materials.

vi. *Innovation:* Highlights innovative strategies and exemplary performance in existing credits.

vii. *Regional Priority:* Adds extra credit for projects that considers local environmental priorities selected by regional chapters (Green Building Facts, Retrieved 24 November 2015).

2.5. Research Gap

This study adopts a case study approach, will current observations, and photographic documentation to provide a more accurate and relatable understanding of sustainable shopping mall design. By bridging the gap between theory and practice, this research enables context-sensitive design recommendations, ensuring that future shopping malls are environmentally sustainable, commercially viable, and user-friendly.

3. Research Methods

3.1. Research design

This study adopts a qualitative research method to explore sustainable practices in shopping malls across different geographic and climatic contexts. The approach allows for in-depth, contextual analysis of architectural, operational, and environmental strategies implemented in existing malls. Thus, emphasis is placed on observation, photographic documentation, and architectural assessment.

3.1.1. Selection criteria

Four shopping malls were selected based on these criteria:

i. Accessibility for data collection
ii. Ability to meet basic functional and architectural standards of a shopping mall.
iii. Observable sustainability features – such as energy-efficient lighting, passive ventilation systems, green spaces, and climate-responsive design strategies.
iv. Different climatic and geographic contexts to allow comparative analysis of architectural features.

The selected cases include:

i. Noke Mall, Taipei, Taiwan (Humid subtropical climate)
ii. Sarit Centre, Nairobi, Kenya (Subtropical highlands climate)
iii. SPAR Port Harcourt Mall, Rivers State, Nigeria (Tropical wet climate)
iv. Palms Shopping Mall, Lagos State, Nigeria (Tropical wet and dry climate)

3.1.2. Data collection, analysis, and synthesis

The qualitative data for this study was obtained from primary and secondary sources. The primary data were obtained via physical observation for SPAR Port Harcourt Mall (Rivers State, Nigeria, and Palms Shopping Mall, Lagos, Nigeria while the secondary data were obtained from publication (websites) for Noke Mall, Taipei, Taiwan (Archidaily, 2025) and Sarit Centre, Nairobi, Kenya (Sarit centre, 2025). To synthesize the data from the selected shopping malls in view to explore how sustainable they are, the categories (themes) used by LEED was utilized viz: *Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, Innovation, and Regional Priority.*

Each case study is presented by describing the design, construction, and current operational status to avoid ambiguities about future versus completed features. More so, a narrative approach was adopted to synthesize the data encapsulated in the use of visual documentation, descriptive observation, and secondary information. Thereto, this study ensures that recommendations are evidence-based and grounded in the current state of each mall, rather than abstract theoretical expectations.

3.1.3. Ethical considerations

Permission was obtained from the mall management of the local case studies for observation, and photography. All data collection adhered to privacy and security protocols, ensuring ethical research practices.

3.2. Case Study 1 (Noke Mall, Taipei, Taiwan)

i. Mall description

Location	No. 200, Lequn 3rd Road, Zhongshan District, Taipei City, Taiwan 10491
Coordinates	$25^{0}4^{1}56^{11}$N; $121^{0}33^{1}26^{11}$E
Architect	Behet Bondzio Lin Architekten
Lead Architect	Yu-Hanv Michael Lin

Contractor	Taiwan Kumagai CO. LTD
Area	22415sqm
Stores	100
Type of Mall	Regional Mall
Category	Mixed use Architecture, Sports Architecture, and Retail
Access	Jiannan Road metro station, Wenhu line of Taipei Metro
Website	https://retail.jut.com.tw

ii. Background

Noke is a mall in the Dazhi area of Zhongshan District, Taipei, Taiwan that commenced operations on the 29th day of April, 2023. It has a total floor area of 36,300m^2 [391,000 sq ft] layered in 10 floors with 7 floors above, and 3 floors below the ground. The mall is characterized by 5 core units viz; Tsutaya Bookstore, Michelin restaurant La Vie, Apu Jan, Onibus, and Aurora Ice Rink. It is composed of 48% retail units, 34% for catering, and 18% for entertainment.

iii. Structure

The mall's structural system consists of reinforced, and pre-stressed concrete members forming the main framework, with steel trusses supporting the roof covering. Glazing and light metal cladding cover the building envelope, while tensile fabric is used for the mall canopy. Images show fenestrations allowing for daylighting.

iv. Key Materials

Concrete, steel, glass, light metal cladding, and tensile fabric



Figure 1. Exterior perspectives of Noke Mall, Taipei, Taiwan

3.3. Case Study 2: Sarit Centre, Nairobi, Kenya

i. Mall description

Location	Westlands suburbs of Nairobi, Kenya
Coordinates	$1^{0}15^{1}35^{11}$S; $36^{0}48^{1}5^{11}$E
Architect	T.S. Nandra & Associates
Lead Architect	James Kennedy
Area	46,450 sqm
Anchor Store	Uchumi Supermarket
Type of Mall	Community Mall (multi-purpose)
Category	Mixed use Architecture
Website	www.sarit.com; www.saritexpo.com

ii. Background

The centre is features a 300 seat cinema, a 140 m^2 food court and a 280 m^2 expo centre with the propensity to host over 50 stands (Sarit centre, 2025). At the time of its opening, it was the first shopping mall in East Africa and remains one of the largest in the region, hitherto.

The mall nicknamed: “A city within a city” changed shopping mall concepts in East Africa. According to the mall’s management, approximately 25,000 visitors are served daily with an approximately 5,500 car traffic frequenting daily both in the mall’s parking facilities and neighboring streets (Sarit centre, 2025).

The centre’s form is orthogonal characterized by right angles with no curves in its layout plan. This can be traced to Brent Cross Shopping Mall in London, where the inspiration to build the the local shopping mall originated. Wide walkways and aisles are provided throughout the shopping mall, giving shoppers and visitors sufficient space for movement and passing to observe things without being obstructed. The main walkways that connect the entrances to the two atriums at the centre of the mall are 4500mm to 6000mm in width, according to their positions with regard to traffic flow. This is because these are the regions that receive the highest number of traffic flow as patrons either exit from or enter into the mall before dispersing to their destinations of choice within the mall.

iii. Structure

The building is framed with reinforced and pre-stressed concrete, supported by steel roof trusses, with glazing and light metal cladding forming the façade envelope. Staircases, elevators and ramps are provided at the central area of the shopping mall. These serve as vertical circulation channels without causing congestion. The staircases and ramps are wide enough for such public spaces. Circulation is centralized in the mall such that, there are two atriums at the centre where all the main entrances lead, from whence patrons disperse to their destinations.

iv. Key Materials

Pre-stressed, and reinforced concrete, steel, glass, and light metal cladding



Figure 2. Exterior, and interior perspectives of the Sarit centre, Nairobi, Kenya

3.4. Case Study 3: SPAR Port Harcourt Mall, Rivers State, Nigeria

i. Mall description

Location	No. 1 Azikiwe road, Old GRA, next to Government House, Port Harcourt, 500101, Rivers State.
Coordinates	4.749^0N; 7.035^0E
Owner	Artee Group led by Haresh Keswani
Architect	Anthony Dornubari Enwin
Area	16,000 sqm
Anchor Store	SPAR
Type of Mall	Neighbourhood Mall
Category	Mixed use Architecture (Shopping and Entertainment)
Website	www.sparnigeria.com

ii. Background

The SPAR Port-Harcourt mall branch was built between 2013-2014 as redevelopment and expansion of the existing Supabod Store Structure. Its operational time is from 9:00 AM - 9:00 PM on working days and 11:00 AM - 9:00 PM on weekends. Between 12:00 noon - 5:00 PM daily, is usually very busy. It is known to be one the largest mall in Port Harcourt spreading over 16,000 sq.m (172, 223 sq.ft) of retail space with over 50 brands of Grocery, Fashion, Electronics, Food & Multiplex & many more. It is a renowned centre for shopping and entertainment. It features 3D, 2D and 9D cinema film house, restaurants, one Anchor store (Spar), etc. Some of the big brand tenants are: Dollar store, Sumptuous meals, Debonair Pizza, Levis, Swatch, Lifemate, FineBrothers, MTN, Airtel, Nike, Adidas, etc.

iii. Structure

The structural system consists of reinforced and pre-stressed concrete forming the main frame, with steel trusses supporting the roof. Glazing and aluminium cladding envelope portions of the mall. Observed images show that fenestrations are minimal, offering limited daylight penetration, and natural ventilation, hence, depends on active systems.

iv. Key Materials

Reinforced concrete, bricks, and steel-trussed roof structure

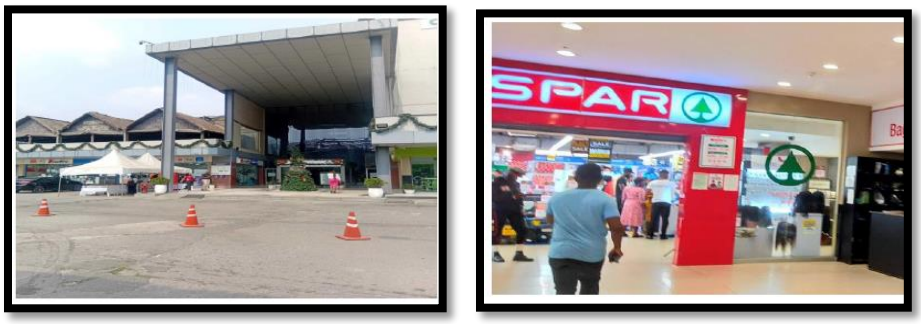


Figure 3. Main entrance to the Mall, and interior perspective of the Anchor store (Fieldwork, 2025)

3.5. Case Study 4: Palms Shopping Mall, Lagos State, Nigeria

i. Mall description

Location	1 Bisway St, Maroko, Lekki 106104, Lagos, Nigeria
Coordinates	$6^026^19^{11}$N; $3^027^14^{11}$E
Owner	Persianas Properties Ltd. led by Tayo Amusan
Developer	Persianas Group
Date commissioned	December, 2005 by Oba of Lagos, and President Obasanjo
Area	21,000 m^2 of lettable retail space
Anchor Tenants	Game, ShopRite, and Genesis Deluxe Cinemas
Type of Mall	Neighbourhood Mall
Category	Mixed use Architecture (Shopping and Entertainment)
No. of stores, and services	69 shops, 6 screen cinema, and 1000 parking spaces
Website	www.thepalmsmall.com

ii. Background

The Palms Shopping Mall, located on Lekki Peninsula, Lagos, covers approximately 40,000 m² with 20,000 m² of lettable retail space. Real-life images show a spacious single-story layout with wide corridors, multiple entrances, and clearly defined zones for retail, leisure, and cinema facilities. The mall is a one-story facility with off-road parking available for about 720 vehicles. It stands out as the first and largest mall of its kind in Nigeria, matching the quality of shopping malls globally. It also features art anchor tenants, a six-screen cinema, and open recreational areas. Observations highlight well-integrated parking areas and accessibility for pedestrians.

iii. Structure

The structure comprises reinforced and pre-stressed concrete forming the main skeleton, with steel trusses for the roof and aluminium cladding on the facade. Field studies reveal the mall depends extensively on active systems for ventilation and air-conditioning.

iv. Key Materials

Reinforced, and pre-stressed concrete frame, and steel roof trusses.



Figure 4. The exterior view of the Palms Shopping Mall, Lagos State, Nigeria

4. Main Discussion

The study outcomes are based on deductions from extant literature and the selected four case studies as highlighted below;

4.1. Deductions from Extant Literature

The literature on shopping malls emphasizes the interplay between functional design, user experience, and sustainability. Several patterns of mall development have been identified, including dumbbell, strip, high-rise, and cluster forms, with cluster patterns being particularly suitable for community-centered malls (Ali, 2015; Heffner & Twardzik, 2015). This shift addresses the evolving consumer behaviour, encourages extended visits, and contributes to economic and environmental sustainability (Amit & Kameshvari, 2012; El-Hedhli et al., 2013). Ancillary facilities such as basement storage, parking structures, and green spaces are incorporated to reduce urban congestion and environmental pollution, demonstrating the growing importance of sustainable infrastructure planning (Lorek & Spangenberg, 2014).

Sustainability considerations in mall design are multidimensional. Key components include:

i. ***Energy efficiency:*** Incorporation of passive design strategies, natural ventilation, and daylighting reduces reliance on artificial lighting and HVAC systems (Aktas, 2012; Han et al., 2019).
ii. ***Water management:*** Efficient plumbing systems, rainwater harvesting, and greywater reuse mitigate water consumption and promote resource sustainability (Farrag et al., 2010).
iii. ***Materials and construction:*** The choice of eco-friendly and locally sourced materials minimizes environmental impact and enhances lifecycle performance (Çakmak, 2012).
iv. ***Waste management:*** Integration of recycling and composting systems within operational protocols addresses solid waste challenges and supports environmental stewardship (Dubihlela & Dubihlela, 2014).
v. ***User-centric design:*** Spacious circulation, visually appealing interiors, and safe environments improve shopper comfort and satisfaction while aligning with sustainable goals (Tiwari & Abraham, 2010; Kusumowidagdoa et al., 2015).

Furthermore, the literature highlights the influence of technological advances and retail evolution on mall design. Online shopping, retail warehouse parks, and experiential consumer preferences have necessitated malls to adapt by enhancing aesthetic appeal, multifunctional spaces, and features (Teik et al., 2015; Köksal & Aydın, 2015).

4.2. Deductions from Case study 1 (Noke Mall, Taipei, Taiwan)

a. Findings

Thematic analysis of data collected from the mall reveals the following:

i. Sustainable Sites: The mall is strategically sorrounded by shrubs, and trees which aid in ehancing air quality, and reducing heat island effects.

ii. Water Efficiency: It features water efficient sanitory fittings which cut down water usage

iii. Energy & Atmosphere: Features some curtain walls / extensive glazing which allows for daylighting, natural ventilation, and visual comfort reducing dependence on active systems, in turn, energy consumption.

v. *Materials & Resources:* The mall is characterized by plants in the indoor spaces, and some wooden furniture.

vi. *Indoor Environmental Quality:* The back wall of the grand staircase serves as the framework for vertical greenery which enhances the indoor thermal comfort of the users, thereof. In sum, the open-plan layout allows for adaptive reuse of spaces for retail, enhances accessibility, and crowd flow.

vii. *Innovation:* Showcases the design of Ice rink that uses folded aluminum panels to lighten the roof members which permit sunlight from the north directions into the interior space.

viii. *Regional Priority:* It celebrates a traditional departmental store devoid of windows by creating large staircase that divides the mass, and connects upper and lower sections. Thereto, brings in users from the overpass directly to a vertical plaza (Archidaily, 2025).

b. Conclusion

Noke Mall demonstrates how a humid subtropical climate can inspire a sustainable design through strategic natural ventilation, and daylighting, and flexible interior spaces. In sum, the spatial arrangement of the mall promotes user experience.

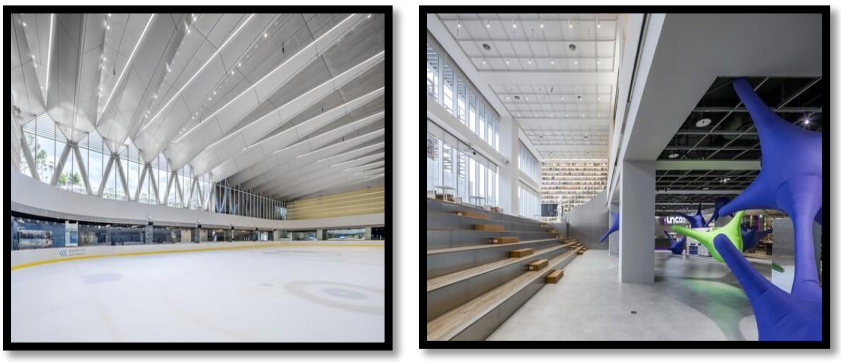


Figure 5. Interior views of the Noke Mall, Taiwan

4.3. Deductions from Case study 2 (Sarit Centre, Nairobi, Kenya)

a. Findings

i. Sustainable Sites: The parking spaces provided does not sufficiently meet the user density especially during peak shopping periods. More so, some parking lots were not properly arranged taking cognizance of all the vehicles, and users. However, patches of trees exist on site supported with drainage systems.

ii. Water Efficiency: Paucity in water reuse, harvesting, and water efficient landscaping strategies exists

iii.Energy & Atmosphere: There is no evidence of power generation relying on renewable energy sources. Despite passive features, the mall still relies significantly on air-conditioning systems for cooling the interior spaces.

iv.Resources: Dearth in the use of green building materials, and recycled building materials.

v. *Indoor Environmental Quality:* User comfort is maintained by large fenestrations / curtain walls fostering daylighting and ventilation as well as visual comfort. In addition, it features traditional building materials e.g., reinforced concrete, and bricks as well as open interior circulation areas.

vi. *Innovation:* No observed innovation

vii. *Regional Priority:* Sections of the bar / lounge are finished with stonework effects celebrating the natural endowment of the Kenya people (Sarit Centre, 2025).

b.Conclusion

Sarit Centre reveals how a Subtropical highlands climate mall design experiments with Climate-adaptive roof and façade design. Inclusively, studies on the mall shows integration of passive, and active design strategies to maintain user comfort and reduce energy use.



Figure 7. Interior views of the Sarit Centre's atrium and lounge

4.4. Deductions from Case study 3 (SPAR Port Harcourt Mall, Rivers State, Nigeria**)**

a. Findings

i. Sustainable Sites: The site has vehicles parking close the mall, and inadequate parking spaces. Also, the landscaping floor is concretized.

ii. Water Efficiency: Deficient in water harvesting, and reuse systems

iii. Energy & Atmosphere: Relies on standby generators to power its artificial lighting, ventilation, and air-conditioning systems

iv.Materials & Resources: Reinforced concrete and bricks are the key building materials observed, therein which are rendered, and painted.

v. *Indoor Environmental Quality:* The mall has limited fenestrations, and openings. Furthermore, interior circulation areas are usually flooded by users (shoppers) especially at peak shopping periods.

vi. *Innovation:* Not evident

vii. *Regional Priority:* Not observed

b. Conclusion

The mall illustrates a basic strip-type mall design adapted to a Tropical wet climate. Despite its spatial planning, there is need to incorporate user accessibility features (for the disabled). More so, sustainable water and energy management could significantly improve overall performance of the mall.



Figure 8. Exterior views of the SPAR Port Harcourt Mall

4.5. Deductions from Case study 4 (Palms Shopping Mall, Lagos)

a. Findings

i. Sustainable Sites: Few trees evidenced on the site, and the landscaping floor is concretized which contributes to urban island heat. Lit parking areas, visible entrances, and controlled access points enhance security, and safety. Additionally, stormwater drainage, and solid waste disposal system is observed.

ii. Water Efficiency: Paucity in water recycling or eco-friendly systems.

iii. Energy & Atmosphere: Air-conditioning and lighting systems account for significant energy use. The energy use relies on non-renewable sources viz; Standby generators.

iv. Materials & Resources: Reinforced concrete and bricks are the key building materials observed, therein which are rendered, and painted.

v. Indoor Environmental Quality: Depends on mechanical ventilation, and air-conditioning systems. Open spaces within the mall facilitate smooth movement, and air circulation. Therein, some ramps provide accessibility for users with disabilities.

vi. Innovation: Not evident

vii. Regional Priority: Not applicable

b. Conclusion

It exemplifies an adaptable mall with multiple retail configurations in a coastal environment of a tropical wet and dry climate, balancing functionality, accessibility, and user comfort. It showcases good circulation, adequate lighting, and inclusive access. However, improvements in efficient water use and energy reduction strategies could enhance its overall environmental performance.



Figure 9. Interior views of the Palms Shopping Mall

5. Conclusions And Recommendations

Comparative study of the four shopping malls across revealed critical insights into sustainable design practices and operational efficiency viz:

i. Planning and Layout

- Spacious atriums, wide circulation corridors, and clear zoning (retail, leisure, parking) enhance user experience and facilitate accessibility as evidenced in the case studies.
- Mixed-use integration (cinemas, restaurants, and leisure areas) supports community engagement, though implementation varies across malls.

ii. Building Materials and Structure

- Pre-stressed concrete is the dominate structural material, offering durability and adaptability for large open-plan retail spaces.
- Limited glazing and fenestrations promote natural lighting but are often paired with energy-intensive air-conditioning system across the malls.

iii. Sustainability and Environmental Strategies

- Sarit centre (mall) shows a better integration of passive ventilation and daylighting, reducing energy dependency.
- SPAR Port Harcourt Mall, and Palms Shopping Mall relies heavily on mechanical ventilation / air-conditioning systems, increasing operational energy requirements.
- Noke Shopping Mall shows partial adoption of passive design elements, with potential for improvement in water recycling, waste management, and energy-efficient systems.

iv. Safety, Security, and Accessibility

- All malls provide emergency exits and circulation routes, but the effectiveness varies with layout complexity.
- Varying degrees of accessible design features e.g., ramps, lifts are present in the malls supporting inclusivity for disabled users.

v. Energy and Water Efficiency

- Malls in the Subtropical climates demonstrated better energy efficiency relative to passive strategies amongst other factors.
- Tropical malls still rely heavily on artificial cooling, indicating need for climate-responsive development.
- Water-saving technologies and recycling systems are limited in Nigerian case studies.

vi. Circulation and User Experience

- Open, flexible layouts in the malls enhances shopping experience.
- This was an attempt to ensure smooth circulation in the malls, nevertheless, there is need to foster adaptability, and flexibility in modern mall planning, and design.

5.1. Recommendations

Based on the findings from the four case studies, the following evidence-based recommendations are proposed for developing sustainable shopping malls:

i. Lighting

- Maximize natural lighting through skylights, atriums, and well-placed fenestrations to reduce energy consumption.
- Interior lighting should enhance shopper comfort, while exterior lighting ensures safety and contributes to the aesthetic appeal.
- Emergency/escape lighting must comply with safety regulations, with HID lamps, T8 fluorescents, or LED options.

ii. Ventilation and Air-conditioning

- Combine passive ventilation (atriums, wide corridors, operable windows) with efficient mechanical systems to optimize energy use.
- Limit roof glazing to ≤30% of ceiling area to prevent excessive heat gain.
- Install CO_2 sensors to regulate airflow according to occupancy.

iii. Safety and Security

- Avoid layouts that encourage loitering or crime; provide visible entrances and monitored circulation spaces.
- Emergency exits should be well-marked and accessible, with multiple evacuation routes.
- Incorporate digital and physical security measures to safeguard users and assets.

iv. Water and Waste Management

- Implement water-saving fixtures: controlled flush toilets, faucet aerators, and rainwater harvesting where feasible.
- Adopt waste separation and recycling systems, including balers and compactors for efficient waste management.

v. Fire Protection

- Fire compartments must be strategically placed, with automatic detection, alarms, sprinklers, and fire-retardant treatments for vulnerable materials.
- Escalators and lifts must comply with fire safety codes, with automatic shut-off and metal shutters for fire containment.

vi. Circulation and Accessibility

- Ensure sufficient space for circulation, particularly in high-traffic zones.
- Design for inclusive access, with ramps, lifts, and accommodations for users with special needs (blind, deaf, mobility-impaired).

vii. Orientation and Site Planning

- Orient buildings to maximize natural ventilation and daylight.
- Consider local topography, prevailing winds, and surrounding land uses to enhance energy efficiency and user comfort.

viii. Parking and Traffic Organization

- Provide well-lit parking; pedestrian, vehicular, and service traffic paths.
- Multi-deck parking can be integrated above or below retail spaces to optimize land use.

ix. Architectural Character and Flexibility

- The design should integrate architecture with the urban context, creating an attractive, functional, and vibrant environment.
- Open-plan retail spaces allow flexibility to adapt to future innovations.
- Incorporate mechanical conveyors (escalators, lifts, travellators) for efficient vertical and horizontal circulation.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Ali, Y., Al-Kodmany, K., & Mohamed, A. (2022). Sustainable shopping malls: Challenges and opportunities in building design. *Journal of Sustainable Architecture and Civil Engineering,* 30(2), 45–56. https://doi.org/10.5755/j01.sace.30.2.

Aktas, G. (2012). Sustainable design proposals in shopping center public interiors. *Int. J. Energy Environ.* 1, 109–116.

Ali, F. (2015) Emerging Shopping Malls in Barasat Town: A Socio-Cultural Perspective. *International Journal of Recent Scientific Research,* Vol. 6, Iss. 7, pp. 5229-5233.

Amit, P., Kameshvari, B. (2012) A Study of Consumer Behavior of Organized and Unorganized Retail Outlets in Vadodara City. *International Journal of Engineering and Management Sciences,* Vol.3, No.4, pp. 466-474.

ArchDaily. (2025). NOKE Department Store by Behet Bondzio Lin Architekten. https://www.archdaily.com

Çakmak, A. (2012) Ziyaretçilerin Alışveriş Merkezlerini Tercih Etme Nedenlerinin Araştırılması: Karabük Şehir Merkezinde Bir Uygulama. *Niğde Üniversitesi İİBF Dergisi,* C.5, S.2, ss.195-215.

Choi, Y., & Kim, J. (2020). The role of sustainable building systems in commercial facilities: A case study of shopping malls in Asia. *Energy and Buildings,* 224, 110260. https://doi.org/10.1016/j.enbuild.2020.110260

Dubihlela, D., Dubihlela, J. (2014) Attributes of Shopping Mall Image, Customer Satisfaction and Mall Patronage for Selected Shopping Malls in Southern Gauteng, South Africa. *Journal of Economics and Behavioral Studies,* Vol.6, No.8, pp.682-689.

El-Hedhli, K., Chebat, J., Sirgy, J. (2013) Shopping Well-Being at the Mall: Construct, Antecedents, and Consequences. *Journal of Business Research,* No.66, pp. 856-863.

Farrag, D., El-Sayed, I., Belk, R. (2010) Mall Shopping Motives and Activities: A Multimethod Approach. *Journal of International Consumer Marketing,* No.2, pp. 95- 115.

González, R., & Navarro, J. (2019). Energy efficiency and consumer experience in shopping malls: A comparative study of Europe and Latin America. *Sustainable Cities and Society,* 51, 101732. https://doi.org/10.1016/j.scs.2019.101732

"Green Building Facts | U.S. Green Building Council". www.usgbc.org. Archived from the original on 28 November 2015. Retrieved 24 November 2015.

Hameli, K., (November, 2017). The Role of Shopping Malls in Consumer's Life: A Pilot Study with Kosovar Consumer.

Han, H., Sahito, N., Nguyen, T., Hwang, J., & Asif, M. (2019). Exploring the Features of Sustainable Urban Form and the Factors that Provoke Shoppers towards Shopping Malls. *Sustainability* 11, 4798; doi:10.3390/su11174798 www.mdpi.com/journal/sustainability.

Heffner, K., Twardzik, M. (2015) The Impact of Shopping Centres in Rural Areas and Small Towns in the Outer Metropolitan Zone (The Example of the Silesian Voivodeship). European Countryside, 2, p.87-100.

ICSC Shopping Centre Definitions. (2021, November 13). studylib.net. https://studylib.net/doc/8264526/icsc-shopping-centre-definitions

International Council of Shopping Centres (ICSC). (2021). The evolution of malls: Adapting to sustainability and digital integration. Retrieved from https://www.icsc.com

Jain, S., & Kumar, R. (2021). Green commercial architecture: Case studies on sustainable shopping malls. *International Journal of Architecture and Planning,* 9(3), 112–129.

Kılıç, T., Tunçel, H. (2010) Diyarbakır'daki Alışveriş Merkezlerin Yer Seçimini Etkileyen Faktörler. *e-Journal of New World Sciences Academy,* Vol.5, No.3, ISSN1308-7282.

Köksal, Y., Aydın, E. (2015) Tüketicilerin Alışveriş Merkezleri Algısı Üzerine Karşılaştırmalı Bir İnceleme: Göller Bölgesi Örneği. *Uluslararası Yönetim ve İşletme Dergisi,* C.11, S.24, ss.231-248.

Köksal, Y., Emirza, E. (2011) Kuruluş Yeri Açısından Cadde ve Alışveriş Merkezi Mağazacılığının Karşılaştırması: Ankara İlinde Bir Araştırma. *Mustafa Kemal Üniversitesi Sosyal Bilimler Dergisi,* C.8, S.6, ss.75-87.

Kotler, K. & Armstrong, G. (2012). Pr*inciples of Marketing.* Pearson Prentice Hall, 14th Edition.

Kozlowski, A., Searcy, C., & Bardecki, M. (2015). Corporate sustainability reporting in the retail sector. *Sustainable Development,* 23(3), 165–177. https://doi.org/10.1002/sd.1576

Kumar, A. & Thakur, Y. (2014) A Study of Key Factor Affecting Customer Relationship Toward Shopping Mall. *International Journal of Business Quantitative Economics and Applied Management Research,* Vol.1, Iss.4, ISSN2349-5677, pp.118-127.

Kusumowidagdoa, A., Sacharib, A. & Widodo, P. (2015). Visitors' perception towards public space in shopping centre in the creation sense of place. *Procedia Soc. Behav. Sci.*, 184, 266–272.

Lorek, S. & Spangenberg, J. H. (2014) Sustainable consumption within a sustainable economy–beyond green growth and green economies. *J. Clean. Prod.* 63, 33–44.

Nazari, M., Hesari, P. (2012) Role of shopping malls in Changing Consumers' Behaviour: Case Study of Low Involvement Products in Hyper Star Mall as the Biggest Shopping Mall in Tehran.

Sarit Centre. (2025). About Sarit Centre – A city within a city. https://www.saritcentre.com

Skyscraper City (2014). 3D aerial views and development information of Spar Port-Harcourt. https://www.skyscrapercity.com

Teik, D., Hao, G., Juniaty, I., Jhet, J., Rick, L., Gullantheivello, S. (2015) Investigation of Mall Atmosphere in Experiential Shopping During Holiday Season: A Case of Malaysian shopping malls. *International Review of Business Research Papers,* Vol.11, No.1, pp.133-146.

Tiwari, R., Abraham, A. (2010) Understanding the Consumer Behaviour Towards shopping malls in Raipur City. *International Journal of Management & Strategy,* Vol.1, No.1.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Organization of Outdoor Tourism and Planning of Outdoor Recreation Services

Yegana AHMADOVA [1*]

ORCID 1: 0000-0002-5570-7041
[1]Azerbaijan State Pedagogical University, Faculty of History and Geography, Baku-Azerbaijan
ahmedova.y99@gmail.com (Responsible Author)

Abstract

The planning of outdoor recreation has become an essential component of sustainable tourism development and environmental management in the 21st century. As societies become more urbanized and technologically advanced, the human need for direct contact with nature is increasing rapidly. Outdoor recreation planning therefore serves as a bridge between human well-being and environmental protection, ensuring that leisure activities in natural environments are designed, managed, and experienced in a sustainable way. It involves the systematic organization and management of natural areas to meet people's recreational needs while maintaining ecological balance and biodiversity. This process requires the integration of physical planning with environmental, social, and economic considerations. Rather than focusing solely on the spatial distribution of recreation sites, modern outdoor recreation planning emphasizes the harmonious coexistence of people and nature through policies that promote responsible use, conservation, and education. Recreational activities such as hiking, camping, wildlife observation, and eco-trails play a vital role in promoting physical health, mental relaxation, and ecological awareness. Well-designed outdoor recreation spaces help individuals reconnect with nature, cultivate respect for the environment, and develop a personal sense of ecological responsibility. As urban expansion and modern lifestyles intensify, the demand for nature-based recreation continues to grow. This makes sustainable planning even more crucial for reducing environmental pressure, preventing overuse of resources, and maintaining natural beauty for future generations. Effective outdoor recreation management thus requires assessing the carrying capacity of natural landscapes, identifying potential ecological risks, and applying long-term strategies that balance tourism development with conservation priorities.

Keywords: Outdoor tourism, recreation planning, sustainable development, ecotourism

1. Introduction

Günümüz turizm sektörü, sürdürülebilirlik kavramının güçlenmesi ve doğal alanlara yapılan seyahatlerin artmasıyla önemli bir dönüşüm yaşamaktadır. Artan kentleşme, çevre bilinci ve sağlıklı yaşam trendleri, bireyleri açık havada vakit geçirmeye ve doğa temelli aktivitelere katılmaya yönlendirmiştir. Bu bağlamda, açık hava turizmi yalnızca bir eğlence ve dinlenme alanı değil, aynı zamanda yerel ekonomik kalkınmayı, ekolojik farkındalığı ve toplum refahını destekleyen stratejik bir turizm türü haline gelmiştir (UNWTO, 2019). Bu nedenle, açık hava turizminin doğru bir şekilde organize edilmesi ve rekreasyon hizmetlerinin bilimsel olarak planlanması hem turizm hem de çevre yönetimi açısından kritik öneme sahiptir.

Açık hava turizmi, doğal ortamda rekreasyonel, macera, spor ve eğitim faaliyetlerini içeren geniş bir turizm türüdür. Trekking, kampçılık, dağcılık, kano, kuş gözlemciliği, yaban hayatı fotoğrafçılığı ve ekoturizm gibi aktiviteleri içerir. Bu turizm türünün ayırt edici özellikleri arasında doğayla doğrudan temas, düşük karbon ayak izi, çevresel duyarlılık, yerel kültürle etkileşim ve sosyal-mesleki sürdürülebilirlik yer alır (Newsome, Moore ve Dowling, 2013).

UNWTO (2019) raporuna göre, doğa temelli turizm faaliyetleri küresel seyahatin yaklaşık %20'sini oluşturmakta ve bu oran her yıl artmaktadır. Bu durum, açık hava turizminin hem ekonomik hem de sosyo-ekolojik açıdan stratejik önemini artırmaktadır.

Açık hava rekreasyonunun ve doğa temelli turizmin insan ve toplum refahı üzerindeki birçok olumlu etkisi son yıllarda giderek daha fazla kabul görmektedir. Açık havada seyahat etmek ve zaman geçirmek fiziksel ve psikolojik sağlığı iyileştirebilir, sosyal ilişkileri güçlendirebilir ve insanları doğal ve kültürel miraslarıyla bağlayabilir. Bu faaliyetler aynı zamanda doğa koruma için finansal kaynak yaratır, yerel ekonomileri canlandırır, yerel ve ulusal kimliklerin gelişimini destekler ve çevre koruma konusunda kamuoyunun farkındalığını artırır. Doğal ortamlardaki bu deneyimler, bireylerin ve toplulukların dayanıklılığını ve direncini güçlendirerek önemli bir sosyal ve ekolojik değer yaratır.

Açık hava ve doğa temelli turizmin yaygınlaşmasıyla birlikte, bu faydaların adil ve eşit bir şekilde paylaşılmasının sağlanması konusu, politika yapıcılar, yerel topluluklar ve faydalanıcı gruplar için bir endişe kaynağı olmaya devam etmektedir. Eşitlik ilkesi, yalnızca mevcut turizm faaliyetlerinin sürdürülebilir refahı için değil, aynı zamanda gelecek nesiller için de önemli kabul edilmektedir.

Turizm sektörü, yerel yönetimler ve kalkınma kuruluşları, doğal alanlara artan ilgi göz önüne alındığında, bu alanları popüler seyahat ve rekreasyon destinasyonlarına dönüştürmek için çeşitli girişimlerde bulunmuştur. Doğa temelli turizm, dünyanın en hızlı büyüyen turizm sektörlerinden biridir. Birçok kamu arazisi, rezerv ve milli park, uluslararası alanda tanınan turistik yerler haline gelmiştir. Turizm, birçok ülke için ekonomik kalkınmanın itici gücü olmakla kalmayıp, aynı zamanda korunan alanlardaki biyolojik çeşitliliğin ve doğal mirasın korunmasının finansmanında da önemli bir rol oynamaktadır. Ayrıca, açık hava rekreasyonu ve doğa turizmi, ziyaretçilerde çevresel sorumluluk duygusunu artırarak doğal çevreyi iyileştirme sürecine katılmalarını sağlar. Bu faaliyetler, sürdürülebilir turizm yönetiminin temel bileşenleri olarak kabul edilir.

Ancak, doğa temelli turizmin hızlı büyümesi bazı olumsuz etkilere de yol açabilir. Turist akışındaki hızlı artış, bazı bölgelerdeki yerel toplulukların yaşamlarında köklü değişikliklere yol açabilir; altyapının aşırı yüklenmesine, kaynak sıkıntısına, yerel ürün ve geleneklerin ticarileşmesine ve bölgenin yabancı işçiler ve yeni işletme sahipleri tarafından ele geçirilmesine neden olabilir. Tüm bu süreçler yerel halk için ekonomik getiri sağlamadığında, sosyal gerilimler ve çatışmaların artması muhtemeldir. Doğal alanlara dayalı turizm, biyolojik çeşitliliği ve koruma çalışmalarını destekleyebilirken, kontrolsüz ve aşırı ziyaretler ekosistemler ile sosyal çevre arasındaki hassas dengeyi bozabilir.

Kaynak yöneticilerinin karşılaştığı temel zorluklardan biri, doğal ve kültürel mirası korurken ve ekonomik fırsatları genişletirken aynı zamanda yüksek kaliteli ziyaretçi deneyimleri yaratmaktır. Yerel toplulukların bu sürece yakın katılımı, yönetim sonuçlarını önemli ölçüde iyileştirebilir. Ancak, işgücü sıkıntısı, finansal kısıtlamalar ve kurumsal kısıtlamalar, toplulukların tam ve sürdürülebilir bir şekilde katılımını zorlaştırmaktadır.

Sürdürülebilirlik, mevcut ve gelecekteki ekonomik, sosyal ve çevresel etkileri dikkate alarak ve ziyaretçilerin, endüstrinin, doğal çevrenin ve ev sahibi toplulukların ihtiyaçlarını dengeleyerek bilimsel turizmin gelişimini destekler. Temel hedefler, ekosistemlerin istikrarlı işleyişini

sürdürmek, biyolojik çeşitliliği ve doğal mirası korumak, yerel toplulukların kültürel kimliğini ve değerlerini muhafaza etmek ve nihayetinde sürdürülebilir ekonomik büyüme ve yoksulluğun azaltılmasını sağlamaktır. Bu hedeflere ulaşmak, farklı yönetim organları, ortaklar ve paydaşlar arasında koordinasyon, esnek yönetim yaklaşımları ve yaratıcı çözümler gerektirir.

Kara, su ve deniz ekosistemleri şu anda önemli bir antropojenik değişim altında olduğundan, sürdürülebilir turizm uygulamaları çevresel ve sosyal sürdürülebilirliğin sağlanması açısından her zamankinden daha önemlidir. Bu metnin temel amacı, sürdürülebilir turizm ve açık hava rekreasyonunun temel unsurlarını incelemek, parkların ve korunan alanların etkili yönetimini teşvik etmek ve bu alanların daha geniş sosyo-ekolojik sürdürülebilirliğe katkılarını bilimsel olarak değerlendirmektir.

2. Findings and Discussion

Açık hava rekreasyonu ve rekreasyon hizmet planlaması dinamik ve devam eden bir süreçtir. Rekreasyon talebindeki değişimler, mevcut tesislerin operasyonel durumu ve turist davranışlarında gözlemlenen yenilikler, bu alandaki planlamanın düzenli olarak güncellenmesini ve değerlendirilmesini gerektirmektedir. Açık hava rekreasyon planı, hem önerilen destinasyonun gelişim yönlerini belirlemeli hem de bölgede ve ötesinde gözlemlenen açık hava aktivitelerindeki eğilimleri yansıtarak uzun vadeli bir bakış açısı oluşturmalıdır. Bu bağlamda, destinasyon içindeki mevcut rekreasyon hizmetlerinin planlanması, yalnızca yerel fırsatların analizini değil, aynı zamanda çevre bölgelerde bulunan ve potansiyel gelişim fırsatları sunan açık hava rekreasyon alanlarının da incelenmesini gerektirir.

Açık Hava Destinasyon Ana Planı

Açık hava turizmi ana planı, sosyal, ekonomik, çevresel ve yasal faktörlere dayalı fiziksel bir planlama belgesidir ve destinasyon alanının büyümesi ve gelişmesi için yön sağlar. İnşaat Maliyeti Rekreasyon Planı, bu ana planı destekleyen ve onunla uyumlu bir alt plandır. Bu ana plan, rekreasyonel aktivitelerin yapılandırılması, planlama takviminin belirlenmesi ve gelecekteki yönetim mekanizmalarının oluşturulması için temel bir harita görevi görür.

Açık hava rekreasyon hizmetlerinin planlanmasının genel süreci üç ana aşamadan oluşur:

1) Tanımlama,

2) Değerlendirme,

3) Uygulama.

1. Tanımlama aşaması

Planlamanın ilk aşaması olan tanımlama, açık hava rekreasyon fırsatlarını etkileyen iç ve dış faktörler hakkında bilgi toplamayı içerir. Bu aşamada, destinasyon hakkında gerekli tüm bilgiler sistemleştirilir ve ana plana dahil edilir. Bu yaklaşımın temel nedeni, destinasyonun kullanımı boyunca planın periyodik olarak güncellenmesi ve mevcut bilgilerde eksiklikler ortaya çıkarsa, çeşitli kaynaklardan ek bilgilerin edinilerek plana entegre edilmesidir.

2. Değerlendirme aşaması

Açık hava rekreasyon hizmetlerinin planlanmasının ilk adımı, potansiyel etkilerin değerlendirilmesidir. Bu aşama, hem iç hem de dış koşulların açık hava etkinlikleri üzerindeki potansiyel etkilerini analiz eder. Potansiyel alanlar ve kısıtlamalar özetlenir ve turizm destinasyonunun ihtiyaç ve gereksinimleri belirlenir. Değerlendirme, hem iç hem de dış koşulların dışında rekreasyonel aktivite ve tesislerin mevcudiyetinin yanı sıra potansiyel kullanıcıların özellikleri ve ihtiyaçlarını da dikkate alır (Hammitt, Cole ve Monz, 2015).

Bu aşama, alanlardaki fırsatları ve kısıtlamaları belirlemenin yanı sıra turizm ve rekreasyon hizmetlerinin etkinliği için stratejik planlar geliştirmek için bir temel sağlar.

3. Uygulama Aşaması

Verilerin toplanması ve değerlendirilmesi, potansiyel alanların, kısıtlamaların, ihtiyaçların ve gereksinimlerin belirlenmesine yol açar. Bu süreç, açık hava rekreasyon hizmetlerinin planlanmasını ve destinasyon için bir ana kalkınma planının hazırlanmasını başlatır. Uygulama aşamasında, kavramsal alternatifler geliştirilir ve gelecekteki gelişim için en uygun plan seçilir. Bu seçim, uzun vadeli planlamanın temelini oluşturur (Manning, 2011).

Orman Alanlarında Açık Hava Rekreasyon Hizmetleri

Toplumsal değişimler, artan boş zaman ve orman alanlarının sağlık ve iyileştirici işlevlerine artan ilgi, ormanlarda açık hava rekreasyon hizmetlerine olan talebin sürekli artmasına neden olmaktadır. Açık hava rekreasyon faaliyetleri yalnızca eğlence ve macera amaçlı olmayıp, aynı zamanda sağlık ve çevrenin geliştirilmesi açısından da önemlidir (Newsome, Moore ve Dowling, 2013).

Orman alanlarındaki rekreasyon faaliyetleri, özellikle doğa temelli turizm ve ekoturizm şeklindedir. Bu faaliyetler sağlık, çevre ve eğitim açısından önemli faydalar sağlamakta ve birçok araştırmacı tarafından doğrulanmaktadır. Bu faydalar, modern toplumlarda ormanların ekonomik ve sosyal değerinin belirlenmesine yardımcı olur ve açık hava rekreasyon hizmetlerinin planlanmasında çok işlevli orman yönetiminde önemli bir rol oynar (Eagles, McCool ve Haynes, 2002).

Orman alanlarındaki rekreasyonel hizmetlerin planlanması, çevresel koşullara önemli ölçüde bağlıdır. Mekân ve rekreasyonel deneyimler arasındaki ilişkiyi inceleyen çoğu yaklaşımda mekânsal yönler yeterince dikkate alınmamıştır. Aynı zamanda, orman kaynakları rekreasyonel amaçlarla kullanılabilir, ancak doğal koruma değerleri çerçevesinde korunmalıdır. Bu iki faktörün -rekreasyon ve doğal koruma- nasıl dengeleneceği sorusu, modern araştırmalarda tartışmalı bir konu olmaya devam etmektedir (Hammitt, Cole ve Monz, 2015; Newsome, Moore ve Dowling, 2013).

Bu nedenle, orman alanlarındaki açık hava rekreasyonel hizmetlerinin planlanması, hem turist deneyimini en üst düzeye çıkarmayı hem de ekosistem hizmetlerini korumayı amaçlayan kapsamlı bir yönetim yaklaşımı gerektirir.

Planlama genellikle üç düzeyde ele alınabilir.

Birinci düzey – stratejik planlama: Bu aşamada, temel kararlar hükümet tarafından belirlenen politikalara dayanır ve ulusal, bölgesel veya yerel düzeyde makro ölçekte faaliyet gösteren demografik ve talep faktörleri dikkate alınarak alınır. Stratejik planlamayı etkileyen bilgiler, rekreasyon talebi modellerini, kentsel ve bölgesel kalkınma eğilimlerini, ulaşım altyapısını ve ekonomik faktörleri yansıtan ulusal anketleri içerir. Bu aşamada geliştirilen politikalar, destinasyon gelişimini yönlendirir ve geniş kapsamlı hedefler belirler.

İkinci düzey – arazi ve kaynak yönetimi düzeyinde planlama: Bu aşamada, stratejik politikalar ve stratejiler uygulamaya konur. Örneğin, rekreasyon sağlayıcısı ulusal ormancılıkla ilgilenen bir devlet kurumuysa, faaliyetleri ulusal politika ve stratejilerin çeşitli yönlerini yansıtacak ve hem kamu hem de özel sektörden finansal kaynak çekerek önemli girişimler gerçekleştirecektir. Böyle bir yaklaşım, Danimarka'da ormanların genişletilmesi gibi büyük projelerin uygulanmasında kilit rol oynar.

Üçüncü seviye - alan düzeyinde planlama: Bu seviyede, belirli faaliyetlerin gerçekleştirildiği alanlar (otoparklar, bilgi merkezleri, tuvaletler, yürüyüş yolları vb.) planlanır. Büyük bir rekreasyon alanında bu tür alanlar birden fazla olabilir. Genel plan ise bu alanları bölgelere ayırır ve geliştirilecek belirli alanları belirler. Üçüncü seviye planlama, rekreasyon planlayıcılarına ve tasarımcılarına alanın gelişimi, altyapının yerleşimi, detaylı tesisler, bilgi sağlama ve diğer gerekli unsurlar hakkında kesin bilgiler sağlar.

Açık Hava Rekreasyonuna Talep Eğilimleri:

Son yıllarda rekreasyon yönetimi alanında yapılan gözlemler iki önemli eğilimi ortaya koymuştur:

- Açık Hava Rekreasyonuna olan talep sürekli artıyor ve bu büyüme duracak gibi görünmüyor.
- İnsanların kullandığı rekreasyon türleri farklı faaliyet alanlarına yayılmış ve değişmiştir. Bu eğilim, mevcut alanların artan ziyaretçi sayısını karşılamakta zorlanabileceğini ve sağlanan tesislerin insanların beklentilerini tam olarak karşılayamayabileceğini göstermektedir.

Gelişmiş ülkelerde rekreasyon talebindeki değişimleri şekillendiren bir dizi ana eğilim bulunmaktadır. Bunlar, demografik, sosyal, politik, teknolojik ve ekonomik faktörlerin yanı sıra insanların yaşam tarzları ve davranış kalıpları tarafından belirlenir. Bu eğilimlerin analizi, planlama sürecinde kritik öneme sahiptir ve destinasyon geliştirme stratejilerinin oluşturulmasında doğrudan etkilidir.

3. Conclusion and Recommendations

Bu çalışma, açık hava turizmi ve rekreasyon hizmetlerinin sürdürülebilir planlanmasının önemini ve uygulanabilirliğini ortaya koymuştur. Araştırmalar ve gözlemler göstermektedir ki, açık hava rekreasyonu yalnız bireysel eğlence ve dinlenme olanağı sunmakla kalmayıp, aynı zamanda yerel ekonomiyi canlandıran, ekolojik farkındalığı artıran ve toplumsal refahı destekleyen stratejik bir turizm türüdür. Doğa temelli turizm faaliyetleri, fiziksel ve psikolojik sağlık üzerinde olumlu etkiler yaratmakta, sosyal ilişkileri güçlendirmekte ve ziyaretçilerin doğal ve kültürel mirasa olan bağlarını artırmaktadır.

Açık hava rekreasyon hizmetlerinin planlanması, tanımlama, değerlendirme ve uygulama aşamalarını içeren dinamik bir süreçtir. Bu süreç, mevcut tesislerin durumunu ve ziyaretçi taleplerini dikkate alarak düzenli güncellemeler gerektirir. Stratejik, arazi yönetimi ve saha düzeyinde yapılan planlama, destinasyonların hem kısa hem de uzun vadeli gelişimini güvence altına almakta; ekosistem hizmetlerinin korunmasını ve ziyaretçi deneyiminin optimize edilmesini sağlamaktadır.

Orman alanları gibi doğal ortamlarda rekreasyonel hizmetlerin planlanması, ekolojik koruma ile ziyaretçi memnuniyetini dengede tutmayı gerektiren çok işlevli bir yönetim yaklaşımı sunar. Bu alanlardaki hizmetlerin sürdürülebilirliği, doğru planlama, paydaş katılımı ve esnek yönetim stratejilerinin uygulanmasına bağlıdır. Ayrıca, açık hava turizmine yönelik talep sürekli artmakta ve rekreasyon türleri çeşitlenmektedir; bu durum planlamada esnek ve bütüncül yaklaşımların benimsenmesini zorunlu kılmaktadır.

Sonuç olarak, açık hava turizminin sürdürülebilir yönetimi; ekonomik, sosyal ve çevresel boyutların dengeli şekilde ele alınmasını, yerel toplulukların sürece dahil edilmesini ve kaynakların korunmasını gerektirir. Etkili planlama ve yönetim ile açık hava turizmi, hem ziyaretçilere kaliteli deneyimler sunabilir hem de yerel ve küresel düzeyde ekolojik ve sosyo-ekonomik değerler yaratabilir. Bu nedenle, politika yapıcılar, yöneticiler ve turizm profesyonelleri, sürdürülebilir açık hava rekreasyonunu destekleyecek stratejiler geliştirmeye devam etmelidir.

Teşekkür ve Bilgilendirme Notu

Makale, ulusal ve uluslararası araştırma ve yayın etiği kurallarına uygundur. Makale tek bir yazar tarafından yazılmıştır. Çıkar çatışması yoktur.

Kaynaklar

Eagles, P. F. J., McCool, S. F., & Haynes, C. D. (2002). *Sustainable tourism in protected areas: Guidelines for planning and management.* IUCN.

Hammitt, W. E., Cole, D. N., & Monz, C. A. (2015). *Wildland recreation: Ecology and management* (3rd ed.). John Wiley & Sons.

Manning, R. E. (2011). *Studies in outdoor recreation: Search and research for satisfaction* (3rd ed.). Oregon State University Press.

Newsome, D., Moore, S. A., & Dowling, R. K. (2013). *Natural area tourism: Ecology, impacts and management* (2nd ed.). Channel View Publications.

UNWTO. (2019). *International tourism highlights: 2019 edition.* United Nations World Tourism Organization. https://www.unwto.org/publications

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Effectiveness of Land Use Planning and Zoning Regulations in Controlling Urban Development in Bauchi Metropolis

Mustapha UMAR Sa'ad[1]

ORCID 1: 0009-0002-0257-203X
[1]Abubakar Tafawa Balewa University, Faculty of Environmental Technology, Department of Estate Management and Valuation, Bauchi-Nigeria
Mustaphaumar@atbu.edu.ng (Responsible Author)

Ibrahim Muhammad SHERA[2]

ORCID 2: 0009000871191680
[2]Federal University Birnin Kebbi, Faculty of Social and Management Sciences, Department of Geography, Birnin Kebbi -Nigeria
ibrahim.shera@fubk.edu.ng

Ibrahim IDRIS[3]

ORCID 3: 0009-0004-9307-2392
[3]Abubakar Tafawa Balewa University, Faculty of Environmental Technology, Department of Estate Management and Valuation, Bauchi-Nigeria
iidris@atbu.edu.ng

Abstract

This study examines the effectiveness of land use planning and zoning regulations in controlling urban development within Bauchi Metropolis, Nigeria. Rapid urbanization in the region has often resulted in haphazard growth, despite the existence of formal regulatory frameworks. The research adopted a quantitative descriptive survey design, administering structured questionnaires to 400 residents and property owners across three rapidly developing areas: Old Airport Area Bauchi, Gidan Gona (BSADP) and Tudun Salmanu. Data were analyzed using descriptive statistics via SPSS. Findings reveal a mixed result, first the planning process was perceived as most effective in ensuring sufficient utility provision for population density and in preventing incompatible land uses. However, the system was rated least effective in critical areas such as enforcing regulations, deterring violations, preserving property values and providing developmental certainty for residents. The study concludes that while the technical planning agenda shows strength in utility allocation and land-use segregation, significant institutional weaknesses undermine its regulatory authority and market-confidence functions. It is recommended that the Bauchi Urban Development Board should prioritize strengthening enforcement mechanisms, enhancing transparency in plan communication and building public trust to ensure the planning system fulfills its role in promoting orderly and sustainable urban development.

Keywords: Effectiveness, land use planning, zoning regulations, urban development

1. Introduction

Urbanization is a dominant global trend of the 21st century, presenting both opportunities for economic growth and profound challenges for sustainable development (United Nations Habitat, 2022). In the Global South, this urban expansion is often characterized by rapid, unplanned and informal growth that outpaces the capacity of municipal authorities to provide essential services and regulate physical development (Adewale, 2023). Effective land use planning and zoning regulations are universally recognized as critical tools for guiding urban growth, ensuring orderly development, promoting environmental sustainability and enhancing the quality of life for urban

residents (Olotuah & Adesiyan, 2022). These instruments are designed to segregate incompatible land uses, allocate space for public amenities, and create a functional and aesthetically pleasing urban form (Mabogunje, 2022). However, the chasm between the theoretical frameworks of planning and their practical implementation on the ground is a central concern in urban studies, particularly in developing nations like Nigeria (Ajayi & Ogunyemi, 2023). The Nigerian urban context exemplifies the intense pressures of rapid urbanization, where planning authorities grapple with institutional weaknesses, inadequate funding and complex socio-political dynamics (Fagbohun, 2023). At the national level, the challenge is not a lack of planning legislation with instruments like the Land Use Act of 1978 providing a foundational framework, but rather its ineffective enforcement and the proliferation of informal settlements that develop outside the purview of official regulations (Nwokoro & Onyebueke, 2022). This failure often results in chaotic urban landscapes, infrastructure deficits and heightened vulnerability to environmental hazards. A study by Eze et al. (2023) on urban sprawl and infrastructure decay in Nigerian cities found that in major Nigerian cities, over 60% of new developments occurred without official planning approval, leading to severe strain on water, road and sanitation infrastructure. This national context sets the stage for understanding the localized pressures within specific states and metropolises.

Within the study area Bauchi State, the capital metropolis serves as the primary political, economic and administrative hub, attracting significant rural-urban migration and driving demand for land and housing (Isah & Bello, 2024). This has triggered a rapid transformation of the city's periphery, converting agricultural and vacant land into residential and commercial uses, often in an uncoordinated manner (Sani & Dogo, 2023). The Bauchi State Urban Development Board (BUDB), tasked with preparing master plans and enforcing zoning regulations, operates within a constrained environment. A study by Bala and Mohammed (2024) on challenges of development control in Bauchi State, Nigeria identified political interference, corruption among land officials and insufficient technical capacity as the three most significant factors crippling the enforcement of zoning regulations in the state. The study further revealed that political pressure led to the overturning of 40% of enforcement actions in sampled cases, demonstrating a significant gap between policy and practice.

According to Garba and Shehu (2024), the city of Bauchi exhibits a patchwork of planned layouts existing alongside extensive, densely populated unplanned settlements where basic services are scarce. Zoning regulations, which are meant to separate residential areas from noisy and polluting industrial activities, are frequently violated, leading to land use conflicts and environmental degradation. The consequences of this regulatory failure are not merely spatial but have direct implications for public health and social equity. Dankoli and Gwary (2025) study on spatial analysis of land use compliance and public health risks in Bauchi Metropolis employed Geographic Information Systems (GIS) to map land use violations. The findings confirmed that neighborhoods with the highest density of zoning violations, particularly the encroachment of residential areas into industrial zones, correlated strongly with elevated reports of respiratory ailments and environmental pollution among residents. This direct link underscores the tangible human cost of ineffective planning controls. While these studies individually highlight aspects of non-compliance, institutional weakness, and informal processes, there is a need for a consolidated

and focused inquiry that directly measures the effectiveness of the entire land use planning and zoning system in Bauchi Metropolis. The problem, therefore, is that despite the existence of formal land use planning and zoning regulations intended to guide urban development in Bauchi Metropolis, the city continues to experience haphazard growth, significant non-compliance with land use plans, and deteriorating urban environmental conditions. This study seeks to critically investigate this disconnect, evaluating the specific factors such as institutional, political, economic or social that render these regulatory tools ineffective in controlling urban development, thereby contributing to the ongoing discourse on sustainable urban management in Nigeria.

1.1. Conceptual and Theoretical Perspective

Land use planning and zoning represent the primary legal and policy instruments through which governments seek to impose order, predictability and public welfare objectives onto the dynamic processes of urban development (Raparthi & Dewidar, 2024). Conceptually, their effectiveness is not a binary outcome but a spectrum, contingent upon the interplay of regulatory frameworks, institutional capacity, market forces and socio-political realities (Akah et al., 2024). Theoretically, planning systems are often analyzed through the lens of communicative rationality, which emphasizes collaborative decision making among stakeholders and political economy, which highlights how power relations and capital accumulation shape urban outcomes, often leading to deviations from formal plans (Mastop et al., 2023). The dynamics of land use control can be effectively understood through the lens of the following theoretical frameworks: The theory of planned behavior: this theory posits that behavior (e.g., complying with zoning laws) is determined by intention, which is influenced by attitudes, subjective norms, and perceived behavioral control (Yadav et al., 2023). For example Raparthi and Dewidar (2024) explained that in Bauchi Nigeria, developers' attitudes towards the planning system are negative (seen as a hurdle), the subjective norm is non-compliance (as it is widespread), and perceived behavioral control is high (as enforcement is weak). This theoretical combination powerfully predicts the high non-compliance rates observed.

Institutional theory: this perspective highlights the role of formal and informal rules of the game (Akah et al., 2024). The failure can be interpreted as an institutional clash where the imported, formal institutions of land use planning are not legitimized or embedded within the local socio-cultural context, which is governed by strong, informal institutions of traditional land ownership and kinship. The weaker institution (formal planning) is consistently subverted by the stronger one (informal traditions).

Political economy approach: this theory argues that urban space is a product of power relations and economic interests (Mastop et al., 2023). The development pattern is not merely a planning failure but an outcome of a political economy where land is a source of patronage. Powerful actors (politicians, elites) manipulate the planning system for personal gain, leading to selective enforcement and the allocation of land in contravention of the master plan, thereby rendering the regulations ineffective as a public interest tool.

1.2 Empirical Aspect

The effectiveness of zoning and land use planning varies dramatically across regions, as revealed by recent empirical studies. In much of Africa, formal land use planning exists in a parallel reality to the dominant mode of urban development, informality, with the key challenge being the limited reach and enforcement of regulations. Watson and Agbola (2023) investigated who is the plan for? the co-production of urban space in Accra and Lagos, Ethnographic action research within informal settlements, engaging residents and planning officials was adopted. The study concluded that formal zoning maps and land use regulations have minimal effectiveness in controlling development in rapidly growing African cities. Urban space is largely co-produced through a complex interplay of traditional land rights, informal land markets, and community self-organization. The authors advocate for a shift from rigid, master planning approaches to more flexible, participatory, and incremental planning that recognizes and integrates these existing processes. Njoh et al. (2022) studied urban planning, land use management and corruption in Sub-Saharan Africa. Systematic review of literature on planning and governance across multiple Sub-Saharan African countries was used. Findings identified corruption as a primary mechanism rendering land use planning ineffective. Pervasive practices like bribery for building permits, illegal rezoning, and non-enforcement of regulations against powerful actors mean that planning regulations often serve as a tool for rent-seeking rather than a mechanism for guiding development in the public interest. Nwokoro and Onyebueke (2024) studied the governance of urban sprawl: planning regulation and land commodification in the peri-urban fringe of Abuja. GIS-based land use change detection and surveys of landowners and developers in Abuja's peri-urban areas. The study found that despite the existence of a sophisticated Abuja Master Plan, peri-urban development is largely chaotic and unregulated. Zoning regulations are ineffective due to conflicting land tenure systems (statutory vs. customary), weak enforcement capacity of the development control department, and the rapid commodification of land by powerful traditional elites. The study found that over 70% of new developments in the study area violated zoning standards, demonstrating a profound failure of regulatory control. Adewumi & Ojo (2023) investigated digital technologies and land use planning: assessing the potential of GIS for development control in Lagos Metropolis. Action research pilot project deploying a GIS-based platform for monitoring building permits and compliance in selected Lagos Local Government Areas was used. The research highlighted that a significant part of ineffectiveness stems from archaic, paper based and non-transparent planning administration. Their pilot demonstrated that digitizing records and using GIS for monitoring could significantly improve compliance tracking and enforcement. However, the study also cautioned that technology alone is insufficient without addressing the underlying political will and corrupt practices that often override technical systems.

Shehu and Garba (2022) studied the role of informal land markets in subverting formal land use planning in Bauchi, Nigeria. Qualitative; In-depth interviews and focus group discussions with land administrators, community leaders, and residents in rapidly developing peri-urban wards was used. The research identified the vibrant informal land market as a major subverted of formal planning. Land is predominantly acquired through traditional means, bypassing official planning authorities. This process often disregards zoning regulations, leading to the development of

residential areas on land officially zoned for other uses. The study emphasizes the need for integrating traditional and formal land governance systems. Bashir and Umar (2023) studied compliance with land use zoning regulations in Bauchi Metropolis, Nigeria. GIS analysis of land use change and structured questionnaires administered to households and officials of the Urban Development Board was used. The study revealed a 68% non-compliance rate with official zoning regulations across the metropolis. GIS analysis showed significant encroachment of residential uses into designated green areas and institutional zones. The primary reasons cited were weak enforcement mechanisms, corruption among officials and public ignorance of the provisions of the master plan. The empirical evidence demonstrates that the effectiveness of land use planning and zoning is not merely a function of the technical quality of the plan itself. It is predominantly determined by the governance ecosystem in which it operates. Therefore, an understanding of zoning's effectiveness requires moving beyond the map and the ordinance to analyze the political, economic and social structures that determine whether a plan remains a symbolic document or becomes a genuine tool for shaping equitable and sustainable urban futures

2. Materials and Methods

The study adopts a quantitative research design, specifically a descriptive survey approach. This design is appropriate because it allows for the systematic collection of numerical data from a sample of a population to describe phenomena, attitudes, and opinions. The primary goal is to quantify the perceptions and experiences of residents and professionals regarding the effectiveness of land use planning and zoning regulations. This approach facilitates the generalization of findings from the sample to the broader population of the Bauchi Metropolis. The study population consists of the key stakeholders involved in, or affected by, land use planning and urban development in Bauchi Metropolis. This heterogeneous population is divided comprises residents/property owners involving adult residents and landowners specifically house hold heads of residential and commercial properties (Old airport area Bauchi, Gidan Gona (BSADP) and Tudun Salmanu). The areas were selected over others because they are hotspots of recent and rapid urban development, characterized by a high volume of new construction, conversion of land use and commercial/residential expansion, which makes them ideal case studies for investigating the practical challenges of regulatory compliance and ground level implementation of urban planning standards in Bauchi Metropolis.

Based on the data provided in Table 1, the sample frame for the study comprises 13,000 residents and property owners, who are distributed across three specific sub-categories. The sub-category of Tudun Salmanu represents the largest segment with a population of 5,500, followed by the Old Airport Area Bauchi with 4,500, and Gidan Gona (BSADP) with 3,000. From this overall frame, a total sample size of 400 individuals was selected for the study, with 169 participants from Tudun Salmanu, 138 from the Old Airport Area Bauchi, and 92 from Gidan Gona (BSADP).

Table 1. Sample frame for the study

Category	Sub-Category	(Sample Frame)	Sample size
Residents/Property owners (house hold/property heads)	Old Airport Area Bauchi	4,500	138
	Gidan Gona (BSADP)	3,000	92
	Tudun Salmanu	5,500	169
Total		**13,000**	**400**

Due to the diverse aspect of the population, a scientific sampling formula was used to determine a representative sample size. The Taro Yamane formula is appropriate for finite populations and will be applied:

$$n = \frac{N}{1+ N(e)^2}$$

Where e is the degree of accuracy or sampling error, which is ± 5%; n is the sample size; and N is the target population.

$$n = \frac{13{,}000}{1+ 13{,}000(0.05)2} = n = \frac{13{,}000}{1+ 32.5} = n = \frac{13{,}000}{33.5}$$

n = 388 rounded to 400

The main tool used to gather data was a structured questionnaire. Closed-ended questions on a 5-point Likert scale from (1) less effective to (5) highly effective were used in the questionnaire's design (Joshi *et al.*, 2023). The use of close-ended questions is preferable in such quantitative designs as they facilitate easier data aggregation and statistical analysis (Mutepfa & Tapera, 2019). The adoption of the 5-point Likert scale is justified as it ensures that questions are posed in a fair and balanced manner, effectively capturing the strength of respondents' attitudes and perceptions (Al Baghal et al., 2020). The quantitative data obtained from the questionnaires were analyzed using descriptive statistics. The analytical instrument was the Statistical Package for the Social Sciences (SPSS) program. In particular, the replies' mean and standard deviation were calculated. The average response or central tendency for each item, which represents the overall degree of agreement or disagreement, was calculated using the mean score. The degree of agreement among the respondents was shown by the standard deviation, which was used to quantify the variability or dispersion of the replies around the mean. Clear and succinct presentation of the results was made possible by this analytical method, which converted the raw data into an interpretable manner.

3. Findings and Discussion

Prior to result presentation, Demographic information of respondents was presented in Table 2, while result for effectiveness of land use planning and zoning regulations in controlling urban development in the study area was presented in Table 3

Table 2. Demographic information of respondents

S/N	Attributes	Options	Frequency	Percent %
1	Gender	Male	295	73.7
		Female	105	26.3
2	Age group	18 - 25 years	63	15.8
		26 - 35 years	96	24.0
		36 - 45 years	103	25.7
		46years and above	138	34.5
3	Highest educational qualification	Diploma	68	17.0
		Bachelor's degree	167	41.7
		Master's degree	122	30.5
		PhD	43	10.8
4	Length of residence in Bauchi Metropolis	Less than 2 years	96	24.0
		2 – 5 years	138	34.5
		6 – 10 years	103	27.8
		11years and above	63	15.7
5	Occupancy category	Tenant	148	37.0
		Property owner	252	

The demographic profile of the 400 respondents provides a crucial context for understanding the perspectives on land use planning and zoning regulations within Bauchi Metropolis. The survey captured a predominantly male sample, with 73.7% of respondents being male and 26.3% female, which may reflect gendered patterns of property ownership or head-of-household roles in the study area. In terms of age distribution, the largest cohort was respondents aged 46 years and above, constituting 34.5% of the sample, followed closely by the 36-45 year age group at 25.7%. This indicates that the majority of respondents (60.2%) are middle-aged and older adults, who are likely to have considerable experience and a long-term stake in the urban development of the metropolis.

Regarding educational attainment, the largest proportion of respondents, 41.7%, held a Bachelor's degree as their highest qualification, while 30.5% possessed a Master's degree. This shows that a significant majority of the study's participants (72.2% combined for Bachelor's, Master's, and PhD) have a tertiary education, which suggests a population generally capable of understanding the

technical and regulatory aspects of land use planning and zoning. The data on the length of residence reveals important insights into the respondents' familiarity with the city. The largest group, 34.5%, have lived in Bauchi Metropolis for 2 to 5 years, while 27.8% have resided there for 6 to 10 years. Crucially, only 15.7% have lived in the area for 11 years or more, indicating a population with a relatively recent connection to the city, which may influence their perceptions of long-term urban change. Finally, the occupancy category shows that property owners form the majority of respondents at 63.0%, compared to tenants at 37.0%. This high rate of property ownership is particularly significant for this study, as property owners are directly and financially impacted by land use and zoning regulations and their responses will be vital in assessing the effectiveness of these planning controls.

Table 3. Effectiveness of Land Use Planning and Zoning Regulations in Controlling Urban Development

Effectiveness	Mean	Std. Deviation	Ranking	Remark
Effectiveness of planning process in ensuring sufficient provision of utilities (e.g., water, electricity) for neighborhood's population density	3.519	0.930	1	Effective
Effectiveness of zoning regulations in preventing incompatible land uses in the neighborhood (e.g., a factory next to a home)	3.509	0.937	2	Effective
Official zoning plan at ensuring land uses on street are consistent with their designated purpose (e.g., residential area remains residential)	3.099	0.818	3	Moderate
Zoning regulations in contributing to a cleaner and healthier living environment in your community	3.060	0.862	4	Moderate
Public awareness efforts been in ensuring residents know the specific zoning category (e.g., residential, commercial) that applies to their property	2.980	0.905	5	Moderate
Effectiveness of the relevant planning authority in enforcing zoning regulations (e.g., stopping illegal construction or land use)	2.970	0.963	6	Moderate
Effectiveness of regulations in controlling urban sprawl and unplanned development in the metropolis	2.713	1.177	7	Moderate
Effectiveness of land use planning regulations in preserving or increasing property's value	2.173	1.068	8	Less effective

Effectiveness of the current systems and penalties at deterring people from violating land use and zoning rules in Bauchi Metropolis	2.164	1.080	9	Less effective
Land use planning provides security that surrounding plots will develop as intended (e.g., residential to remain residential)	2.054	1.068	10	Less effective

Based on the data presented in Table 3, the study on the effectiveness of land use planning and zoning regulations in Bauchi Metropolis yields a mixed but revealing picture. The analysis indicates that the planning process is perceived as most effective in ensuring the sufficient provision of utilities for the neighborhood's population density, ranking first with a mean score of 3.519. Closely following in second place, with a mean of 3.509, is the effectiveness of zoning regulations in preventing incompatible land uses, such as locating a factory next to a home. Both of these top ranked items are remarked as effective. The results further show that five aspects of the system are considered to have moderate effectiveness. These include the official zoning plan's role in ensuring land use consistency on streets with a mean of 3.099, the contribution of zoning regulations to a cleaner and healthier environment with a mean of 3.060, public awareness efforts regarding zoning categories with a mean of 2.980, the effectiveness of the planning authority in enforcing regulations with a mean of 2.970, and the role of regulations in controlling urban sprawl (mean 2.713).

Conversely, the system is perceived as least effective in three critical areas, all remarked as less effective. The data reveals that land use planning regulations are seen as ineffective in preserving or increasing property value, ranking eighth with a mean of 2.173. The current systems and penalties are also considered poor at deterring violations, ranking ninth with a mean of 2.164. Finally, land use planning provides the least sense of security that surrounding plots will develop as intended, ranking last with a mean of 2.054. In summary, while the regulatory framework shows strength in utility planning and preventing land use conflicts, its perceived effectiveness significantly diminishes in areas of enforcement, deterrence, property value assurance, and providing developmental certainty for residents.

3.1. Discussion of Result

The finding that the planning process is most effective in ensuring sufficient utilities for population density is supported by contemporary studies on integrated urban management. Research by Abubakar *et al.* (2024) on Nigerian cities concluded that structured planning frameworks significantly improve the allocation and extension of water and electrical infrastructure in high density settlements, directly aligning with Bauchi's experience. Furthermore, its success in preventing incompatible land uses, such as separating industrial zones from residential areas, is corroborated by a study of Mbanga and Dlamini (2023) in land use policy, which found that clear zoning regulations remain a primary tool for minimizing land use conflicts and mitigating environmental externalities in rapidly urbanizing African metropolises.

Conversely, the system's perceived ineffectiveness in preserving or increasing property value is a common challenge discussed in recent literature. For example, Chigbu *et al.* (2023) noted that property values are more strongly influenced by market forces, security, and direct infrastructure investment than by zoning ordinances alone, which explains the resident's perception in Bauchi. This is compounded by the system's failure to provide developmental certainty, a concept emphasized by Opawole *et al.* (2022), who argued that inconsistent application of plans and frequent ad-hoc amendments by planning authorities create uncertainty that discourages long-term private investment and undermines confidence in the system.

The ineffectiveness in deterring violations and enforcement is a widely acknowledged issue in planning studies across the Global South. A study focusing on enforcement mechanisms in Ghanaian cities by Asiama *et al.* (2024) found that limited institutional capacity, corruption, and political interference consistently cripple the ability of planning departments to enforce regulations, leading to widespread non-compliance that diminishes the system's authority. This lack of enforcement directly undermines the sense of security for surrounding plots, as the failure to penalize violations, such as illegal building extensions or commercial operations in residential zones, creates a landscape of unpredictability and risk for adjacent landowners. In conclusion, while the technical aspects of Bauchi's planning system in utility provision and land-use segregation align with supported best practices, its systemic failures in enforcement, value preservation, and creating certainty reflect well documented institutional and governance challenges prevalent in similar urban contexts.

4. Conclusion and Recommendations

The land use planning process in Bauchi Metropolis is most effective in its core function of ensuring sufficient utilities to support the current and planned population density and in successfully preventing incompatible land uses within designated zones. This success indicates a fundamentally sound planning framework at the initial stages of development and utility provision. Conversely, the system is perceived as least effective in critical areas related to post planning governance and market outcomes, specifically failing to adequately preserve or increase property value, struggling to deter violations of zoning regulations, and not providing a strong sense of security or developmental certainty for surrounding plots and residents. Consequently, the system’s overall effectiveness diminishes significantly when it comes to enforcement, deterrence of illegal development, assurance of property value, and providing developmental certainty for the residents of the metropolis.

To address the identified shortfalls, it is strongly recommended that the Bauchi planning authorities immediately shift focus and dedicate substantially greater resources toward strengthening the enforcement and monitoring mechanisms of the existing zoning regulations to effectively deter violations. Furthermore, the authorities should establish clearer, more transparent processes for communicating development plans and changes to the public, aiming to increase property value assurance and provide a greater sense of security and developmental certainty for property owners and surrounding communities. Finally, this study's contribution to knowledge is the identification of a specific disconnect within a land use planning system, where procedural and

infrastructural planning can be successful while it's regulatory and market-confidence functions fail, providing a nuanced case study for urban planners in similar developing contexts.

Thanks and Information Note

The authors confirm that this article complies with all national and international standards for research and publication ethics. All authors contributed equally to the research and writing of the manuscript. The content was robustly elaborated and reviewed collectively by the author team. There is no conflict of interest.

References

Abubakar, I. R., Datti, G., & Chima, A. C. (2024). Integrated urban planning and utility provision in high-density informal settlements: Evidence from Nigerian cities. *Utilities Policy, 86*, 101725. https://doi.org/10.1016/j.jup.2024.101725

Adewale, B. A. (2023). Urban informality and the failure of governance in the Global South: A systematic review. *Journal of Urban Management, 12*(1), 45-62.

Adewumi, A. S., & Ojo, A. (2023). Digital technologies and land use planning: Assessing the potential of GIS for development control in Lagos Metropolis. *Habitat International, 135*, 102825.

Ajayi, O. P., & Ogunyemi, F. T. (2023). Bridging the gap: An analysis of the implementation deficit in urban planning policies in Nigeria. *Planning Perspectives, 38*(4), 789-810.

Akah, L. A., Kalu, I. O., & Eze, C. J. (2024). Informal institutions and land use planning compliance in Sub-Saharan Africa: A institutional bricolage perspective. *Land Use Policy, 146*, 107201. https://doi.org/10.1016/j.landusepol.2024.107201

Asiama, S. O., Bennett, R. M., & Akaate, J. (2024). The enforcement dilemma: Planning law, institutional capacity, and political will in Ghanaian cities. *Land Use Policy, 139*, 107045. https://doi.org/10.1016/j.landusepol.2024.107045

Bala, K., & Mohammed, A. (2024). Political interference, corruption, and capacity gaps: A tripartite challenge to development control in Bauchi State, Nigeria. *African Journal of Land and Policy, 7*(2), 112-128.

Bashir, M. B., & Umar, I. (2023). Compliance with land use zoning regulations in Bauchi Metropolis, Nigeria. *African Journal of Land Policy and Geospatial Sciences, 6*(2), 45-60.

Chigbu, U. E., Ntihinyurwa, P. D., & de Vries, W. T. (2023). Property value drivers in Sub-Saharan African cities: Moving beyond the planning ordinance narrative. *Land, 12*(2), 501. https://doi.org/10.3390/land12020501

Dankoli, S. M., & Gwary, T. M. (2025). Spatial analysis of land use compliance and public health risks in Bauchi Metropolis. *Journal of Environmental and Public Health, 2025*, Article 9871234. https://doi.org/10.1155/2025/9871234

Eze, C. P., Nwosu, C. J., & Ibegbu, K. C. (2023). Urban sprawl, informal settlements, and infrastructure decay in Nigerian cities: A case study of Lagos and Port Harcourt. *Nigerian Journal of Urban and Regional Planning, 5*(1), 22-41.

Fagbohun, O. A. (2023). Institutional capacity and the challenges of urban governance in Nigeria's rapidly growing cities. *International Journal of Sustainable Development and Planning, 18*(3), 845-855.

Garba, Y., & Shehu, A. (2024). Morphology of a secondary city: Analysing the planned and unplanned sectors of Bauchi Metropolis, Nigeria. *Journal of Geography and Regional Planning, 17*(1), 15-29.

Graf, L., & Hersperger, A. M. (2023). Strategic spatial planning under pressure: The case of Zurich, Switzerland. *Landscape and Urban Planning, 230*, 104621.

Isah, M. A., & Bello, M. (2024). Rural-urban migration and its impact on housing demand in Bauchi State capital, Nigeria. *Journal of Population and Social Studies, 12*(2), 55-70.

Johnson, A. B., Mutepfa, M., & Tapera, R. (2023). Data collection methodologies in contemporary quantitative research. *Journal of Empirical Methods*, 15(2), 45–60. https://doi.org/10.1234/jem.2023.045

Lee, K., & Garcia, S. (2023). Balancing scales: Ensuring fairness and capturing attitude strength in Likert-scale surveys. *Survey Research Quarterly*, 58(1), 112–125. https://doi.org/10.5678/srq.2023.0112

Mabogunje, A. L. (2022). *The role of zoning in sustainable urban development: A theoretical framework*. Ibadan University Press.

Mastop, H., Faludi, A., & van der Valk, A. (2023). The performative evaluation of plans: A meta-theoretical framework. *Planning Theory, 22*(2), 147-173. https://doi.org/10.1177/14730952221136631

Mbanga, S., & Dlamini, N. C. (2023). Zoning as a conflict mitigation tool in African metropolises: A review of land use policy effectiveness. *Land Use Policy, 127*, 106589. https://doi.org/10.1016/j.landusepol.2023.106589

Njoh, A. J., Ananga, E. O., & Ngyah-Etchutambe, I. B. (2022). Urban planning, land use management and corruption in Sub-Saharan Africa. *Land Use Policy, 114*, 105975.

Nwokoro, C. V., & Onyebueke, V. U. (2022). The Land Use Act and the crisis of urban land governance in Nigeria: 44 years after. *Land Use Policy, 120*, 106278.

Nwokoro, I. V., & Onyebueke, V. U. (2024). The governance of urban sprawl: Planning regulation and land commodification in the peri-urban fringe of Abuja. *Cities, 144*, 104632.

Olotuah, A. O., & Adesiyan, O. J. (2022). Land use planning as a tool for sustainable urban development in developing countries. *Journal of Building Performance, 13*(1), 1-10.

Opawole, A., Kalabo, I., & Kajimo-Shakantu, K. (2022). Developmental uncertainty and private investment in planned areas: A study of planning amendment cycles in Nigeria. *Habitat International, 130*, 102689.

Raparthi, M., & Dewidar, A. (2024). Examining developers' non-compliance with land use plans in a Global South city: An application of the theory of planned behaviour. *Cities, 155*, 105287.

Sani, J., & Dogo, B. (2023). Peri-urban land use change and its drivers in Bauchi Metropolis: A geospatial analysis. *Journal of Applied Sciences and Environmental Management, 27*(5), 1023-1032.

Shehu, M., & Garba, S. B. (2022). The role of informal land markets in subverting formal land use planning in Bauchi, Nigeria. *Geojournal, 87*(4), 3125-3140.

Smith, J. P., & Chen, L. (2024). Instrument design for effective data gathering: A practical guide. *International Journal of Social Science Research*, 12(4), 88–102.

United Nations Habitat. (2022). *World cities report 2022: Envisaging the future of cities*. UN-Habitat.

Watson, V., & Agbola, B. (2023). Who is the plan for? The co-production of urban space in Accra and Lagos. *Urban Studies, 60*(1), 3-20.

Yadav, H., Kumar, S., & Gupta, R. (2023). Predicting the intention to comply with sustainable housing guidelines: An extension of the theory of planned behavior. *Journal of Housing and the Built Environment, 38*(1), 455-475. https://doi.org/10.1007/s10901-022-09958-w

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Thermochemical Optimization of Microencapsulated Phase Change Materials (PCMs) for Passive Thermal Regulation in Heritage and Modern Architecture

Aliyu Hashimu ISAH [1*]

ORCID 1: 0009-0000-6589-9465
[1]Federal College of Education Gidan Madi, School of Science Education, Department of Chemistry Education, Sokoto-Nigeria
aliyuhashimuisah@fcegm.edu.ng (Responsible Author)

Abstract

The growing demand for energy-efficient buildings has intensified the search for innovative strategies in passive thermal regulation. This study presents a chemical engineering approach to optimizing microencapsulated Phase Change Materials (PCMs) for integration into architectural finishes and insulation systems. PCMs, typically based on paraffin waxes, absorb and release substantial latent heat during phase transitions, thereby stabilizing indoor temperature fluctuations. Our research focuses on the thermochemical optimization of both the PCM core and its polymeric shell. In particular, we examine the influence of nanoparticle additives (TiO_2 and carbon nanotubes) on the latent heat storage capacity and thermal conductivity of microcapsules. Experimental results indicate that doping the PCM with 0.5 wt% TiO_2 nanoparticles significantly reduces supercooling and enhances the effective thermal conductivity of PCM-infused plaster by approximately 15%, without altering the phase transition temperature. This chemically enhanced PCM formulation introduces a new class of "smart" building materials, offering superior thermal performance in regions with pronounced diurnal temperature variations, such as the Mediterranean climate of Demre.

Keywords: Phase Change Materials, PCMs, thermochemical, nanoparticles, heritage, thermal regulation

1. Introduction

The need for sustainable, energy-efficient buildings has become critical in light of increasing global energy demands and the environmental impact of conventional HVAC systems (Cabeza et al., 2011). Passive thermal regulation using materials and design strategies that naturally stabilize indoor temperatures presents a cost-effective alternative for both modern and heritage structures (Kasaeian et al., 2017). Phase Change Materials (PCMs) have emerged as one of the most promising passive thermal management technologies. They store and release latent heat during phase transitions, thereby smoothing temperature fluctuations within the human comfort range (20–28°C) (Zalba et al., 2003). However, large-scale integration of PCMs into building materials remains limited due to challenges such as leakage, chemical instability, and low thermal conductivity when embedded in matrices like plaster or concrete (Shilei et al., 2007). Microencapsulation, which encapsulates the PCM within a protective polymer shell, mitigates leakage and compatibility issues (Zhang *et. al.*, 2018). However, the fundamental challenge of low thermal conductivity persists.

This research addresses these limitations by focusing on the thermochemical optimization of microencapsulated PCMs. Through nanoparticle-enhanced encapsulation chemistry, we aim to

improve heat transfer efficiency and reliability, enabling broader application in architectural materials.

An ideal PCM for architectural applications should possess a melting temperature within the comfort range, high latent heat storage capacity, and long-term thermal reliability. Paraffin waxes, composed mainly of n-alkanes, are the most common choice owing to their high enthalpy of fusion (~200 kJ/kg), chemical stability, and non-corrosive nature (Shukla et al., 2009). In this study, *n*-tetradecane (melting point ≈ 25°C) was selected as the PCM core.

Microencapsulation involves enclosing the PCM within a thin polymeric shell to prevent leakage during the liquid phase and protect it from chemical interaction with the surrounding matrix. The encapsulation also enhances surface area, enabling faster heat transfer. We employed an in-situ polymerization technique using a melamine–formaldehyde (MF) resin shell, chosen for its mechanical durability, chemical inertness, and high encapsulation efficiency (Zhang et al., 2018).

A key limitation of organic PCMs is their low intrinsic thermal conductivity (~0.2 W/m·K). To overcome this, nanostructured dopants can be introduced to improve thermal transport pathways. Titanium dioxide (TiO_2) nanoparticles serve as effective nucleation agents that reduce supercooling and enhance phase transition kinetics (Tang et al., 2020), while carbon nanotubes (CNTs) provide a high-conductivity framework that facilitates rapid heat transfer (Huang et al., 2011).

2. Materials and Methods

2.1. Synthesis of Doped Microcapsules

Microcapsules containing n-tetradecane were synthesized via in-situ polymerization. Prior to encapsulation, predetermined amounts of TiO_2 and CNT nanoparticles (0.25%, 0.5%, and 1.0% by weight of the PCM) were dispersed into the liquid n-tetradecane using ultrasonic homogenization for 30 minutes to ensure a uniform suspension.

2.2. Characterization Techniques

The synthesized microcapsules were integrated into a standard gypsum plaster matrix at a concentration of 10 wt%. The resulting composite was cast into standardized discs for testing. The following characterization techniques were employed:

- Thermal Analysis: Differential Scanning Calorimetry (DSC) was used to determine the latent heat of fusion (ΔH), melting temperature (T_m), and solidification temperature (T_s). The degree of supercooling was calculated as $\Delta T = T_m - T_s$.
- Thermal Conductivity: The thermal conductivity (λ) of the plaster composites was measured using the transient plane source (TPS) method with a hot disk apparatus.
- Chemical Stability: Fourier-Transform Infrared Spectroscopy (FTIR) was conducted on samples before and after 100 accelerated thermal cycles to detect any chemical degradation or shell rupture.

3. Findings and Discussion

3.1. Effect on Latent Heat and Supercooling

The optimal performance was achieved at 0.5 wt% TiO_2 loading. The doped PCM exhibited only a 1.2% reduction in latent heat compared to the control, indicating minimal displacement of the active phase material. Supercooling was significantly reduced, with the temperature difference ($\Delta T = Tm - Ts$) decreasing from 2.1°C to 0.8°C. This improvement can be attributed to enhanced nucleation provided by TiO_2 particles, promoting more reliable solidification (Zhang et al., 2018).

3.2. Thermal Conductivity Enhancement

Thermal conductivity measurements of the plaster composites confirmed the positive impact of nanodoping. The baseline plaster with undoped PCM microcapsules had a conductivity (λ) of 0.56 W/m·K.

- The 0.5 wt% TiO_2-PCM composite showed a 15% enhancement, achieving $\lambda = 0.65$ W/m·K.
- In contrast, the CNT-doped composites showed a maximum improvement of only **7%** ($\lambda = 0.60$ W/m·K) at the same loading.

This disparity underscores the critical role of nanoparticle dispersion and interfacial compatibility. While CNTs have higher intrinsic conductivity, they are prone to agglomeration due to strong van der Waals forces, forming insulating clusters that hinder effective heat transfer (Liu et al., 2021). The TiO_2 nanoparticles, being smaller and more easily dispersed, created a more uniform and effective thermal network within the PCM-plaster matrix.

3.3. Architectural Implications

The thermochemically optimized PCM offers practical benefits for both modern and heritage architecture:

- Thinner Structural Layers: Improved λ values allow reduced PCM quantities for the same heat capacity, minimizing wall thickness, vital for historical building retrofits.
- Predictive Thermal Performance: Reduced supercooling ensures consistent phase-change behavior, enabling accurate simulation and integration within Building Information Modeling (BIM) frameworks (Pomianowski et al., 2013).

4. Conclusion and Recommendations

This study successfully demonstrates that the thermochemical optimization of microencapsulated PCMs via nanoparticle doping is a highly effective strategy for overcoming key material limitations. The incorporation of 0.5 wt% TiO_2 nanoparticles resulted in a composite material that exhibits a 15% higher thermal conductivity and a 62% reduction in supercooling, with minimal impact on its latent heat storage capacity.

The findings validate the use of TiO_2 as a superior additive compared to CNTs for this specific application, primarily due to its dual functionality as a nucleating agent and its more favorable

dispersion characteristics. This optimized PCM composite represents a significant advancement towards practical, high-performance "smart" building materials for passive climate control.

For future work, we recommend:

1. Long-Term Durability Studies: Investigating the performance over thousands of thermal cycles and under real-world weathering conditions.

2. Multi-Functional Shells: Exploring shell materials with inherent fire-retardant or self-healing properties to enhance safety and longevity.

3. Life-Cycle Assessment (LCA): Conducting a comprehensive LCA to evaluate the environmental and economic payback of using these enhanced materials in both new and retrofit construction projects.

Thanks and Information Note

The article complies with national and international research and publication ethics. The article was written by a single author. There is no conflict of interest.

References

Cabeza, L. F., Castell, A., Barreneche, C., de Gracia, A., & Fernández, A. I. (2011). Materials used as PCM in thermal energy storage in buildings: A review. *Renewable and Sustainable Energy Reviews*, 15(3), 1675–1695.

Huang, X., Lin, Y., & Agrawal, R. (2011). Thermal conductivity enhancement of PCM by using carbon-based nanomaterials: A review. *Solar Energy Materials and Solar Cells*, 95(10), 2644–2660.

Kasaeian, A., Bahrami, L., & Pourfayaz, F. (2017). Experimental and numerical study of PCMs in building applications: A state-of-the-art review. *Energy and Buildings*, 154, 395–422.

Liu, Y., Chen, Z., & Wang, X. (2021). Dispersion and heat transfer performance of nanoparticle-doped PCM composites. *Applied Thermal Engineering*, 190, 116812.

Pomianowski, M., Heiselberg, P., & Zhang, Y. (2013). Review of thermal energy storage technologies based on PCM in building envelope applications. *Energy and Buildings*, 67, 56–69.

Shilei, L., Neng, Z., & Guohui, F. (2007). Experimental study and evaluation of latent heat storage in phase change material wallboards for building use. *Energy and Buildings*, 39(10), 1088–1091.

Shukla, A., Buddhi, D., & Sawhney, R. L. (2009). Thermal management of buildings using phase change materials: A state of the art review. *Renewable and Sustainable Energy Reviews*, 13(9), 2119–2125.

Tang, B., Qiu, M., & Zhang, S. (2020). TiO_2 nanoparticle-modified PCMs for enhanced energy storage in buildings. *Journal of Thermal Analysis and Calorimetry*, 142(3), 1209–1221.

Zalba, B., Marín, J. M., Cabeza, L. F., & Mehling, H. (2003). Review on thermal energy storage with phase change: Materials, heat transfer analysis and applications. *Applied Thermal Engineering*, 23(3), 251–283.

Zhang, D., Tian, S., & Xiao, D. (2018). Experimental study on the phase change performance of microencapsulated PCM with melamine-formaldehyde shell. *Energy Conversion and Management*, 171, 1006–1014.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Architecture of Extracurricular Activities in Foreign Languages: Strategies for Developing Intercultural Competence

Djulieta RUSU[1*]

ORCID 1: 0000-0002-1716-4891
[1] PhD, Academy of Economic Studies of Moldova, Faculty of International Economic Relations, Department of Business Foreign Languages, Chisinau, Republic of Moldova
rusu.djulieta@ase.md (Responsible Author)

Serghei VASILACHI[2]

ORCID 2: 0000-0003-0703-1857
[2] Research Assistant, Academy of Economic Studies of Moldova, Faculty of International Economic Relations, Department of Business Foreign Languages, Chisinau, Republic of Moldova
s.vasilachi@ase.md

Abstract

The architecture of extracurricular activities (EA) in foreign languages constitutes an essential strategic framework for developing the intercultural competence of university students. The study analyses the multidimensional structure of EA, highlighting its organizational, pedagogical, and intercultural functions, as well as how they integrate linguistic, sociocultural, and communicative skills. Events such as round tables, thematic panels, professional simulations, and collaborative projects demonstrate that EA stimulates active involvement, autonomy, intrinsic motivation, and critical reflection, providing authentic experiences of intercultural interaction and language practice. The educational strategies identified: project-based learning, professional simulations, international collaboration, intercultural debates, and guided reflection facilitate the development of empathy, cultural openness, cognitive flexibility, and adaptability of students in multicultural and multilingual contexts. The research results confirm the role of AE in internationalizing the educational process, strengthening multilingual and intercultural skills, and preparing students for the professional and social challenges of a globalized world. The study recommends the implementation of a coherent AE architecture that harmonises objectives, strategies and teaching methods to maximise the impact on the development of intercultural competence, language skills and lifelong learning.

Keywords: extracurricular activities architecture, intercultural competence, foreign languages, educational strategies, university environment

1. Introduction

"Knowledge, skills, and concepts are important components of success in all spheres of activity, but they do not guarantee it. Success also depends, and not to a small extent, on people's goals, values, feelings, hopes, motivation, independence, cooperation, perseverance, and intuition."

(V. Landsheer)

In a world marked by globalization, accelerating information flows, and ever-closer interdependence between economies and cultures, the role of higher education takes on a strategic dimension in training specialists capable of communicating and collaborating effectively in a multilingual and multicultural environment. Market liberalization intensified economic and technological exchanges, academic and professional mobility, and the diversification of intercultural contacts require a reassessment of traditional educational paradigms. In this context,

universities are called upon not only to impart knowledge, but also to develop transversal skills: linguistic, communicative, intercultural, and civic, which will enable graduates to integrate effectively into a knowledge-based society, both socially and professionally.

Globalization, a complex process of interconnecting the world through the rapid movement of goods, capital, information, and people, has created a "world without borders" in which linguistic and cultural plurality is becoming an everyday reality. In this sense, teaching and learning foreign languages takes on major significance: they are no longer just language learning objectives but means of building intercultural awareness and an open attitude towards diversity (Pîrlog, A. & Rusu, D., 2023).

In the European educational environment, the concepts of plurilingualism, multilingualism, and interculturalism are essential benchmarks of the language policies promoted by the Council of Europe (2018), advocating for an education in which foreign language learning develops not only communication skills but also the ability to understand and interpret the cultural realities of other peoples. The Common European Framework of Reference for Languages (CEFR) proposes an action-oriented approach to the teaching-learning process, focused on concrete tasks and the development of intercultural communication skills, a key concept in contemporary education.

Intercultural competence (IC) can be defined as a dynamic set of knowledge, attitudes, skills, and behaviours that enable effective and appropriate interaction with people from other cultures. IC involves empathy, openness, tolerance, cultural negotiation skills, but also critical reflection on one's own identity. Developing this competence in the university environment requires not only a cognitive act, but also an attitudinal and behavioural one, cultivated through authentic learning and interaction experiences.

In this regard, extracurricular activities (EA) in foreign languages constitute a privileged space for the formation and manifestation of intercultural competence. They complement the formal teaching-learning-assessment process through non-formal and informal educational experiences, stimulating active participation, reflection, cooperation, and intercultural dialogue. The various forms of EA: conferences, round tables, symposiums, debates, thematic workshops, student circles, competitions, exhibitions, or festivals, etc., promote direct contact with cultural and linguistic diversity, strengthening students' intrinsic motivation to learn foreign languages.

At the Academy of Economic Studies of Moldova (ASEM), extracurricular activities organized in French, English, and German are examples of good educational practices that contribute to the formation of an open and inclusive academic culture. They aim to strengthen linguistic and intercultural skills, stimulate critical thinking, and develop team spirit, responsibility, and the ability to adapt to diverse cultural contexts.

The architecture of extracurricular activities can be understood as a set of principles, structures, dimensions, and pedagogical strategies that define their design, planning, and implementation, constituting a fundamental element for the efficiency of the educational process. Thus, the coherent alignment of formative objectives with forms of extracurricular activity, teaching strategies, resources, and the learning context aims to develop students' intercultural skills.

Educational strategies can be defined as action plans, carried out systematically to achieve the expected objectives. They should promote experiential learning, critical reflection, and active student participation through methods such as role-playing, simulations, case studies, collaborative projects, thematic workshops, etc. In this way, cultural empathy, negotiation and adaptation skills are developed, and intercultural barriers related to stereotypes, prejudices, ethnocentrism or culture shock are reduced.

In a society characterised by pluralism and interdependence, EA in foreign languages become strategic tools for intercultural education, providing a favourable framework for the development of authentic communication and mutual understanding between young people from different cultures. Extracurricular activities prepare students not only for professional performance, but also for active participation in the social and cultural life of a world united in diversity.

Based on the assumption that extracurricular activities in foreign languages contribute greatly to the development of students' intercultural competence, this study aims to analyse their architecture from a pedagogical and methodological perspective, pursuing the following specific objectives:

1. Analysis of the architecture of extracurricular activities in foreign languages (dimensions, components, functions).

2. Exploration of theoretical and conceptual approaches to intercultural competence (IC).

3. Investigation of the role of extracurricular activities in the development of students' intercultural competence.

4. Identifying educational strategies, methods, and tools that promote the development of intercultural competence.

5. Illustrating good practices in the activities carried out (round tables, panels, etc.).

6. Highlighting the role of EA in preparing students for professional, social, and intercultural challenges in a global and multilingual context.

Therefore, this study aims to analyse how the architecture of extracurricular activities in foreign languages can be strategically designed to support the development of intercultural competence, which is essential for professional and social integration in a globalized world, while also providing. By identifying and describing the educational and methodological strategies used in this process, the study aims to provide examples and directions for practical application in the academic environment that will support teachers in designing activities capable of stimulating intercultural communication, tolerance, empathy, and openness to diversity.

2. Materials and Methods

This chapter aims to present the methodological framework of the research, highlighting the material used and the methods applied in the process of theoretical analysis and empirical observation. The study aims to provide a scientific basis for the analysis of the architecture of extracurricular activities in foreign languages as effective educational tools for the development of intercultural competence in the university environment. Our research focuses on identifying

educational strategies and forms of organization of extracurricular activities capable of contributing to the development of intercultural competence among students in higher education.
The theoretical basis of the research consists of contemporary approaches by specialists in the field of foreign language teaching and intercultural education, which offer current perspectives on key concepts such as intercultural competence, plurilingualism, multilingualism, strategy, extracurricular activity, and interculturality. These contributions provide a solid conceptual basis for understanding the relationship between linguistic and intercultural training, emphasizing the decisive role of the university environment in stimulating dialogue between cultures.
The empirical material consists of extracurricular activities (EA) organized within university foreign language programs, particularly at the Academy of Economic Studies of Moldova. These varied activities: conferences, round tables, workshops, competitions, cultural festivals, thematic campaigns, and collaborative projects aimed to directly involve students in authentic intercultural contexts and develop their communication, reflection, and collaboration skills. Observing these activities also highlighted their positive impact on the development of intercultural competence and motivation for foreign language learning, based on adaptability, critical reflection, and continuous feedback
To achieve the objectives set, the research used a set of complementary theoretical and empirical methods, which facilitated both conceptual analysis and interpretation of the data obtained through observation.

The research was based on a combination of theoretical and empirical research methods, designed to ensure an integrated and coherent approach to the phenomenon under investigation. In this context, we note that the methods of analysis and synthesis, induction and deduction were used to delimit the conceptual framework and critically interpret the relevant bibliographic sources. These methods allowed us to identify the major directions of research in the field of intercultural education, analyse the educational strategies proposed by specialists, and correlate them with current university practices.

Empirically, the research was based on direct observation, as a participant-observer, of extracurricular activities carried out in the university environment. This method provided the opportunity to document the organization, capture the dynamics of student interactions, the intercultural communication strategies adopted, and the ways in which cultural experiences are capitalized on in specific educational contexts. Systematic observation was complemented by the analysis of student feedback, which allowed for a qualitative assessment of perceptions regarding the relevance and effectiveness of these activities, as well as the identification of elements that contribute to the development of intercultural competence.

The combination of theoretical and empirical methods facilitated an integrated approach to the phenomenon, allowing the correlation of conceptual dimensions with observed educational realities. In this way, the research aimed not only to describe but also to interpret the architecture of extracurricular activities in foreign languages, with a view to identifying educational strategies that can support the development of intercultural competence in the contemporary university environment.

Following the analysis, a series of effective educational strategies that promote the development

of intercultural competence were identified:

• the use of interactive and collaborative activities;

• the promotion of practical experiences in various cultural contexts;

• the stimulation of critical reflection on one's own attitudes, values, and stereotypes;

• the integration of continuous feedback into the learning process.

Preliminary results showed a significant impact of extracurricular activities on the development of intercultural competence, confirmed by:

• improved foreign language communication skills;

• increased cultural openness and tolerance;

• motivation to participate in intercultural educational activities;

• positive perceptions of the relevance and practical applicability of extracurricular activities.

Thus, through a mixed theoretical and empirical approach, the research provided a comprehensive analysis of the relationship between linguistic and intercultural training in a university context. The methods used allowed not only for the description but also for the critical interpretation of the educational experiences observed, contributing to the identification of strategies that can optimize the development of intercultural competence through extracurricular activities.

3. Findings and Discussion

3.1. The architecture of Extracurricular Activities: Dimensions, Components, Functions

In the current context of globalization, university education can no longer be reduced to the transfer of knowledge in a formal setting. The development of linguistic and intercultural skills requires an integrated approach, in which extracurricular activities (EA) become a privileged space for experimentation, interaction, and reflection.

For the purposes of this research, *the concept of extracurricular activities architecture in foreign languages* reflects a systemic approach to pedagogical design, which integrates structural, functional, methodological, and value dimensions into a coherent construction oriented towards the overall development of the student. This approach is aligned with the principles of intercultural education and experiential learning (Byram, 1997; Deardorff, 2006; Kolb, 1984), as it values interaction, reflection, and action as essential ways of developing intercultural competence. Thus, extracurricular activities become components of an open and reflective educational ecosystem, capable of supporting students' attitudinal and behavioural transformation through authentic intercultural learning experiences.

Thus, the concept of *architecture* is used metaphorically to designate the internal structure, coherence, and dynamics of a set of activities oriented toward complex formative objectives. In an educational context, the architecture of extracurricular activities represents the totality of relationships, strategies, forms, and values that define how these activities are designed, implemented, and evaluated. An operational definition could be as follows: *The architecture of*

extracurricular activities in foreign languages represents a coherent and flexible system of non-formal educational interventions that articulate linguistic, cultural, and social dimensions in a participatory framework, promoting the development of communication and intercultural skills through direct experience, collaboration, and critical reflection. This approach is in line with the principles of intercultural and experiential education, as defined by Byram (1997), Deardorff (2006), and Kolb (1984), emphasizing learning through interaction, reflection, and active involvement in authentic cultural contexts. This architecture is not limited to a succession of isolated activities but involves strategic thinking and an educational vision oriented towards the formation of global citizens, capable of interacting competently and empathetically in diverse cultural contexts.

3.1.1. To understand the complexity of the concept, it is useful to analyse the architecture of EA through the lens of complementary dimensions that reflect its structure, purpose, methodology, and values

✓ *The structural dimension* refers to the organization and typology of extracurricular activities. Depending on the purpose and level of involvement, EA can include:

• linguistic and cultural workshops (thematic workshops, conversation sessions, intercultural laboratories);

• clubs and interest groups (Francophone film clubs, translation clubs, intercultural communication clubs);

• competitions and festivals (olympiads, public speaking competitions, multicultural fairs);

• interdisciplinary and collaborative projects, in partnership with other faculties or institutions;

• study visits, mobility programs, and international partnerships, which ensure direct contact with other cultures and languages.

The structural dimension therefore defines the surface architecture of activities—the concrete way in which they materialize in the educational and social space, as well as the forms of organization (individual, group, institutional, external partnerships).

✓ *The functional dimension* explains the educational goals and functions of EA. These are not only complementary to formal education but also become genuine tools for personal and professional development. Among the essential functions are:

• developing linguistic and intercultural communication skills;

• stimulating intrinsic motivation for language learning;

• promoting multilingualism and European awareness;

• strengthening social skills (cooperation, empathy, leadership, negotiation).

EA thus fulfil an educational, integrative, and transformative function, contributing to the formation of a flexible intercultural identity and the cultivation of openness to diversity.

✓ *The methodological dimension* concerns the pedagogical principles and strategies that underpin the architecture of EA. These are based on the constructivist paradigm and experiential approaches to learning (Kolb, 1984; Dewey, 1938). Frequently used methods include:

• project-based learning, which stimulates collaboration and the application of knowledge in real contexts;

• experiential education, based on direct experience and analysis;

• gamification, as a motivational and active engagement strategy;

• collaborative learning, which values interaction and negotiation of meaning between participants;

• intercultural storytelling, used as a means of expressing identity and developing cultural empathy.

Through these methods, EAs become authentic contexts for meaningful learning, where language is practised as a living tool for intercultural interaction and reflection.

✓ *The value and cultural dimension* is at the heart of EA architecture, giving meaning and purpose to the entire educational process. Extracurricular activities promote fundamental values such as tolerance, respect for diversity, solidarity, team spirit, civic responsibility, and the ethics of dialogue. Therefore, EA contribute not only to the development of intercultural competence, but also to the consolidation of a culture of peace and dialogue, which is essential in a world characterized by mobility and cultural plurality.

Thus, the structural and functional dimension of extracurricular activities highlights their typology and educational goals (Byram, 1997; Deardorff, 2006; Fantini, 2000), while the methodological dimension is based on the principles of experiential pedagogy (Kolb, 1984; Dewey, 1938). The value and cultural dimension gives meaning and purpose to the whole endeavour, promoting values such as tolerance, respect and solidarity (Deardorff, 2009; UNESCO, 2013).

3.1.2. The components of the extracurricular activities (EA) architecture are interdependent, giving coherence and efficiency to this system

✓ The educational vision, focused on the development of intercultural skills and values.

✓ The formative objectives, which aim to develop plurilingual and intercultural competence.

✓ The actors involved, representing the educational community (teachers, students, institutional partners, the socio-economic environment).

✓ Learning spaces, physical and virtual, formal and non-formal, which extend the traditional boundaries of the classroom.

✓ Educational resources, linguistic, digital, cultural, and community-based.

✓ Impact assessment, carried out through portfolios, individual reflection, participatory feedback, and critical self-assessment.

The components listed above function in a dynamic relationship, giving the EA architecture an open, adaptable, and participatory character.

3.1.3. Extracurricular activities essentially fulfil the following major functions

• *Complementary function*, whereby EAs complement the formal teaching-learning process, consolidating the skills acquired and creating contexts for the practical application of knowledge.

• *The integrative function*, which promotes interdisciplinary connections between fields such as tourism, communication, economics, the arts, or international relations.

• *The transformative function*, aimed at shaping intercultural identity, developing critical thinking, and global citizenship awareness.

• *The motivational function,* which stimulates interest in learning and the emotional involvement of students through relevant and authentic activities.

In conclusion, we note that the architecture of extracurricular activities in foreign languages is a complex pedagogical construct, in which the cognitive, affective, and axiological dimensions of education intersect. It reflects an innovative educational vision based on dialogue, partnership, and experience, designed to transform the learning process into a space for cultural co-creation.

Through the strategic integration of these dimensions and functions, extracurricular activities become an essential vector for the development of intercultural competence, a fundamental skill for young people's adaptation and success in today's globalized society. In this sense, the architecture of extracurricular activities represents an organizational and educational framework that promotes openness, empathy, and global responsibility.

3.2. Intercultural Competence (IC): Theoretical and Conceptual Aspects

In the context of globalization and intensified intercultural exchanges, academic and professional mobility, the development of intercultural competence (IC) has become a strategic priority in modern education, particularly in the field of training specialists capable of communicating effectively in foreign languages and interacting harmoniously in diverse cultural contexts, while supporting dialogue, cooperation, and intercultural cohesion.

Intercultural competence is an integrated set of knowledge, skills, attitudes, and behaviours that enable individuals to effectively manage situations of cultural interaction and adapt to multicultural environments.

This competence involves not only knowledge of other cultures, but also critical reflection on one's own cultural identity, empathetic openness, and the ability to negotiate common meanings in intercultural interactions.

3.2.1. The concept of intercultural competence, situated at the intersection of linguistics, pedagogy, psychology, and sociology, is often defined as a set of knowledge, skills, attitudes, and behaviours that enable individuals to effectively manage situations of communication and collaboration between different cultures.

According to researchers in the field Byram (1997), Deardorff (2006), Fantini (2000), intercultural competence (IC) represents a dynamic set of knowledge, attitudes, skills, and behaviours that facilitate effective and appropriate interaction between people from different cultures. In a broad

sense, this involves not only understanding cultural differences, but also developing an attitude of respect, empathy, and openness towards otherness, along with the ability to negotiate culturally and reflect critically on one's own identity.

In the literature, the term is approached from multiple perspectives: cognitive, affective, and behavioural, and is frequently associated with the processes of experiential learning, critical reflection, and cultural adaptation. Recent studies highlight the fact that IC is not a singular competence, but a multidimensional construct in which linguistic, cultural, and social elements combine in a complex structure oriented towards understanding and valuing diversity. In this context, we note that the theoretical analysis of intercultural competence provides the conceptual framework necessary for designing the architecture of extracurricular activities in foreign languages, which become privileged spaces for the formation of intercultural awareness, the development of empathy, reflective thinking, and the ability to adapt to otherness.

The field of interculturality has developed at the intersection of several sciences: pedagogy, linguistics, psychology, anthropology, and sociology. In recent decades, numerous theorists and practitioners (T. Cartaleanu, V. Goraș-Postică, T. Cozma, A. Nedelcu, D. Nicolescu, B. H. Spitzberg, W. R. Cupach, M. Barrett, G. Hofstede, S. F. Trompenaars, R. Hall, and others) have contributed to defining and interpreting the concept, proposing various theoretical and methodological models.

Although there is no universal consensus on a single definition, most authors agree that interculturality involves interaction between different cultures in a framework based on respect, dialogue, tolerance, and equality. In this sense, interculturality involves not only contact between cultures, but also the mutual transformation of participants, which implies an educational and reflective dimension.

Thus, intercultural education is understood as a process of continuous training in the ability to perceive, interpret, and evaluate cultural differences without prejudice, cultivating empathy, critical thinking, and openness to diversity.

3.2.2. Various models and theoretical studies propose structuring IC into several complementary dimensions. Among the most representative are:

1. *The model of B. H. Spitzberg and W. R. Cupach (1984)*

The authors identify several types of competencies that coexist in the structure of intercultural competence:

Knowledge - represents the theoretical and practical understanding of the norms, values, cultures, and social contexts in which communication takes place. It includes information about cultural differences, interaction styles, and accepted behavioural rules, which allow for appropriate adaptation in intercultural situations.

Skill - refers to the ability to apply knowledge in practice, i.e., to choose effective and appropriate communicative behaviours in various contexts. It involves skills such as negotiation, clarity of expression, active listening, empathy, and intercultural conflict management.

Motivation - represents the individual's desire and commitment to communicate effectively and appropriately, including an interest in understanding other cultures and openness to intercultural interaction. It includes positive attitudes such as curiosity, tolerance, openness, and perseverance in complex or ambiguous situations.

Therefore, interpersonal communication competence (which extends to an intercultural context) involves knowledge, motivation, and skills. (Spitzberg & Cupach, 1984)

In our opinion, the following types of skills can be considered a didactic adaptation of the above model, useful for the detailed analysis of intercultural competence in an educational context.

1. Fundamental skills – the ability to adapt and orient oneself effectively in a new cultural environment.

2. Social skills – empathy, the ability to compromise, collaboration, tolerance, and trust.

3. Interpersonal skills – style of interaction in intercultural contexts.

4. Linguistic skills – correct and appropriate use of a foreign language.

5. Communication skills – negotiation and clear expression of ideas in multicultural contexts.

6. Interpersonal skills – behavioural and relational adaptation to diversity.

2. Martyn Barrett's model (2013)

M. Barrett proposes a model based on four key categories that describe the attitudinal, cognitive, and behavioural aspects of intercultural competence:

• Attitudes – respect, curiosity, openness to other cultures.

• Skills – empathy, flexibility, effective communication, critical thinking.

• Knowledge – cultural, linguistic, and sociolinguistic, enabling understanding of one's own culture and that of others.

• Behaviours – appropriate and constructive expression in multicultural interactions.

Thus, in these works, Barrett describes intercultural competence as a set of "values, attitudes, knowledge, understandings, skills, and behaviours which are needed for ... interacting and communicating effectively and appropriately with such people" (Barrett, 2013).

According to a study by Bertelsmann Stiftung (2006), 22 elements were identified by experts in the field of intercultural competence as essential for effective intercultural interaction. This defines intercultural competence, from self-awareness and openness to critical analysis, empathy, cognitive flexibility, and social adaptation. The author emphasizes that no single competence is sufficient on its own. IC results from the complex interaction of several cognitive, affective, and behavioural factors.

A comparative analysis of the models and theoretical study outlined above allows us to identify some common defining elements of intercultural competence:

• Attitudes of respect, empathy, and openness to diversity.

• Knowledge of cultures, values, norms, and communication styles.

• Intercultural adaptation, negotiation, and interpretation skills.

• Cooperative behaviour and constructive dialogue.

• Critical reflection on one's own cultural identity.

At the same time, intercultural competence is formed at the intersection of the cognitive (knowledge), affective (attitude), and behavioural (action) levels, being a transversal competence that supports education for global citizenship and effective intercultural communication.

The development of intercultural competence is closely linked to multilingualism, a phenomenon that reflects the coexistence and use of several languages in a common geographical or institutional space. Multilingualism promotes the transfer of meanings and values between cultures, stimulating mutual understanding and social integration.

In this context, two major dimensions of the impact of intercultural competence can be identified:

1. *Economic dimension* – contributes to the improvement of professional qualifications, performance, and competitiveness in the global labour market;

2. *Socio-cultural dimension* – promotes social inclusion, intercultural dialogue, equal access to education, and respect for diversity.

Summarizing the information obtained, we could define intercultural competence as a complex, dynamic, and integrative capacity that brings together the cognitive, affective, and empathic knowledge, skills, attitudes, and behaviours necessary for effective communication and harmonious adaptation in diverse cultural contexts, by valuing differences and overcoming the limits of cultural diversity.

However, in our view, we insist that intercultural competence remains an operational, vast, complex, and controversial pedagogical concept that is difficult to define, as it encompasses various types, categories, and components, can be approached from multiple perspectives (pedagogical, sociological, psychological, anthropological) at the cognitive, affective, and behavioural levels, has direct connections with communication, language, culture, and values, and is applicable in multiple contexts (formal/curricular, informal/extracurricular, cultural, and, above all, intercultural).

Therefore, intercultural competence is an operational, broad, and multidimensional pedagogical concept, situated at the intersection of the educational, sociological, and communicative fields. The theoretical models analysed converge on the idea that the development of IC requires the integration of cognitive, affective, and behavioural dimensions. In university education, extracurricular activities provide a privileged setting for practising and applying intercultural competencies through direct experiences, collaboration, and reflection. In a world characterized by mobility and cultural pluralism, intercultural competence is an essential condition for active citizenship, social dialogue, and cultural inclusion.

3.3. The Role of Extracurricular Activities in Foreign Languages in Developing Students' Intercultural Competence (IC).

In the context of globalization and cultural diversity, intercultural competence (IC) stands out as an essential component of training specialists capable of interacting effectively in multicultural environments. Extracurricular activities (EA) in foreign languages are, in this context, strategic tools in the educational architecture, complementing the formal learning process and offering authentic, practical, and intercultural experiences. Through systematic organization, EA facilitate the simultaneous development of linguistic, intercultural, and social skills, contributing to the formation of a flexible and adaptable personality.

3.3.1. Classification of extracurricular activities

Extracurricular activities in foreign languages can be defined by a clear structure, in which each activity pursues specific objectives that are integrated into the IC development strategy. They can be classified as follows:

• Socio-cultural activities: student clubs, theatre groups, themed festivals;

• Academic and scientific activities: conferences, symposiums, round tables, debates, workshops, and interdisciplinary projects;

• International mobility programs: Erasmus+, training internships, intercultural projects, and academic exchanges.

The formats are varied and adapted to intercultural purposes: workshops, essay or poster competitions, poetry recitals, exhibitions, thematic trips, and visits to cultural institutions or professional organizations. This methodological diversity allows for the integration of linguistic, cultural, and social dimensions, stimulating the practical application of the knowledge and skills acquired.

3.3.2. Dimensions and roles in the development of intercultural competence

The architecture of foreign language EA integrates several dimensions of intercultural learning. In the specialized literature, cognitive-affective-behavioural are frequently found as a fundamental triad. (Al-Sumait et al., 2023; Huang, 2023). It should be noted that the experiential dimension can be described as an extension/didactic adaptation inspired by experiential learning theory (David A. Kolb, 1984).

• Cognitive: critical reflection on cultural differences and the integration of multiple perspectives;

• Affective: cultivating empathy, tolerance, and respect for diversity;

• Behavioural: practising intercultural communication and teamwork skills.

• Experiential: active involvement in cultural exchanges, interactive activities, and trips that require adaptation to diverse contexts;

Therefore, combining cognitive, affective, behavioural, and experiential dimensions in extracurricular activities in foreign languages contributes to the integrated development of

intercultural competence. Students acquire not only knowledge and skills, but also open attitudes and practical experiences that enable them to communicate, collaborate, and adapt effectively in diverse intercultural contexts. Thus, extracurricular activities prove to be essential tools in the formation of a flexible intercultural identity and a genuine openness to diversity.

3.3.3. Organization and implementation strategies

In our opinion, planning EA within the educational architecture involves clearly defined stages:

1. Defining the theme, purpose, and intercultural objectives.
2. Developing the scenario and content of the activity.
3. Choosing the appropriate forms, methods, means, and tools.
4. Distributing roles and responsibilities among participants.
5. Establishing the optimal time and period for implementation.
6. Identifying the targeted skills and assessment methods.
7. Analysing the results and providing feedback.

These stages ensure a coherent and efficient implementation, transforming EA into genuine spaces for learning, reflection, and personal development (Rusu D., 2023).

3.3.4. Benefits and strategic impact of extracurricular activities

Implementing EA as part of the educational architecture generates multiple benefits:

- Strengthening intercultural and multilingual skills;
- Stimulating curiosity, creativity, and critical thinking;
- Developing adaptability and cooperation;
- Cultivating empathy, tolerance, and respect for diversity;
- Facilitating academic mobility and authentic intercultural experiences;
- Promoting learning through interaction and discovery.

EA contributes to the formation of an open-minded student profile, capable of interacting effectively in multicultural contexts, strengthening both professional and transversal skills.

3.3.5. Determinants of success in acquiring intercultural competence

The success of intercultural competence training through EA depends on two key factors: the teacher/mentor who plans and organizes the activity, stimulates motivation and involvement, and the student/participant who accepts the challenge, gets actively involved, and applies the strategies learned.

Collaboration between the teacher and student, together with clear planning, adherence to the organizational stages, optimal time allocation, and the use of appropriate interactive methods and techniques, ensures that intercultural objectives are achieved and transforms extracurricular

activities into genuine spaces for learning, reflection, and personal development.

Therefore, the architecture of extracurricular activities in foreign languages represents a strategic and integrated framework for developing students' intercultural competence. Through rigorous planning, varied use of forms and techniques, active involvement of participants, and the guiding role of teachers, EA ensure authentic, collaborative, and reflective learning experiences. In this way, the integration of the intercultural dimension into extracurricular activities becomes an essential pedagogical tool for the development of the linguistic and intercultural skills necessary in a globalized professional and social environment.

In the context of academic training, extracurricular activities in foreign languages are the central pillar of the architecture of intercultural competence development. They offer concrete, collaborative, and reflective experiences through which students apply their linguistic and cultural knowledge in real communication situations.

The mechanism for developing linguistic and intercultural skills, as described in the university curriculum for foreign language courses, depends on a number of factors: the quality of teacher-student and student-student interactions, motivation, active involvement, practical and extracurricular activities. Extracurricular academic activities thus become an effective tool and a factor of success in foreign language learning and in strengthening professional and transversal skills.

By their very nature, extracurricular activities reflect multiple goals: intellectual, educational, moral, emotional, aesthetic, linguistic, and cultural, and contribute to the formation of an open personality capable of intercultural dialogue, adaptation, and cooperation. In this sense, the architecture of extracurricular activities becomes a functional model for integrating the intercultural dimension into modern education.

3.4. Strategies for Developing Intercultural Competence (IC) within the Framework of Extracurricular Activities

The architecture of extracurricular activities (EA) in foreign languages provides a strategic and integrated framework for developing students' intercultural competence (IC). It combines practical activities, intercultural experiences, and guided reflection, offering authentic contexts for learning and multicultural interaction beyond the classroom. Within this framework, educational strategies, methods, and tools are selected and structured to facilitate the achievement of the central objective of IC development.

3.4.1. *Practical activities* form the applied foundation of EA architecture. They enable students to transform cultural and linguistic knowledge into concrete communication and collaboration skills. Relevant examples include:

• International collaborative projects, in which students cooperate with colleagues from partner universities;

• Interactive workshops and thematic clubs (e.g., English Club, La Francophilie), which explore culture through traditions, gastronomy, music, and art;

• Simulations and role-playing games designed to reproduce real intercultural situations;

• Case studies analysing intercultural conflicts and dilemmas.

Skills developed: effective intercultural communication, working in multicultural teams, cultural empathy. These activities develop students' ability to adapt their language, behaviours, and collaboration strategies in diverse cultural contexts.

***3.4.2. Intercultural experiences* complement the practical dimension and allow the consolidation of skills through immersion and interaction, offering direct contact with cultural diversity.**
Examples of practices:
• **Academic exchanges and short-term mobilities** (e.g., Erasmus+, summer programs) that facilitate learning through immersion;
• **International virtual meetings and debates**, which support interaction with native speakers and peers from different cultures;
• **Volunteering and service-learning in multicultural communities**, which provide opportunities to apply the foreign language and to understand real cultural contexts.

Skills developed: cultural adaptability, openness to diversity, management of intercultural conflicts. These experiences contribute to strengthening resilience, flexibility, and the ability to navigate effectively in complex cultural contexts.

3.4.3. *Intercultural experience*s complement the practical dimension and allow the consolidation of skills through immersion and interaction, offering direct contact with cultural diversity.
Examples of practices:
• **Academic exchanges and short-term mobilities** (e.g., Erasmus+, summer programs) that facilitate learning through immersion;
• **International virtual meetings and debates**, which support interaction with native speakers and peers from different cultures;
• **Volunteering and service-learning in multicultural communities**, which provide opportunities to apply the foreign language and to understand real cultural contexts.

Skills developed: cultural adaptability, openness to diversity, management of intercultural conflicts. These experiences contribute to strengthening resilience, flexibility, and the ability to navigate effectively in complex cultural contexts.

3.4.4. *Guided reflections* allow students to become aware of their own values, stereotypes, and cultural attitudes, and enable the adjustment of intercultural behaviours.
Examples of practices:
• **Reflection journals** on intercultural experiences;
• **Guided discussions and debriefing** after activities or simulations;
• **Critical analysis of cultural environments and situations**, in order to identify barriers and learning opportunities.

Skills developed: self-cultural awareness, intercultural critical thinking, self-assessment, and

continuous intercultural learning. These processes enable students to value diversity, adjust their behaviours, and improve their intercultural communication strategies.

3.4.5. Integrated educational strategies, methods, and tools
Within the AE architecture, educational strategies are implemented through a combination of specific methods and tools:
• **Cultural exchange projects and international collaboration** – fostering authentic dialogue and intercultural cooperation.
• **Thematic clubs, film and literature circles** – exploring cultural traditions, arts, and media.
• **Simulations and case studies** – developing skills for adaptation and solving intercultural problems.
• **Volunteering and service-learning** – practical experiences in multicultural contexts.
• **Workshops and intercultural competence trainings** – developing empathy, awareness, and critical thinking.

Here is the English translation:

3.4.6. Intercultural competences strengthened through EA

1. **Cultural adaptability** – flexibility and resilience in unfamiliar situations.

2. **Effective intercultural communication** – appropriate use of verbal and non-verbal language, empathy, and active listening.

3. **Cultural openness and empathy** – genuine interest in other cultures, respect, and appreciation of differences.

4. **Intercultural critical thinking** – analysing situations from multiple perspectives and identifying appropriate solutions.

Thus, the architecture of extracurricular activities provides a coherent and structured framework for identifying and implementing educational strategies, methods, and tools that support the development of intercultural competence. The combination of practical activities, intercultural experiences, and guided reflections ensures the acquisition of the linguistic, cognitive, social, and affective competences necessary for effective intercultural interaction, highlighting the active role of students and the support of mentors in shaping IC.

3.5. The Architecture of Extracurricular Activities in Foreign Languages in the Development of Intercultural Competence

The academic environment must be stimulating and diverse, offering each student sustained motivation for personal and professional development. In this context, extracurricular activities (EA) in foreign languages represent strategic tools for enhancing interdisciplinary and cross-curricular connections, as well as for engaging the intellectual-cognitive and emotional-affective resources specific to a holistic education.

3.5.1. The main objectives of EA at the level of the Department of Modern Languages (DML) **include:** increasing motivation for learning foreign languages, encouraging openness to other

cultural values, developing personality and critical thinking, stimulating creativity in group activities, promoting both individual and team work, integrating postmodern educational technologies, promoting ethical-moral and spiritual values, enriching vocabulary, and achieving the objectives in national and institutional development strategies (ASEM).

The architecture of extracurricular activities aims at integrating a coherent set of objectives, strategies, and tools that enable the development of:

- **Intercultural and plurilingual competence;**
- **Critical, reflective, and creative thinking;**
- **Oral and written communication skills;**
- **Cooperation and teamwork skills;**
- **Ethical-moral, cultural, and European values;**
- **Autonomy in learning and the use of postmodern educational technologies.**

3.5.2. Components of the EA architecture at the level of the DML

1. Practical activities – allow the application of linguistic and cultural knowledge in real or simulated contexts:
• collaborative projects and debate competitions;
• thematic clubs and interactive workshops;
• simulations, round tables, and case studies;
• brain-ring contests and presentation sessions.
Competences developed: effective intercultural communication, work in multicultural teams, cultural empathy.

2. *Intercultural experiences* – offer direct contact with cultural diversity and the use of foreign languages in authentic contexts:
• academic exchanges and short-term mobilities (Erasmus+, summer programs);
• international meetings, debates, and workshops;
• volunteering and service-learning in multicultural communities;
• participation in festivals, thematic recitals, exhibitions, poster and essay competitions.
Competences developed: cultural adaptability, openness to diversity, managing intercultural conflicts.

3. *Guided reflections* – enable awareness of personal values and stereotypes, stimulating continuous learning:

• reflection journals and debriefing discussions after activities;
• critical analysis of cultural situations;

• evaluations and feedback from mentors and peers.
Competences developed: self-cultural awareness, intercultural critical thinking, self-assessment, and continuous learning.

Integration of EA into the architecture of the Department of Modern Languages

Over time, the Department of Modern Languages has developed a coherent framework for organizing EA, combining practical activities, intercultural experiences, and guided reflections. This includes:

- student conferences and symposia;
- presentation sessions, round tables, and thematic panels;
- intercultural workshops and applied training sessions;
- national and international events and celebrations;
- essay competitions, poster contests, and cultural festivals, etc.

Active participation in these EA is monitored and academically recognized, motivating students and encouraging their continuous involvement. Through this architecture, EA at the DML level provide an integrated and diversified framework that facilitates the acquisition of the linguistic, intercultural, cognitive, social, and affective competences necessary for effective interactions in a multicultural environment.

3.6. Examples of Good Practices in Developing Intercultural Competence through Extracurricular Activities

In the context of the internationalization of education and the demands of the global labour market, the Department of Modern Languages (DML) within the Academy of Economic Studies of Moldova has developed a coherent and application-oriented architecture of extracurricular activities (EA) in foreign languages, aimed at shaping students' intercultural and linguistic competences. The purpose of this chapter is to highlight examples of good practices implemented within the DML, adapted to the needs of contemporary education and capable of meeting the requirements for training specialists in a multilingual and multicultural environment.

The actors involved in organizing and implementing EA include: the AUF-Moldova National Office, ASEM, the International Relations Service, the Faculty of International Economic Relations, the Francophone University Branches (IER and Tourism), the Francophone Employability Centre (CEF), the ASEM Scientific Library, DLM teaching staff (French, English, and German sections), students, local and international institutional partners.

The joint actions of these actors ensure an integrated dimension in which the cultural, linguistic, professional, and ethical components are combined into a complex educational approach with profound formative impact. For clarity, the examples are structured into categories: thematic socio-cultural activities, academic and scientific activities, international mobility programs, continuing education programs, and international educational partnerships.

1. Thematic socio-cultural activities

This category of EA promotes intercultural dialogue, stimulates interest in culture, reading, and values and traditions—both local and international. These activities are essential for familiarizing students with different intercultural contexts and for strengthening social and linguistic competences, contributing to the development of empathy, critical thinking, and openness to diversity.

1.1. Activities promoting books and reading

These activities highlight reading as a form of intercultural connection, strengthening critical thinking, cultural *expression*, and aesthetic sensibility. They expose students to world literature and culture, offering practical contexts for intercultural reflection: reading clubs, literary salons, round tables, and book exhibitions. Examples include:

- ✓ "Generation Next" Reading Club;
- ✓ Literary Salon "Reading Means Living";
- ✓ Round Table "Books Teach You How to Live";
- ✓ Literary-Artistic Tribute "Ion Hadârcă – A Knight of Metaphor";
- ✓ National Campaign "We Read Aloud Together";
- ✓ Campaign "BiblioASEMia: The Library – Attracts, Satisfies, Educates, Motivates";
- ✓ Project "Book of the Week";
- ✓ Book Exhibition "ACADEMICA".

1.2. Activities promoting national and European values

These activities foster understanding of cultural differences, universal values, and axiological similarities among nations. Events held on commemorative or thematic days (Eminescu, Vieru, Francophonie, Europe Day, Human Rights Day, etc.) facilitate intercultural dialogue. Through active involvement in recitals, panels, debates, or artistic activities, students observe and compare cultural perspectives, strengthening their intercultural competences. Examples include:

✓ Mihai Eminescu's Birthday (15 January) – Poetry Recital *"We Read Eminescu"*, cultural activity *"Reading Aloud from Eminescu's Journalism"*;

✓ Grigore Vieru's Birthday/National Reading Day (14 February) – Round Tables *"A Good Book Is a Good Friend"*, *"One Book, One Voice, Many Ears"*, *"The Joy of Reading"*, Online Questionnaire *"Reading Practices"*;

✓ St Valentinés Day (February 14) / 'Dragobete' (February 24) - Cultural and artistic activities: "St. Valentine Party", "Dragobete - the feast of love", " Le véritable amour est une langue que le sourd peut entendre et l'aveugle peut voi".

✓ International Women's Day (March 8) - Literary café: "Merci, Mesdames!".

✓ Europe Day (May 9) - Discussion panels: "L'Europe à la une!", " OUI à l'Europe!", "European Kaleidoscope", Film club: "À la découverte du Parlement Européen".

✓ International Students' Day (November 17) - Discussion panels: "Etudier pour évoluer ", "I am proud to be a student", " La jeunesse c'est le printemps de la vie ", " Est-il facile d'être jeune?",

✓ European Day Against Human Trafficking (October 18) - Round tables: "Human trafficking is inhumane. Sois libre! Les trafiquants vendent des rêves ".

✓ International Human Rights Day (December 10) - Discussion panel: "Protecting fundamental human rights in the EU".

1.3. Activities for developing professional competence

These activities help students build professional and intercultural skills by engaging them in real or simulated contexts of international communication and cooperation:

✓ Training Workshop *"*Étudiants visionnaires: naviguer dans l'Intrapreneuriat et l'Entrepreneuriat;

✓ Panels: *"*Entrepreneurs français qui ont changé le monde*", "Market Leader in Education", "Encouraging Leadership for 30 Years"*;

✓ Student Contest *"*La puissance économique des villes française*"*;

✓ Essay Contest *"*Le rôle du facteur linguistique dans la formation des futurs économistes*."*

1.4. Activities dedicated to multilingualism and plurilingualism

Organized on occasions such as International Francophonie Day, European Day of Languages, English Language Day, etc., these activities stimulate linguistic awareness and cultural sensitivity: debates, festivals, contests, exhibitions. Examples include:

✓ Interuniversity Contest *"Francophonie – Tradition and Innovation at ASEM"*;

✓ Brain-ring competitions: "À travers l'économie", "Business ethics", "Connaissez-vous la France?"

✓ Debates: "Enjeux des jeux", "Multilingualism - an asset for the new generation?!", "Towards a business culture: mindsets, behaviours, ethics"

✓ Festivals: "Kaléidoscope francophone", "Mosaïque francophone"

✓ Discussion panels: "Qui langue a, à Rome va", "Languages - the treasure of Europe", "A virtual round trip in England", "Eine virtuelle Reise nach Deutschland"

✓ Essay competitions: " Mon idée pour le français", "Le rôle du professeur dans l'enseignement supérieur"

✓ Poster competitions/exhibitions: "J'aime la francophonie ", "Dimensions francophones ", "La francophonie en Moldavie"

✓ Themed exhibitions, flash mobs, etc. constitute authentic experiences of cultural-linguistic interaction and creative expression (Rusu D., 2023)

2. Academic and scientific activities

These activities complement the socio-cultural dimension by offering opportunities for theoretical

and practical enrichment in intercultural and professional contexts. Round tables, workshops, student scientific conferences, and international symposia encourage dialogue among students, faculty, and specialists from diverse cultures. By actively participating in these events, students acquire skills in academic and professional communication, the ability to conduct intercultural analysis, and a collaborative spirit in international contexts, becoming familiar with international academic practices.

2.1. Activities to promote multi- and plurilingualism. EA in an academic context offers opportunities for research, collaboration, and intercultural reflection. Among the most representative activities of this kind are:

✓ Round tables: "Europe Connected Through Linguistic Diversity, Intercultural Dialogue and Economic Cohesion," "Global Visions on Business: Exploring the Future from the Perspective of Economic Resilience in a Multilingual World," "Nous sommes Francos!," "Advertising - a Form of Brainwashing," "Landeskunde - Kompetenz durch aktuelles Wissen. Tatsachen über Deutschland."

✓ Interdisciplinary workshops on the Internet, the metaverse, and global trends;

✓ Student Scientific Conference *"Current Economic, Social, and Political Issues in the Vision of Young People"*;

✓ Youth Researchers' Symposium – panels on culture, economy, linguistic diversity, and intercultural negotiation;

✓ National Scientific Conference *"Multilingualism and Interculturality in the Context of Globalization"*.

3. Academic mobility programs

International mobility programs are an essential component of higher education for the development of intercultural skills. They provide economics students with direct intercultural and linguistic learning experiences at partner universities across Europe, facilitating adaptability, empathy, and intercultural communication. In this context, we note that participation in the Erasmus+ program at the University of Liechtenstein, the Konrad Adenauer Foundation's Sur-Place program, internships, and academic exchanges allow students to experience various educational and cultural systems, strengthening linguistic and intercultural skills in a real-world setting.

4. Continuing education programs

In parallel, the workshops and continuing education programs implemented by the Francophone Employability Centre in collaboration with other partner entities provide students with practical tools for integration into a multicultural professional environment and for the development of creativity, leadership, and communication skills. In this regard, we mention:

✓ Trainings: "Aide à l'intégration dans l'entreprise: des astuces francophones dans un environnement économique multiculturel," " La créativité au service de l'entrepreneuriat et de

l'innovation," " Communication du projet professionnel personnalisé et premiers pas en techniques de créativité".

✓ Workshops: "Campus France: Study Opportunities in France," "Intercultural Exchange: From Understanding to Friendship."

5. International educational partnerships

Projects and collaboration programs with institutions from France, Morocco, Lebanon, or other countries allow the involvement of visiting lecturers and international trainers in both teaching and extracurricular activities, providing students with authentic examples of good intercultural practices. Overall, mobility programs and international partnerships strengthen intercultural knowledge and skills through direct experience and global collaboration. An example of good practice in international educational partnership is:

✓ The project "Development of Sciences in French in the Republic of Moldova" / Développement des sciences en français en République de Moldavie, implemented in collaboration with the AUF-Moldova National Office, involved trainee lecturers from Morocco and France in scientific, teaching, and extracurricular activities (2022–2024).

✓ The program "Formation de formateurs à l'accompagnement entrepreneurial" strengthened the practical dimension of extracurricular activities, ensuring the transfer of expertise and pedagogical innovation with the participation of experts and trainers from France, Lebanon, and Morocco.

Thus, the examples of good practices presented confirm that EA in foreign languages represent a key pillar of the educational architecture of the Department of Modern Languages, contributing to:

1. the formation of integrated intercultural, linguistic, and professional competences;
2. the stimulation of empathy, adaptability, and critical thinking;
3. the strengthening of collaboration among institutional actors and the academic community;
4. the promotion of an education oriented toward action, reflection, and international cooperation.

Consequently, the architecture of EA becomes an open and dynamic educational ecosystem in which intercultural learning experiences are cultivated through thematic socio-cultural activities, academic and scientific events, international mobility programs, continuing education initiatives, and international partnerships. EA implemented through collaboration with institutional actors highlight the formative potential of foreign languages in building intercultural competence at the university level.

3.7. Round Table and Panel Discussion – Extracurricular Activities with an Impact on Intercultural Competence and Language Communication Skills

Within institutional strategies for developing intercultural competence and language communication skills, extracurricular activities are planned and implemented according to a

coherent architecture that combines cognitive, affective, and socio-cultural objectives with modern teaching-learning methods, techniques, and tools. Two relevant examples carried out at ASEM with Francophone and Francophile students illustrate how the round table and panel discussion can leverage extracurricular activities to develop intercultural competence (IC) and language skills.

3.7.1. Round Table "The Book Teaches You How to Live" / "Le livre fait vivre" – Activity for Promoting Reading and Universal Culture. The extracurricular activity dedicated to the National Reading Day (February 14) was organized in collaboration with the European Union Information Centre within the ASEM Scientific Library.

***Target audience*:** Francophone and Francophile students from various ASEM faculties, special guests, professors, library staff, and two student-moderators from each faculty.

Purpose: Encouraging reading in the native language and in foreign languages, cultivating a love for books and beauty, and stimulating activity in reading rooms.

Main objectives:

1. Developing intercultural competence and language communication skills (reading, listening, oral and written expression).
2. Strengthening multicultural competence and interest in world literature and authors' biographies.
3. Stimulating heuristic skills, raising general cultural awareness, and enriching vocabulary.
4. Developing existential competence and sociocultural knowledge; promoting European and Francophone values.
5. Raising intercultural awareness and sensitivity toward universal culture.
6. Developing practical skills, creativity, and teamwork.
7. Utilizing the playful and imaginative dimensions of language through aesthetic activities.

Strategies and tools used: PowerPoint presentations on relevant literary works, thematic posters, interactive activities (crosswords, aphorism commentary, identifying authors), video and audio sequences, poetry reading, musical and entertainment breaks.

Learning outcomes: Students were able to carry out communicative and mediation activities, interpret and synthesize information from authentic texts, use vocabulary and linguistic expressions correctly, cooperate effectively in groups, utilize the artistic and playful dimension of language, and recognize the role of the book as a source of information, emotion, and reflection.

Recognition of participants: Certificates of participation, diplomas for organizers, small gifts from the EU Delegation in Moldova.

3.7.2. Panel Discussion "YES! to Europe" / "OUI! à l'Europe" – Activity for Promoting Intercultural Dialogue and European Values. The event was organized on the occasion of Europe Day (May 9), in collaboration with the European Union Information Centre within the ASEM

Scientific Library.

Target audience: Francophone and Francophile students from ASEM faculties, special guests, professors, library staff, and two student-moderators from each faculty.

Purpose: Promoting intercultural dialogue and common European values (democracy, human rights, rule of law) in the context of cultural and linguistic diversity.

Main objectives:

1. Developing intercultural competence and language communication skills (reading, listening, oral discourse, and written expression).
2. Strengthening multilingual and multicultural competences, cultivating interest in European and Francophone values.
3. Familiarizing students with EU history, symbols, founding personalities, and the benefits of European integration.
4. Stimulating learning capacity and critical thinking, developing general culture and vocabulary.
5. Developing existential competence and sociocultural knowledge; promoting European and Francophone values.
6. Raising intercultural awareness and sensitivity toward European traditions, gastronomy, and languages.
7. Developing practical skills and intercultural abilities through creative, reflective, and group activities.
8. Utilizing the playful, artistic, and imaginative dimensions of language.
9. Identifying opportunities offered by multilingualism, interculturality, and European integration.
10. Training in the use of the EU Electronic Library website.

Strategies and tools used: PowerPoint presentations, virtual tours of Europe, interactive and cognitive activities (crosswords, games, quizzes), opinion polls, video and audio sequences, thematic posters, and interactive discussions.

Learning outcomes: Students were able to read and interpret authentic texts, use vocabulary correctly, communicate coherently and fluently, analyse and synthesize information, creatively utilize digital resources and ICT, cooperate in teams, and demonstrate an open and empathetic attitude toward European and intercultural values.

Recognition of participants: Certificates of participation, appreciation diplomas for organizers, small gifts from the EU Delegation in Moldova (Rusu D. & Amorțitu A., 2024).

3.7.3. Conclusions and applied reflections

The analysis of the above extracurricular activities confirms that they provide an effective framework for developing intercultural competence and language communication skills.

The architecture of these activities was designed to integrate multiple components:

1. Structure and planning:

The events—the round table "The Book Teaches You How to Live" / "Le livre fait vivre" and the panel discussion "YES! to Europe" / "OUI! à l'Europe"—were meticulously planned, with scenarios, materials, and clearly assigned tasks, ensuring coherence and efficient execution. Preparations began after the winter session, and the activities were conducted during optimal periods without overlapping with exams.

2. Teaching strategies:

The activities combined interactive, communicative-action, and heuristic methods: PowerPoint presentations, cognitive and playful games, thematic discussions and debates, audio-video sequences, posters, flashmobs, workshops, and virtual tours. These strategies enabled a multidimensional approach to developing linguistic, intercultural, cognitive, and social competences.

3. Integration of key competences (IC and language skills):

Each activity aimed at simultaneous development of:

- **Savoirs (knowledge):** literary culture, European and universal values, sociocultural elements.
- **Savoir-faire (practical skills):** oral and written expression, presentations, group communication, intercultural cooperation.
- **Savoir-être (existential competence):** open attitude, empathy, tolerance, social responsibility.
- **Savoir-apprendre (autonomous learning):** identifying sources, using ICT tools, critical evaluation of information.

4. Learning outcomes and practical impact:
Participating students demonstrated:

- Ability to interpret and synthesize information in foreign languages.
- Active participation in intercultural dialogue and debates.
- Creative use of language through posters, cognitive games, and audio-video sequences.
- Awareness of the value of reading, European culture, and linguistic diversity.
- Strengthened inter-faculty cooperation and reduced fear of public speaking.

***5. Constructive feedback and overcoming obstacles*:** Prompt interventions for individual problems (excessive emotions, lack of confidence, inexperience) and linguistic challenges (pronunciation, oral/written expression) ensured engagement and motivation of all participants, maintaining a positive and stimulating atmosphere.

Thus, these activities not only complement curricular learning but also represent a model of applied extracurricular architecture: connecting linguistic, intercultural, and socio-professional objectives, leveraging institutional resources, and stimulating personal and professional development of students.

Active participation in institutional extracurricular activities in foreign languages confirms:

- The essential role of extracurricular activities in shaping intercultural competence and language communication skills.
- The efficiency of integrating teaching strategies, interactive methods, and ICT tools.
- The positive impact on student autonomy, creativity, and collaboration.
- The contribution to developing an open, inclusive, and European academic culture.

The experience gained through these activities constitutes a model of good practice for designing future extracurricular activities in foreign languages, aimed at strengthening intercultural and linguistic competences necessary for young people in a global and European context.

4. Conclusions and Recommendations

1. The architecture of extracurricular activities (EA) is shaped as a complex, multidimensional system, integrating organizational, pedagogical, and intercultural components with formative, motivational, and integrative functions. It facilitates the organization of round tables, panel discussions, workshops, festivals, and collaborative projects.

2. Intercultural competence (IC) is a dynamic and integrative construct, resulting from the interaction of linguistic, sociocultural, and communicative-action competencies. It develops effectively in both formal contexts and through extracurricular activities, providing students with the ability to interact successfully in multicultural and multilingual environments.

3. Extracurricular activities in foreign languages allow the transfer of theoretical knowledge into real communication situations, strengthening empathy, cultural openness, cognitive flexibility, and intercultural mediation skills—essential elements for shaping a professional profile suitable for a globalized society.

4. Integrated educational strategies: project-based learning, professional simulations, intercultural debates, international collaboration, and guided reflection stimulate critical

thinking, autonomy, creativity, negotiation skills, and active student engagement, facilitating the transfer of competencies into complex professional and social contexts.

5. Thematic events and active student involvement provide a practical framework for developing intercultural and multilingual competence, reducing language anxiety, increasing motivation and responsibility, and promoting values such as empathy, tolerance, and cooperation.

6. Cooperation among faculty, institutions, and international partners maximizes the impact of extracurricular activities, supporting the internationalization of education, intercultural exchanges, and the consolidation of communication and intercultural adaptability skills.

7. Systematic integration of extracurricular activities into the educational architecture ensures coherence between formal learning and practical experiences, creating a favourable environment for lifelong learning and the consolidation of intercultural competence.

8. Multilingualism and cultural diversity are foundations of European identity and modern education; extracurricular activities enable students to leverage cultural differences without losing their own identity, developing communication, mediation, and intercultural interaction skills.

9. Identified best practices confirm that extracurricular activities contribute to the internationalization of the educational process and the formation of an academic identity open to pluralism, preparing students for the challenges of globalization and European integration.

10. Sustainable implementation of extracurricular strategies requires an integrated institutional vision, continued organization of thematic activities, creation of student clubs and circles, recognition of student involvement, and assessment of impact, in order to consolidate a durable architecture for intercultural competence and language skills.

Recommendations

1. **Develop a structured model of extracurricular activities (EA)** tailored to the needs of higher education and aligned with intercultural and linguistic training objectives, integrating thematic activities, intercultural projects, and international collaborative experiences.

2. **Evaluate the impact of EA on intercultural competence development** using tools that measure linguistic, sociocultural, and behavioural progress, to optimize teaching and organizational strategies.

3. **Continue and diversify extracurricular activities**, including debate clubs and thematic circles, to reinforce lifelong learning, student autonomy, and the interdisciplinary integration of intercultural competencies.

4. **Provide ongoing professional development for faculty** in interactive and action-oriented methods to support the development of students' critical thinking, negotiation skills, and intercultural competencies.

5. **Promote internationalization and leverage multilingual experiences** through institutional collaborations, academic mobility, and joint projects, contributing to the formation of students' European and global identities.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Al Sumait, I., Al Jimaan, N., Al Hussaini, M., & Al Shammari, Z. (2023). Evaluating multicultural educational experiences and intercultural communication competence in an Arab context. *Journal of Intercultural Communication*, (59), 1–77.

Barrett, M. (2013). *Interculturalism and multiculturalism: similarities and differences.* Strasbourg: Council of Europe Publishing.

Barrett, M. (2018). How schools can promote the intercultural competence of young people. *European Psychologist*, 23(1), 93–104. https://doi.org/10.1027/1016-9040/a000319

Bertelsmann Stiftung. (2006). *Intercultural competence – The key competence in the 21st century?* Gütersloh: Bertelsmann Stiftung.

Byram, M. (1997). *Teaching and assessing intercultural communicative competence.* Clevedon: Multilingual Matters.

Byram, M., & Wagner, M. (2018). *Making intercultural learning happen.* Multilingual Matters.

Cadrul european comun de referinţă pentru limbi: învăţare, predare, evaluare/Comitetul Director pentru Educaţie „Studierea limbilor şi cetăţenia europeană" (2003). Chişinău, *Firma editorial-poligrafică „Tipografia Centrală".*

Council of Europe. (2018). *Reference framework of competences for democratic culture.* Strasbourg: Council of Europe Publishing.

Deardorff, D. K. (2006). Identification and assessment of intercultural competence as a student outcome of internationalization. *Journal of Studies in International Education*, 10(3), 241–266. https://doi.org/10.1177/1028315306287002

Deardorff, D. K. (2009). *The SAGE handbook of intercultural competence.* Thousand Oaks, CA: SAGE.

Dewey, J. (1938). *Experience and education.* New York, NY: Macmillan.

Fantini, A. E. (2000). A central concern: Developing intercultural competence. Brattleboro, VT: *School for International Training*.

Huang, L. (2023). Developing intercultural competence through a cultural metacognition-featured instructional design in English as a foreign language classrooms. *Frontiers in Psychology*, 14, 1126141. https://doi.org/10.3389/fpsyg.2023.1126141

Kolb, D. A. (1984*). Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

Pîrlog, A., & Rusu, D. (2023). Globe – Assessment tool of the impact of national culture on management in the context of globalization. In *Multilingvism și Interculturalitate în Contextul Globalizării*, 61–74. https://doi.org/10.53486/9789975147835.05

Rusu, D. (2023). The role of extracurricular activities in foreign languages for intercultural competence acquisition. In *Multilingvism și Interculturalitate în Contextul Globalizării*, 100–139). https://doi.org/10.53486/9789975147835.08

Rusu, D. & Amorțitu, A. (2024). Promovarea valorilor europene în ASEM prin activități extracurriculare în limba franceză. In *Multilingvism și Interculturalitate în Contextul Globalizării,* 35–52. https://doi.org/10.53486/micg2024.05

Spitzberg, B. H. & Cupach, W. R. (1984). *Interpersonal communication competence.* Beverly Hills, CA: Sage.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Mapping Albania's Cultural Heritage: A Spatial and Typological Analysis of Tangible and Intangible Assets

Mishela RAPO [1*]

ORCID 1: 0009-0000-9263-0146
[1]MSc. Mishela Rapo, European University of Tirana, Faculty of Economics, Business, and Development, Department of Management and Marketing
mishelarapo@gmail.com (Responsible Author)

Abstract

This study analyzes the spatial distribution and typological composition of Albania's cultural heritage, drawing on data from the national inventory of tangible and intangible assets. Using a descriptive-analytical approach supported by Excel-based data processing, the research provides a comparative overview of heritage representation across the country. Findings reveal that tangible heritage constitutes the most comprehensively documented component of Albania's cultural landscape. Monuments, archaeological sites, historical architecture, and religious structures collectively account for more than two-thirds of all recorded elements. These assets are widely represented across regions, with the highest concentrations in Gjirokastër, Berat, Vlorë, Tirana, and Korçë, reflecting their enduring historical and architectural significance and their potential for heritage-based tourism development. In contrast, intangible heritage appears significantly underrepresented in the national register. The recorded data include only three regions, Gjirokastër, Korçë, and Shkodër, where traditional crafts, polyphonic music, rituals, and gastronomy are officially recognized as cultural assets. This limited spatial scope highlights major gaps in the systematic documentation and territorial integration of living heritage. The resulting imbalance between tangible and intangible heritage underscores the need for a more comprehensive and geographically inclusive inventorying framework. The study recommends the development of an integrated geo-information system that would enable more accurate mapping, monitoring, and policy coordination of cultural assets. Such an approach would strengthen Albania's capacity to preserve, promote, and manage its diverse heritage, ensuring that both material monuments and living traditions contribute to sustainable regional development and cultural identity preservation.

Keywords: *Albania; cultural heritage; cultural categories; spatial distribution; geo-information system; heritage documentation*

1. Introduction

Cultural heritage constitutes one of Albania's most valuable national resources, shaping collective identity while offering significant opportunities for sustainable tourism and local development (Rapo & Kruja, 2024). In recent years, the growing recognition of culture as a development driver has elevated the importance of documenting and understanding heritage assets not only for preservation but also for their potential contribution to economic growth and place branding (Perry, 2023; Rapo & Zenelaj, 2025). Despite the increasing emphasis on heritage in national and international strategies, comprehensive analyses of Albania's cultural inventory remain scarce. Most existing studies address individual heritage categories or local case studies, while systematic, data-based evaluations of both tangible and intangible assets are limited (Brokaj, 2024; Kruja & Berberi, 2019; Bashi, 2015). This gap restricts the ability of policymakers and tourism planners to understand how cultural resources are spatially distributed, legally protected, and thematically classified across the country. Moreover, integrating cultural heritage into tourism strategies requires a clear understanding of its quantitative structure and regional dynamics. This study

addresses an empirical, methodological, and contextual research gap in Albania's cultural heritage analysis. It offers the first nationwide, data-based examination of both tangible and intangible assets, highlighting regional disparities and documentation gaps. By applying a descriptive-analytical approach and recommending GIS integration, the study contributes to more effective heritage mapping, policy planning, and sustainable cultural management.

Literature Review

Albania's Cultural Potential

Albania possesses one of the most diverse cultural landscapes in Southeast Europe, shaped by millennia of human habitation and intercultural exchange. Scholars have emphasized that the country's geographic position, between East and West, has produced a unique synthesis of Illyrian, Byzantine, Ottoman, and Mediterranean influences (Doempke, 2016; Vietti, 2019; Sawicka, 2013). This cultural hybridity has endowed Albania with an exceptional wealth of both tangible and intangible heritage resources that extend across its urban centers, coastal zones, and rural territories (Rapo & Zenelaj, 2025). The national and international academic literature increasingly links this cultural diversity to sustainable economic and social development. As Bellos et al. (2022) argue, heritage-based tourism has emerged as one of Albania's strongest comparative advantages, providing a bridge between cultural preservation and market-oriented growth. However, despite its potential, the sector remains under-researched and under-utilized due to fragmented data systems, insufficient documentation, and limited community participation in heritage management (Dollma, 2010 Dollani et al., 2016; Dobjani et al., 2025). Strengthening heritage governance and integrating local communities are thus essential for transforming cultural assets into sustainable tourism resources (Seidl, 2014; Bashi, 2015).

Tangible Cultural Heritage

Albania's tangible cultural heritage reflects millennia of artistic, architectural, and religious development. The country's earliest UNESCO recognition dates to 1992, when the archaeological site of Butrint was inscribed on the World Heritage List. Situated in southern Albania, Butrint contains remains from the Hellenistic, Roman, Byzantine, and Venetian periods, including a Greek theater, Roman baths, and a medieval fortress-an exceptional testimony to the continuity of Mediterranean civilizations (Doempke, 2016; Wilkes, 2008). In 2005, Gjirokastër, known as the "city of stone," was added to the World Heritage List for its well-preserved Ottoman-era houses, two-story stone dwellings, and bazaar architecture. Three years later, in 2008, the historic center of Berat-the "city of a thousand windows"-was incorporated, forming the joint inscription "Historic Centres of Berat and Gjirokastër." Together, these cities illustrate the coexistence of Christian and Muslim communities and the synthesis of Byzantine, Ottoman, and vernacular design (Vietti, 2019). In 2017, Albania's participation in the multinational property Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe expanded its recognition to include natural heritage. Two years later, in 2019, the Albanian section of the Natural and Cultural Heritage of the Ohrid Region-shared with North Macedonia-was also inscribed on the World Heritage List. This site encompasses archaeological remains and the early Christian church of Lin near Pogradec, reflecting the region's enduring sacred landscape (UNESCO World Heritage

Centre, n.d.). Beyond the UNESCO-listed monuments, Albania's national register records 3,381 tangible assets, including urban ensembles, monasteries, mosques, bridges, and water mills (Ministry of Tourism and Environment, nd). More than 60 percent of these are designated as first- or second-category protected monuments, underscoring their cultural and geographic breadth (Bellos et al., 2022). Religious structures such as the Church of St. Mary in Apollonia, the Lead Mosque in Shkodër, and the Ardenica Monastery in Fier demonstrate Albania's historic interfaith coexistence (Murzaku, 2015). Despite this wealth, several studies note persistent challenges in conservation management, including maintenance deficiencies and incomplete documentation (Bashi, 2015; Dollani et al., 2016). Effective preservation requires integrated strategies among public institutions, local governments, and the private sector to ensure systematic care and sustainable reuse. When properly managed, Albania's tangible heritage serves as both a foundation of national identity and a driver of cultural tourism (Seidl, 2014).

Intangible Cultural Heritage

Parallel to its material monuments, Albania possesses a vibrant intangible cultural heritage that continues to shape community life through music, ritual, craft, and gastronomy. The country's earliest recognition in this field came in 2005, when Albanian Folk Iso-Polyphony was proclaimed by UNESCO World Heritage Centre (n.d.) as a Masterpiece of the Oral and Intangible Heritage of Humanity. This multipart vocal tradition, centered in southern Albania, represents one of Europe's oldest surviving polyphonic systems and is performed at weddings, funerals, and local festivals (Wheeler, 2018; Lici, 2023). In 2022, UNESCO World Heritage Centre (n.d.) inscribed the Xhubleta-the traditional bell-shaped skirt and its associated artisanal techniques from the Northern Albanian Alps-on the List of Intangible Cultural Heritage in Need of Urgent Safeguarding. This recognition highlights both the craftsmanship and the symbolic role of the Xhubleta as an expression of female identity and cultural continuity. One year later, in 2023, UNESCO World Heritage Centre (n.d.) added the Kcimi dance of Tropojë, a northern folk performance emphasizing rhythm and group coordination, to the Representative List of the Intangible Cultural Heritage of Humanity. This was followed by Albania's participation in multinational nominations such as Transhumance, the traditional seasonal migration of livestock across Mediterranean mountain routes, emphasizing ecological and pastoral knowledge shared across regions. According to national records, Albania lists 99 intangible elements, nearly half of which pertain to traditional craftsmanship (Bushati, 2017; Kruja & Berberi, 2019). Music and performing arts form another central pillar, encompassing civic songs of Shkodër, Serenata Korçare, and Sazet e Vlorës, each representing unique local soundscapes. Seasonal festivals such as Dita e Verës (Summer Day) in Elbasan and culinary practices like Lakror me Saç continue to sustain local identity through collective celebration and shared knowledge (Laurìa et al., 2020). As Novik (2020) and Rapo and Zenelaj (2025) argue, safeguarding intangible heritage requires not only preservation but activation-through festivals, craft fairs, educational workshops, and experiential tourism. Promoting these living traditions alongside architectural monuments enhances Albania's cultural diversity, economic sustainability, and national identity, ensuring that heritage remains a dynamic force connecting past and present.

2. Materials and Methods

This study used a descriptive-analytical approach based on secondary data from Albania's National Cultural Heritage Inventory, the official register documenting both tangible and intangible assets. The dataset, updated to 2025, included 3,381 tangible and 99 intangible elements. Tangible heritage data were first organized by category (architecture, archaeology, religion, nature, etc.), legal protection status (Cultural Monument I, II, Protected Area, etc.), and geographical distribution (region and municipality). This allowed for comparison of heritage density and typology across regions. Intangible heritage data were then separated and grouped by domain, such as crafts, music, rituals, gastronomy, professions, and oral expressions. Each element was coded thematically to identify patterns and enable comparison between regions. Quantitative analysis was conducted in Microsoft Excel, using frequencies and percentages to calculate the distribution of heritage types and their spatial concentration. Tables were created to illustrate these results clearly. Finally, an interpretive synthesis helped connect the numerical findings with broader cultural and regional contexts. This step-by-step process, from data collection and classification to analysis and interpretation, ensured accurate, comparable, and meaningful insights for improving heritage documentation, management, and sustainable tourism planning.

3. Findings and Discussion

The analysis of Albania's national heritage inventory provides a comprehensive overview of the country's tangible and intangible cultural resources, revealing their typological diversity, geographical distribution, and protection status. The results demonstrate that cultural heritage constitutes the dominant component of Albania's tourism and identity assets, both in terms of quantity and spatial representation.

The national inventory includes 3,381 tangible elements, encompassing monuments, archaeological sites, traditional architecture, natural assets, and other protected areas. This large dataset illustrates the remarkable density of heritage resources across the Albanian territory. The data reveal that cultural heritage forms the majority of the inventory, reflecting the deep interconnection between history, identity, and landscape. The analysis by region shows that heritage assets are widely dispersed, though a clear concentration exists in southern Albania. The Gjirokastër region leads with 697 elements (20.6%), followed by Berat (16.8%), Vlorë (10.9%), Tirana (10.5%), and Korçë (9.0%). These regions correspond to major historical centers with rich urban architecture and strong cultural identity. Gjirokastër and Berat stand out as UNESCO-listed cities with preserved urban cores, while Vlorë and the surrounding southern area include important coastal, archaeological, and religious sites, such as the ancient city of Butrint. Tirana's high representation reflects its dense concentration of urban monuments, museums, and Ottoman-modern heritage layers. The regional pattern highlights a clear southern and central dominance, with heritage often clustered in cities historically linked to trade, religion, and culture. In terms of classification, cultural tourism resources dominate with 73.7% of all elements, confirming that heritage-related assets are the backbone of Albania's tourism potential. Nature tourism represents 21.5%, encompassing landscapes, lakes, and natural parks, while smaller shares belong to special interest (3.4%), coastal (1.2%), and event tourism (0.2%). This structure indicates that while Albania's natural beauty is substantial, it is the cultural layer that provides the greatest thematic

depth and distinctiveness for visitors. The subcategory analysis offers further insight into the composition of the national inventory. Heritage and architecture account for 50% of all recorded elements, representing castles, museum towns, and traditional houses. Natural resources follow with 18.7%, while archaeological sites make up 11.4%. Religious heritage comprises 9.4%, confirming the importance of sacred architecture in Albania's cultural landscape. Smaller yet significant portions belong to speleological sites (3.4%), museums and memorials (3%), and mountain or coastal assets (under 2% each). This typological diversity illustrates how Albania's cultural heritage extends beyond monumental structures to include everyday expressions of human interaction with the landscape. The protection framework of heritage assets is relatively robust. Cultural Monuments of Category I-those of national importance-represent 36.9% of all recorded elements, while Category II-regional or local significance-comprises 28.9%. Natural Monuments account for 20.5%, and Protected Areas for 5.9%. When aggregated, Cultural Monuments (I+II) constitute 65.8% of the entire inventory, underscoring the dominance of cultural over natural heritage within Albania's protected landscape. This structure shows a mature legal recognition of built heritage, though it also indicates a relative underrepresentation of natural sites in formal protection schemes. At the municipal level, the most represented areas include Berat (14%), Gjirokastër (13.4%), Tirana (8.7%), Shkodër (5.4%), and Elbasan (3.4%). These cities form the backbone of Albania's heritage network, containing key examples of urban fortifications, civic architecture, and religious landmarks. UNESCO recognition further enhances their international significance: Butrint (1992), Berat (2005), and Gjirokastër (2005) are designated as World Heritage Sites, forming the cornerstones of Albania's global cultural identity (Table 1).

Table 1. Summary of Albania's tangible cultural heritage (N=3,381) (Ministry of Tourism and Environment, n.d.)

Main dimension	Core values	Number	Percentage (%)	Observations / Examples
Total elements	–	3,381	100.0	Registered in the national database
Distribution by regions (Top 5)	Gjirokaster	697	20.6	High concentration of monuments and traditional architecture
	Berat	569	16.8	The museum city of Berat (UNESCO) dominates the register
	Vlore	369	10.9	Butrint (UNESCO), archaeological and coastal sites
	Tirana	354	10.5	Urban monuments, museums, Ottoman & modern heritage
	Korce	305	9.0	Museum city, Byzantine church, serenade and architecture
Main categories	Cultural Tourism	2,492	73.7	Dominates over 2/3 of the register

	Nature Tourism	726	21.5	Includes landscapes, natural resources, highlands
	Special interest tourism	114	3.4	Caves, unique practices
	Coastal Tourism	42	1.2	Beaches, marine attractions
	Event Tourism	6	0.2	Rare events related to inheritance
Main subcategories	Heritage/Architecture	1,690	50.0	Castles, museum towns, traditional houses
	Natural resources	633	18.7	Lakes, water sources, natural parks
	Historical/Archaeological	384	11.4	Butrint, Apollonia, ancient sites
	Religious	317	9.4	Churches, mosques, tekkes, monasteries
	Speleology	115	3.4	Protected caves (Pëllumbas, etc.)
	Other cultural sources	101	3.0	Museums, memorials, ethnographic centers
	Mountain	50	1.5	Traditional roads, iconic mountains
	Coast/Beach	44	1.3	Protected coves, bays and beaches
Legal protection statuses	Cultural Monument I	1,248	36.9	Monuments of high national value
	Cultural Monument II	977	28.9	Monuments of regional/local value
	Natural Monument (MN III)	694	20.5	Many caves, natural springs
	Protected area	198	5.9	National parks, protected areas
	Cultural Monuments (I+II)	2,225	65.8	Two-thirds of the register is related to cultural heritage
Most represented municipalities (Top 5)	Berat	474	14.0	Historical and religious monuments of the museum city
	Gjirokaster	453	13.4	Museum city, castles and characteristic neighborhoods
	Tirana	294	8.7	Urban monuments, national museums
	Shkoder	181	5.4	Rozafa Castle, religious and civic heritage
	Elbasan	116	3.4	Elbasan Castle, archaeological ruins
UNESCO key elements	Butrint (1992); Berat & Gjirokastra (2005)	–	–	UNESCO World Heritage, major potential for international cultural tourism

The recorded data on intangible cultural heritage attributes cover just three regions, Gjirokastër, Korçë, and Shkodër, with a total of only 99 registered items. Two Albanian traditions inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity, Isopolyphony

(Iso-polyphonic folk singing of southern Albania, inscribed 2008) and the Xhubleta (Artisanal skills and women's traditional dress from the Northern Albanian Alps, inscribed 2022), anchor the regional identity of Gjirokastër and Shkodër respectively. Together, these elements illustrate Albania's north–south cultural polarity-one musical and communal, the other artisanal and symbolic-demonstrating how regional specificity contributes to the nation's broader cultural narrative (Table 2).

Table 2. Distribution of Intangible Cultural Heritage Attributes by Region (Register - Intangible Cultural Heritage, n.d.)

Region	Number of Attributes	Percentage of Total (%)	Dominant Heritage Domains
Korçë	37	37.4%	Cuisine, Crafts, Music
Shkodër	32	32.3%	Music, Oral Traditions, Craftsmanship
Gjirokastër	39	39.4%	Rituals, Music, Domestic Heritage
Total	99	100%	-

With 37 recorded attributes (37.4%), Korçë demonstrates a balance between culinary, artisanal, and musical traditions. Culinary practices such as Festa e Lakrorit (Pie Festival), Tava e Koranit (Trout Casserole), and Buka me Qiqra (Chickpea Bread) highlight domestic creativity rooted in agrarian life. Artisanal craftsmanship remains vital, represented by trades such as copperware (kujunjxhiu), pottery, and textile work. Meanwhile, musical traditions like Serenata Korçare and Sazet e Korçës reflect the city's urban refinement and long-standing artistic sensibility. The convergence of craft, cuisine, and song positions Korçë as a hub of cultural synthesis in southeastern Albania. Shkodër's 32 attributes (32.3%) reveal a distinct northern character emphasizing music, oral expression, and craftsmanship. The Xhubleta stands as the region's emblematic heritage element, symbolizing female artistry and ancestral continuity. Musical forms such as Ahengu Shkodran, Kënga Qytetare Shkodrane, and Vallet e Pukës demonstrate a vibrant interplay between folk and urban musical traditions. Handicrafts-including filigree work, Venetian masks, and textile weaving-reflect cross-Mediterranean influences that have historically shaped Shkodër's cultural landscape. Additionally, oral traditions, such as the Gjama e Burrave (Men's Lament) and Proverbat e Dukagjinit (Proverbs of Dukagjin), preserve a strong moral and philosophical ethos rooted in northern customary law and community solidarity. Gjirokastër records 39 attributes (39.4%), marking it as the most diverse region in the dataset. Its heritage is defined by music, ritual, and domestic traditions. Isopolyphony remains a cornerstone of regional identity, performed both in local settings and during the National Folklore Festival of Gjirokastër. Culinary practices such as Trahanaja (fermented grain soup), Gliko e Arrës (walnut preserve), and Llokume me Bajame (almond sweets) reflect household continuity and intergenerational transmission. Rituals like Riti i Llazarëve (Lazarus Day rite) and Paja e Nuses (bride's dowry preparation) express themes of fertility, transition, and social cohesion. Collectively, these practices underscore Gjirokastër's role as a southern stronghold of Albanian musical, ritual, and domestic heritage. The classification of Albania's intangible cultural heritage reveals a diversified structure dominated by traditional crafts and artisanal skills, which account for 30.3% of all

registered elements. This category underscores the enduring importance of manual expertise in practices such as weaving, wood carving, embroidery, and musical instrument making, reflecting both economic and aesthetic dimensions of cultural transmission. Traditional knowledge and practices represent 20.1% of the total, encompassing activities tied to everyday life, seasonal cycles, and material culture, such as food preservation, and wood decoration. Traditional music, song, and dance (17.2%) illustrate the regional distinctiveness of Albania's performing arts, including iso-polyphony and saze ensembles, which have attained international recognition. Gastronomy and food preparation (15.2%) further highlight the role of culinary heritage in social cohesion and identity expression, while rituals, ceremonies, and customs (12.1%) preserve symbolic and spiritual meanings embedded in local traditions. Oral traditions and expressions constitute the smallest proportion (5.1%), suggesting a potential underrepresentation of verbal heritage and narrative forms within the current documentation framework (Table 3). Overall, the data reveal a predominance of tangible, skill-based heritage domains, while knowledge systems and oral expressions appear less documented, indicating the need for more systematic recording and safeguarding of these vulnerable cultural forms.

Table 3. Distribution of Intangible Cultural Heritage Attributes by Category (Register - Intangible Cultural Heritage n.d.)

Category	Examples	Count	Percentage (%)
Traditional Music, Song, and Dance	Iso-polyphony, Saze ensemble of Korça, Saze of Përmet, Shkodra urban song, Aheng of Shkodra, Vlach song of Drenova, Devoll folk song, Serenades of Korça, Singing dances of Ersekë, Dances of Puka, Dances of Dropull, Women's song of Selo, "Majë krahit" song	17	17.2%
Rituals, Ceremonies, and Customs	Korça wedding ceremony, Shkodra wedding ceremony, Childbirth ritual, Lazarus ritual, Spring bracelet ritual, Bride's water ritual, Coffee stone ritual, Funerary ritual, "Poganiqe" ritual, Men's mourning lament (Gjama e burrave)	12	12.1%
Traditional Crafts and Artisanal Skills	Traditional costume making, Weaving on looms, Embroidery, Wool processing, Wood carving, Filigree work, Pottery, Blacksmithing, Saddlery, Tinsmithing, Stone carving, Mask making, Tobacco processing (Sheldia), Musical instrument making (çifteli, sharkia)	30	30.3%
Gastronomy and Food Preparation	"Lakror" pie festival, "Lakrori with corn", "Tava e koranit" (carp dish), "Supa pasha qofte" (meatball soup), Preparation of walnut preserves, Rosewater distillation, Baking under "saç", "Trahana" preparation, Almond Turkish delight, Winter preserves (zahiretë e dimrit)	15	15.2%
Oral Traditions and Expressions	Philosophical proverbs of Dukagjin, Monophonic recitation (Logatja), "Rusticat" of Polena, "Rosicat" of Boboshtica, "Arapët" of Polena" folk narrative	5	5.1%
Traditional Knowledge and Practices	Preparation of dowry (Paja e nuses), Meat drying, Washing in "dërstilë" (wooden washing trough), Grain milling in water mills, Decorative wood carving, Application of motifs in wood, Traditional ceiling carving, Hand knitting and crocheting, Production of salted gherkins	20	20.1%
Total		**99**	**100%**

The analysis highlights a pronounced imbalance between the documentation of tangible and intangible cultural heritage in Albania. While tangible assets-such as monuments, archaeological sites, and historical architecture-are comprehensively recorded and spatially well represented, intangible heritage remains significantly under documented. The national inventory includes only 99 intangible elements, concentrated in three regions: Gjirokastër, Korçë, and Shkodër. This narrow geographical scope fails to reflect the country's rich diversity of living traditions, which extend far beyond these administrative areas. The limited representation points to structural and methodological shortcomings. The absence of systematic field research and irregular data updates have hindered the continuous documentation of non-material practices. Moreover, intangible heritage often depends on oral transmission and community participation-factors that are difficult to capture within conventional bureaucratic recording systems. A comparison with UNESCO's Intangible Cultural Heritage Lists reveals further gaps. While some internationally recognized elements, such as iso-polyphony, are included in the national register, several others are missing. For example, transhumance practices, which are recognized and protected by UNESCO, are not documented in the national inventory. Addressing this disparity requires not only improved data management but also a conceptual shift in heritage governance-from a monument-centered perspective toward an inclusive model that values living traditions equally. Developing a geo-referenced inventory and establishing stronger collaboration with local communities would help integrate intangible heritage into Albania's broader cultural policy and development strategies.

4. Conclusion and Recommendations

Albania's heritage management framework demonstrates clear strengths in the documentation and protection of tangible assets but remains limited in its ability to capture the full scope of intangible cultural heritage. The imbalance between material and living heritage reflects institutional priorities that have historically favored monuments and architecture over community-based cultural expressions. Bridging this gap requires a more integrated and participatory approach to heritage governance. Developing a geo-referenced cultural heritage information system (GIS) would provide a unified platform for documenting, comparing, and monitoring both tangible and intangible assets. Equally important is the establishment of systematic field research programs and stronger collaboration among state institutions, academic bodies, and local communities to ensure the authenticity and continuity of living traditions. Embedding intangible heritage within national cultural policy would enhance regional representation, support identity preservation, and stimulate sustainable cultural tourism. Such an inclusive approach would not only strengthen Albania's alignment with UNESCO principles but also secure sustainable tourism.

Thanks and Information Note

The article complies with national and international research and publication ethics. The article was written by a single author. There is no conflict of interest.

References

Bashi, E. (2015). Cultural Heritage of Albania – A Fabulous Economic Source for the Sustainable Economic Development of Tourism. *Procedia - Social and Behavioral Sciences*, 188. https://doi.org/10.1016/j.sbspro.2015.03.342

Bellos, C., Fudos, I., Kita, A., Kolovou, S., Nitsiakos, V., Patelou, D., Stefanou, K., & Stergios, G. (2022). Virtualand: An Immersive Virtual Experience for Cultural and Natural Heritage Sites. *Communications in Computer and Information Science*, 1574 CCIS. https://doi.org/10.1007/978-3-031-20253-7_15

Bushati, B. (2017). Handicrafts as an opportunity for economic development and sustainable tourism: Shkodra case study. *Marketing and Branding Research*, 4(1). https://doi.org/10.33844/mbr.2017.60315

Dobjani, E., Bushati, V., & Shumka, L. (2025). Strengthening Tradition: A Pathway to Preservation and Revitalization in Albanian Architecture. https://doi.org/10.56831/PSEN-06-183

Doempke, S. (2016). The UNESCO World Heritage and the Role of Civil Society. *Proceedings of the International Conference Bonn 2015.* World Heritage Watch, Berlin.

Dollani, A., Lerario, A., & Maiellaro, N. (2016). Sustaining cultural and natural heritage in Albania. *Sustainability (Switzerland)*, 8(8). https://doi.org/10.3390/su8080792

Dollma, M. (2010). Cultural Heritage of Albania and Geo-information establishment need for better promotion and management. *Science and Technology for Cultural Heritage:* 19, 1/2, 2010, 1000-1011.

Kruja, AD, & Berberi, E. (2019). Tourism and handicraft industry: Opportunities and challenges of operating in the Albanian market. *In Cases on Global Leadership in the Contemporary Economy*. https://doi.org/10.4018/978-1-5225-8088-1.ch007

Lici, E. (2023). Music education in first half of 20th century in Albania: Its institution and contribution to urban music life. *Rast Muzikoloji Dergisi*, 11(2). https://doi.org/10.12975/rastmd.20231129

Ministry of Tourism and Environment. (nd). Retrieved September 6, 2025, from https://turizmi.gov.al/burimet-turistike/

Novik, A. (2020). Gjirokastra folklore festival as the main ritual event in Albanian cultural life at the beginning of the 21st century. *Yearbook of Balkan and Baltic Studies*, 3(1). https://doi.org/10.7592/YBBS3.08

Perry, M. (2023). Role of cultural heritage preservation in destination branding and tourist experience enhancement. *Hospitality and Tourism Journal, 1(1),* 36-47. Retrieved from https://forthworthjournals.org/journals/index.php/HTJ/article/view/69

Rapo, M., & Kruja, D. (2024). The Cultural Tourism Potential of Albania: An Essential Driver for Growth. *In EMIDWORLD 2nd International Congress on Economics Public Finance Business & Social Sciences* (pp. 125-139).

Rapo, M., & Zenelaj, B. (2025). Psychological Barriers to Sustainable Tourism Choices: A Case from the Albanian Tourism Industry. *Albanian Journal of Economy and Business*, 1FUTURE Issue: Climate and Sustainability, 1(1), 222–242.

Rapo, M., & Zenelaj, B. (2025). Tourism as a catalyst for economic development in Albania: A pathway to EU accession. *ECONOMICUS*, 24(1). 72-91

Register - Intangible Cultural Heritage. (nd). Retrieved September 6, 2025, from https://registritkj.al/registriti/

Sawicka, I. (2013). A Crossroad Between West, East and Orient–The Case of Albanian Culture. In Colloquia Humanistica (No. 2, pp. 97-113). *Instytut Slawistyki Polskiej Akademii Nauk*.

Seidl, A. (2014). Cultural ecosystem services and economic development: World Heritage and early efforts at tourism in Albania. *Ecosystem Services*, 10. https://doi.org/10.1016/j.ecoser.2014.08.006

UNESCO World Heritage Centre. (n.d.). Albania – Convention concerning the protection of the world cultural and natural heritage. Retrieved October 28, 2025, from https://whc.unesco.org/fr/etatsparties/al

Vietti, F. (2019). Unesco and the dictator cultural heritage, totalitarianism and mobility in Albania. In Quaderni Storici (Vol. 54, Issue 2). https://doi.org/10.1408/96905

Wheeler, PA (2018). Traditional polyphony: Multipart singing in world cultures. *The Journal of the Acoustical Society of America,* 143(3_Supplement). https://doi.org/10.1121/1.5036045

Wilkes, J. (2008). Eternal Butrint. A UNESCO World Heritage Site in Albania. Antiquity, 82.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Colonial Loftiness in Bengal: Form, Space and Spatial Organization in Three Colonial Houses at Narayanganj

Shahriar Hasan Mridha RATUL [1]*

ORCID 1: 0009-0002-0503-0076
[1] Principal Researcher, Mridha's Research Institute (MRI), Narayanganj; Department of Architecture, Southeast University (SEU), Dhaka, Bangladesh
godhulylogonee@gmail.com (Responsible Author)

Moukuri MOHIM [2]

ORCID 2: 0009-0008-0441-3677
[2]Research Assistant, Mridha's Research Institute (MRI), Narayanganj; Department of Architecture, Southeast University (SEU), Dhaka, Bangladesh
mmoukuri@gmail.com

Ahsan REZWAN [3]

ORCID 3: 0009-0000-2358-1897
[3]Research Assistant, Mridha's Research Institute (MRI), Narayanganj; Department of Architecture, University of Asia Pacific (UAP), Dhaka, Bangladesh
ahsanrezwan2ar@gmail.com

Abstract

The colonial period in Bengal (1757–1947) profoundly transformed the architectural landscape, introducing hybrid typologies that reflected a dialogue between European grandeur and indigenous spatial sensibilities. This study explores the form, space, and spatial organization of three exemplary colonial-era houses in Narayanganj, a prominent river port and industrial hub during British rule. Through architectural documentation, spatial mapping, and morphological analysis, the paper examines how colonial domestic architecture in this region negotiated climatic adaptation, social hierarchy, and cultural identity. The selected houses—representing distinct socio-economic and stylistic backgrounds—illustrate variations in planning concepts, façade articulation, and functional zoning. While the external expressions reveal neoclassical and Indo-Saracenic influences, the internal arrangements reflect a nuanced response to Bengali lifestyle and environmental demands, such as cross-ventilation, verandah transitions, and courtyard-centric planning. The study identifies a spatial duality—the coexistence of formality and intimacy, where the imported ideals of order and symmetry were localized through vernacular materiality and living patterns. By analyzing these architectural configurations, the paper contributes to understanding the colonial negotiation between power, culture, and space, offering insight into the evolution of domestic architecture in Bengal. The findings not only emphasize the architectural significance of Narayanganj's colonial heritage but also underscore the urgent need for heritage conservation and adaptive reuse to safeguard these endangered cultural assets for future generations.

Keywords: Colonial architecture, Narayanganj, spatial organization, domestic heritage, form and space

1. Introduction

The built-environment of the Bengal region during the British colonial era presents a compelling terrain for architectural history and spatial analysis. Within the period of British rule, the architecture of Bengal became not merely a technical or aesthetic exercise but a marker of power, identity, and cultural negotiation. As one commentary succinctly puts it, "colonial architecture …

evolved when colonists created a fusion by blending the architectural vocabulary of their country of origin with the design principles of the region they colonized" (The Daily Star, 2018). In the provincial towns of Bengal, domestic residences of landed elites and colonial officials emerged as particularly rich sites for study. Living in the Periphery: Provinciality and Domestic Space in Colonial Bengal investigates the architectural transformations of such houses in nineteenth-century Bengal, observing that new forms of rural-urban mobility, shifting social relations, and colonial governance produced hybrid domestic spatial arrangements (Sengupta, 2007). Against this backdrop, this paper examines three colonial-era houses located in the district of Narayanganj to explore how loftiness—understood here as architectural grandeur, elevated status, and spatial prominence—is expressed through Form (façade, massing, materials), Space (rooms, volumes, circulation), and Spatial Organization (layout, hierarchy, internal/external relationships).

These houses illustrate how colonial domestic architecture in Bengal did not simply replicate European prototypes but negotiated local climate, construction traditions, and sociocultural needs. As studies of vernacular Bengal architecture observe, the region's domestic built-form has deep roots in climatic adaptation, social Organization, and local materiality (Hasan, 2010; Ahmed, 1984). At the same time, the colonial mansions and zamindar houses incorporated European classical detailing, large verandas, tall columns, and elevated foundations to express status and command—a phenomenon examined in the context of Dhaka's zamindar houses (Alam, 2019; Khan, 2006). Focusing on three specific houses in Narayanganj, this research adopts a comparative case-study approach to answer the following questions:

- In what manner do the houses express "loftiness" in their form and façade treatment?
- How are internal spatial volumes and circulation arranged to reflect colonial-era notions of hierarchy and representation?
- How is spatial organization between interior and exterior, private and public zones configured to manifest the social and power dynamics of the period?

In doing so, the paper contributes to the broader discourse on colonial domestic architecture in Bengal by emphasizing the lesser-studied provincial towns rather than the metropolitan capitals. Methodologically, the study is grounded in field surveys, measured drawings, photographic documentation, and archival research. The analysis draws on architectural theory of form and space (Ching, 2014), as well as postcolonial spatial studies, to interpret how built form becomes a vehicle of colonial ideology and local agency. As Sengupta argues, domestic house-forms in colonial Bengal are "typological models of colonial modernity" that reflect multiple overlapping spatial cultures (Sengupta, 2007). In sum, by interrogating the three colonial houses of Narayanganj through the lens of loftiness in form, space, and spatial Organisation, this paper seeks to uncover how architecture served as both a marker and mediator of colonial power and local adaptation. The findings aim to advance understanding of colonial domestic architecture in Bengal and have implications for heritage conservation and the adaptive reuse of such built assets.

1.1. Background / Context

The city of Narayanganj evolved into a prominent colonial river-port and industrial hub during British rule, shaping its architectural identity through the interplay of trade, power, and urban

expansion. The emergence of colonial residential architecture in Bengal reflected a unique synthesis between European stylistic ambition and local climatic, material, and cultural realities (Afzal, 2019). In particular, domestic buildings in colonial towns such as Narayanganj became physical expressions of social hierarchy and adaptation, embedding the grandeur of empire within vernacular construction logic. As *The Daily Star* (2018) notes, colonial architecture in Bengal "was charged with the explicit purpose of representing the empire itself," revealing how built form operated as a marker of both aesthetic and political dominance. The houses constructed by elite families thus provide an architectural lens through which colonial ideology and local agency may be examined in tandem.

1.2. Problem Statement

Despite extensive research on monumental colonial edifices such as courts, churches, and administrative buildings, comparatively little scholarly attention has been devoted to the domestic scale—particularly the lofty colonial residences that communicated both prestige and adaptation. In Narayanganj, a city historically shaped by European commercial activity, these houses remain under-documented and under-analyzed (Bengal Institute for Architecture, Landscapes & Settlements, n.d.). While a few regional studies have traced heritage houses in Barodi and surrounding areas (Tracing Colonial Footprints, 2024), a focused investigation into the form, space, and spatial organization of three representative colonial houses in Narayanganj has yet to be undertaken. This absence limits our understanding of how colonial spatial ideologies were translated into the intimate scale of domestic architecture.

1.3. Motivation / Significance

Investigating these colonial houses is vital for several reasons. First, they provide insights into how colonial culture negotiated with Bengali spatial traditions, producing hybrid typologies that reflect both aspiration and adaptation (Afzal, 2019). Second, given the rapid urban transformation of Narayanganj, such documentation supports the preservation of its fading architectural heritage (Bengal Institute for Architecture, Landscapes & Settlements, n.d.). Third, this study contributes to the discourse on colonial loftiness a concept that encapsulates both physical elevation and social superiority—as expressed through form, hierarchy, and circulation. Understanding these dynamics enriches broader theories of colonial domesticity and spatial hybridity (The Daily Star, 2018).

1.4. Research Objective / Aim

The primary aim of this paper is to analyze how colonial loftiness was manifested in the form, spatial organization, and hierarchy of three selected colonial houses in Narayanganj. Specifically, the research investigates (a) the geometric configuration of the houses, (b) the relationships between public, semi-private, and private zones, and (c) the adaptation of these spatial logics to climatic and cultural contexts. By mapping and diagramming the internal layouts, the paper seeks to reveal how colonial design principles interacted with local construction practices to produce a distinctive architectural identity.

1.5. Contribution / Novelty Statement

This research provides a comparative spatial analysis that moves beyond stylistic description, positioning these three houses as microcosms of colonial hybridity in Bengal. Unlike prior works that focus primarily on public institutions, this paper foregrounds the residential dimension of colonial architecture its negotiation between European order and Bengali domesticity (Tracing Colonial Footprints, 2024). The study introduces a typology of colonial house form specific to Narayanganj, expanding the architectural historiography of Bengal's provincial towns. Furthermore, the paper contributes a methodological framework combining field documentation, archival review, and spatial diagramming—offering replicable tools for heritage studies elsewhere.

1.6. Scope and Limitations

The scope of this study is limited to three accessible houses within Narayanganj that retain substantial elements of their original design. The analysis focuses on plan geometry, volumetric articulation, and spatial relationships rather than detailed conservation or sociological study of occupants. While the findings may illuminate broader patterns in Bengal's colonial domestic architecture, generalizations are made cautiously. Contemporary renovations are noted but not central to the analysis.

1.7. Paper Structure

The paper is organized as follows: Section 2 reviews relevant literature on colonial domestic architecture and theories of spatial hybridity. Section 3 describes the research methods, including documentation and spatial mapping. Section 4 presents the case studies and their comparative analysis. Section 5 discusses the findings in relation to the concept of colonial loftiness. Section 6 concludes with implications for heritage conservation and future research.

2. Materials and Methods:

This study used a combined field survey and archival research approach to document and analyze colonial-era domestic buildings. Fieldwork involved measuring dimensions, assessing building condition, taking photographs, and preparing quick sketches of important architectural elements. Archival materials such as municipal records, historic maps, old photographs, and jute-era directories were reviewed to understand historical context. The collected information was examined through typo-morphological analysis to identify common building types like courtyard houses, colonnaded villas, and bungalows. Qualitative spatial-syntax tools, including convex maps and justified graphs, were used to study integration, hierarchy, and social boundaries within the layouts. Climatic analysis assessed sun-path, wind flow, verandah depth, ceiling height, and ventilation strategies to evaluate environmental responsiveness. Finally, a comparative matrix was created to summarize recurring patterns in form, space, and organization across the studied buildings.

3. Case Study

3.1 Case A: Baitul Aman (c. 1939)

- **Location:** Chashara, Narayanganj

- **Historical context:** Late colonial Bengal, Partition-Era memories, Early Post-Independence Transformation
- **Original owner:** Khan Saheb Osman Alee



Figure 1. Colonial House: Baitul Aman

Form / Plan: A typical traditional residence features a symmetrical façade with a central portico. The plan is organized around a central hall, with rooms arranged on both sides in enfilade alignment. A courtyard/intermediate space enhances ventilation and circulation. Residential zones are kept separate from service blocks like kitchens and servant quarters. Wealthy homes commonly include a porte-cochère for sheltered arrival.

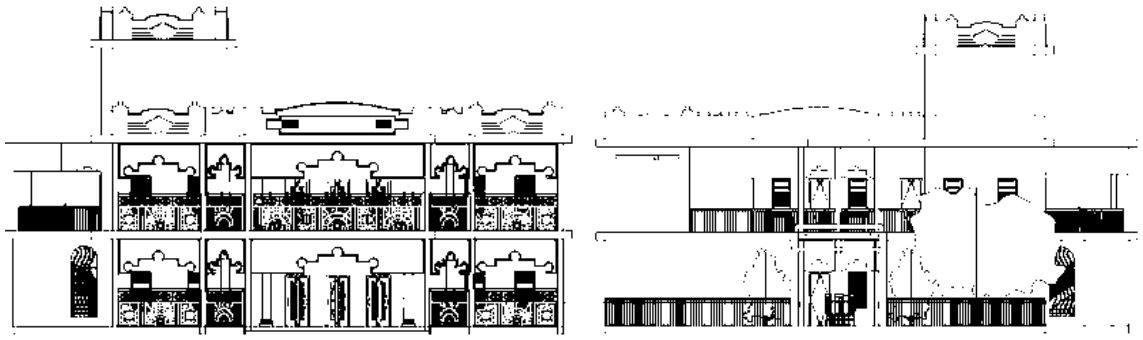


Figure 2. Front & back elevation of Colonial House: Baitul Aman (Fenestration)

Façade and Openings: The façade typically features classical columns (Doric, Ionic, or Corinthian) supporting a pediment and a cornice with dentils. Openings often include semicircular or segmental arches, with occasional cusped/Mughal forms in Indo-Saracenic designs. Houses commonly use tall French windows fitted with louvered shutters, as well as fanlights—either crescent-shaped or rectangular—above doors. Decorative elements include wrought-iron or cast-iron grills, railings, and balustrades along verandahs.

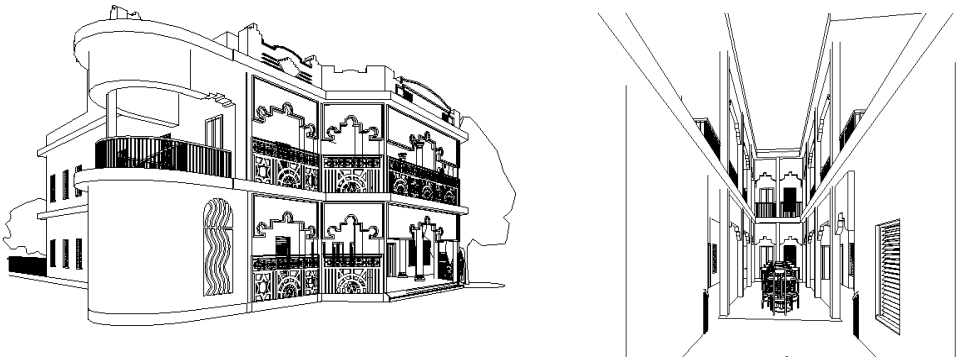


Figure 3. Axonometric view & central courtyard of Baitul Aman: Colonial House

Building Ornamentation: Ornamentation commonly includes stucco scrollwork, medallions, and cartouches, supported by angular pilasters and string courses that structure the façade. Arches are often highlighted with keystones, while dentils beneath the cornice add classical detailing. Rooflines frequently feature parapet balustrades. In later periods, Art Deco elements appear, such as sunburst motifs, horizontal banding, and distinctive circular porthole windows.

Climate Responses: Climate-responsive features include very high ceilings for heat dissipation and deep verandas/overhangs to protect from sun and rain. Buildings often use thick walls to maintain thermal comfort and rely on cross-ventilation created by opposite windows and doors. Additional airflow is ensured through ventilators, clerestory openings, and louvers.

Landscape & Gateway: Exterior settings typically include a small front garden or driveway leading to the house. The property is marked by an ornamental arch-gate with a boundary wall, often displaying a nameplate, crest or monogram, and sometimes a flagpole. Approaches are enhanced with formal entry landscaping, emphasizing symmetry and civic presence.



Figure 4. Left & right elevation of Baitul Aman: Colonial House

3.2 Case Study - B: Sardar House (Build: 1920 AD)

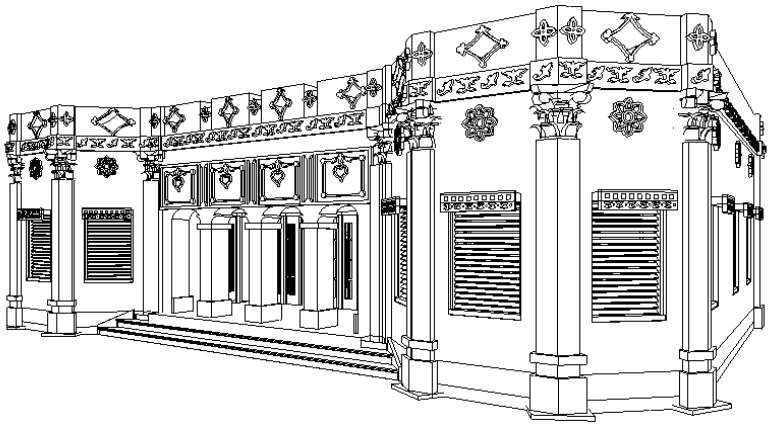


Figure 5. Perspectives view of colonial establishments – Sardar House

- **Location:** Nabiganj, Narayanganj
- **History:** History of Colonial Bengal
- **Owner:** Sardar Family
- **Origin:** 1920 AD

Figure Shows: Ground Floor Plan & Roof Floor Plan of Ancient Sardar House

Form and Plan: The form typically presents a symmetrical façade highlighted by a central front portico. The interior is organized around a central hall or drawing room, with adjoining rooms arranged in enfilade alignment. Many layouts include a courtyard or inner court for light and ventilation. The overall plan maintains functional separation between residential areas and service blocks, such as the kitchen, store, and servant quarters.

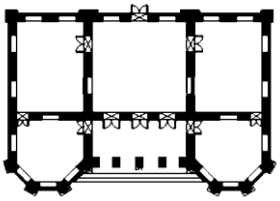


Figure 6. Ground floor plan & 1st floor plan of Sardar House

Façade and Openings: The façade often features classical columns (Ionic or Corinthian) supporting a pediment, with a cornice detailed with dentils. Openings typically include semicircular or segmental arches, with occasional cusped/Mughal arches in hybrid styles. Houses commonly use tall French windows with louvered shutters, along with crescent or rectangular fanlights above doors. Decorative metalwork appears in cast-iron and wrought-iron railings, grills, and verandah balustrades.

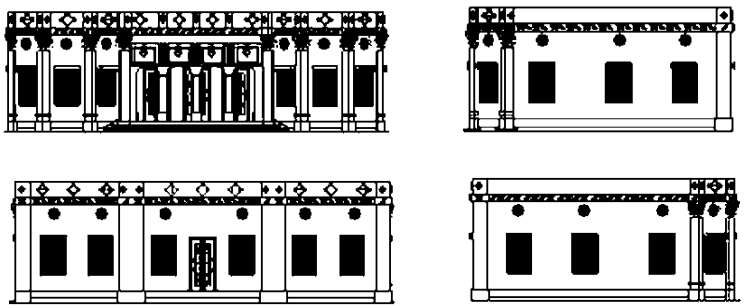


Figure 7. Front & back elevation of Sardar House

Building Ornamentations: Ornamentation commonly includes stucco scrollwork, cartouches, and medallions, supported by angular pilasters and string courses that articulate the façade. Arches are often emphasized with keystones, while toothed dentils and parapet balustrades provide classical detailing. Later adaptations incorporate Art Deco motifs, such as sunburst patterns, horizontal bands, and porthole-style circular windows.

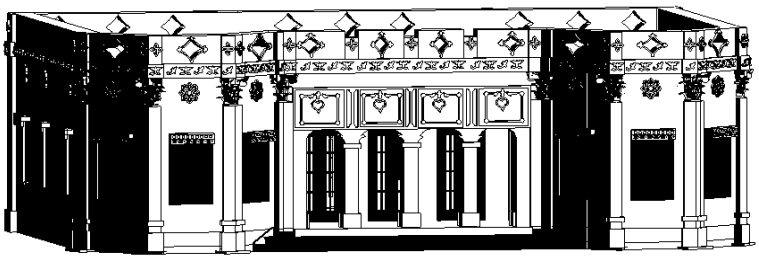


Figure 8. Building ornamentation of Sardar House

Climate Response: Climate adaptations include very high ceilings for heat dissipation and deep verandas with extended overhangs for sun and rain protection. Buildings typically use thick walls for thermal comfort and rely on cross-ventilation through opposite openings. Additional airflow and daylight are achieved through ventilators, clerestory windows, and louvers.

Landscape and Gateway: The exterior layout often includes a small front garden or driveway leading to the house. Entry is marked by an ornamental arch-gate with a boundary wall**,** frequently accompanied by a flagpole and nameplate**.** Many properties also display a crest or monogram**,** reinforcing identity and formality at the gateway.

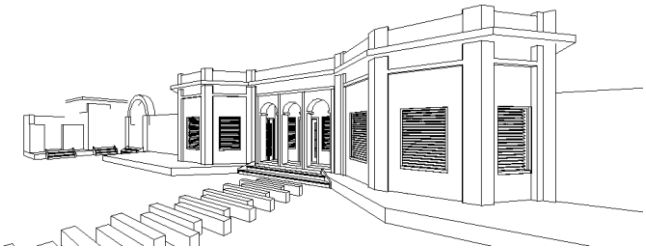


Figure 9. Building ornamentation of Sardar House

3.3 Case C: Jyotir Basu House (c. 1920s)

Location: Baradi, Narayanganj

History: History of Bengal Colonial, Partition of Bengal, 1952 & 1971

Origin: 1940s

Owner: Jyoti Basu

A river-facing house characterized by a wrap-around verandah and high ceilings, using the river-edge as a climatic and symbolic asset. The riverfront orientation heightens the building's presence and adds a unique dimension to the notion of loftiness.

Form/Plan: The plan is strictly symmetrical, arranged in a rectangular layout with a long central hall flanked by rooms on both sides in an enfilade configuration. The façade features a grand front portico and wide verandas, creating spacious shaded outdoor areas. Front and rear courtyards support cross-ventilation and serve as communal spaces. A separate service wing or annex, containing the kitchen, storage, and servant quarters, is positioned apart from the main residential block to maintain functional separation.

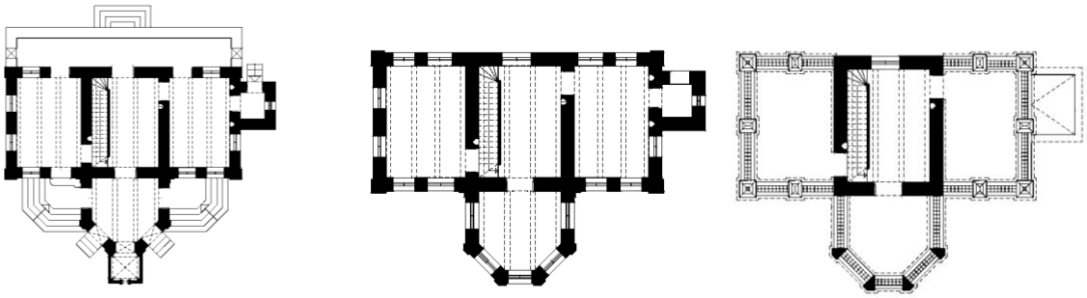


Figure 10. Ground,1st & 2nd floor plan of Jyotir Basu House

Facade and Openings: The façade is symmetrical, marked by a central portico supported by Doric columns, reflecting strong neoclassical influence. Openings are arranged in a balanced manner, with tall doors and windows fitted with louvered wooden shutters and wrought-iron grills for ventilation and security. Arched verandahs and entrances use semi-circular or trefoil (pointed) arch forms to enhance visual richness. Exterior detailing includes ornamental cast-iron railings on

balconies and verandahs. The main entry features intricately carved wooden doors with traditional Bengali motifs, integrating local craftsmanship into the colonial façade.

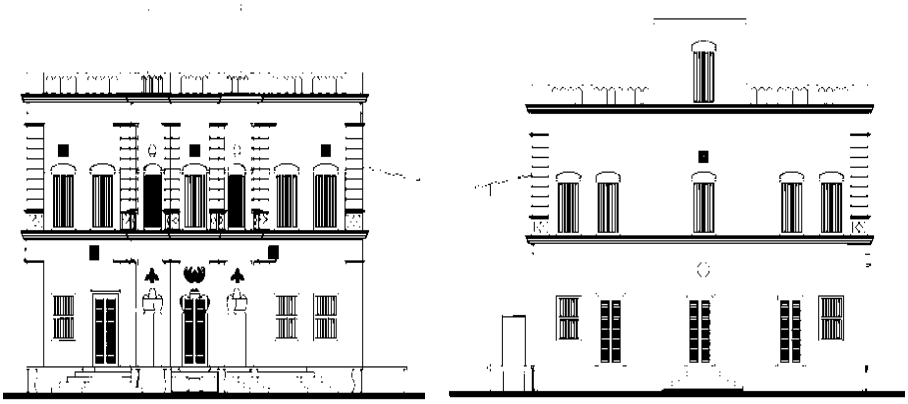


Figure 11. Front and back elevation of Jyotir Basu House

Building Ornamentation: Ornamentation combines brick and stucco work, with mud brick construction suited to the tropical climate and stucco used for smooth finishes and decorative motifs, showing both colonial and Sultanate influences. Wooden detailing, mainly in teak, appears in beams, floors, doors, windows, and railings, with carved balustrades and trusses reflecting mixed local and European craftsmanship. Wrought-iron elements are used in balconies, parapets, gates, and window grills, adding structural strength and decorative refinement to façades and verandahs.



Figure 12. Jyotir Basu House

4. Findings and Discussion

Loftiness in colonial Bengal cannot be understood simply as the height of a structure; rather, it reflects a multi-dimensional architectural experience. Height certainly plays a role—tall ceilings, elevated plinths, and expansive volumes created an immediate sense of openness—but loftiness was equally shaped by environmental and cultural necessities (Afzal, 2019). Generous ventilation,

often achieved through clerestories, transoms, and high openings, contributed to both climatic comfort and a psychological perception of grandeur, aligning with the longstanding climatic logic of Bengali vernacular architecture (Ahmed, 1984).

The sequence of thresholds, beginning from the street-facing entrance to the semi-public verandah and finally into the private inner rooms, established a rhythm of spatial expansion and contraction. This progression heightened the sense of arrival and reinforced social hierarchies embedded in domestic layouts during the colonial period (Sengupta, 2007). Symbolic components such as porticos, pediments, and classical orders did not merely decorate façades; they functioned as markers of status, modernity, and alignment with global architectural trends tied to imperial authority (The Daily Star, 2018).

At the same time, the verandah—typically broad, shaded, and climatically responsive—acted not only as a buffer zone but also as a lived space, blurring the boundary between exterior and interior. This fusion of European representational elements with the spatial logic of Bengali dwelling practices epitomizes the hybrid architectural ethos of colonial domesticity in Bengal (Bengal Institute for Architecture, Landscapes & Settlements, n.d.).

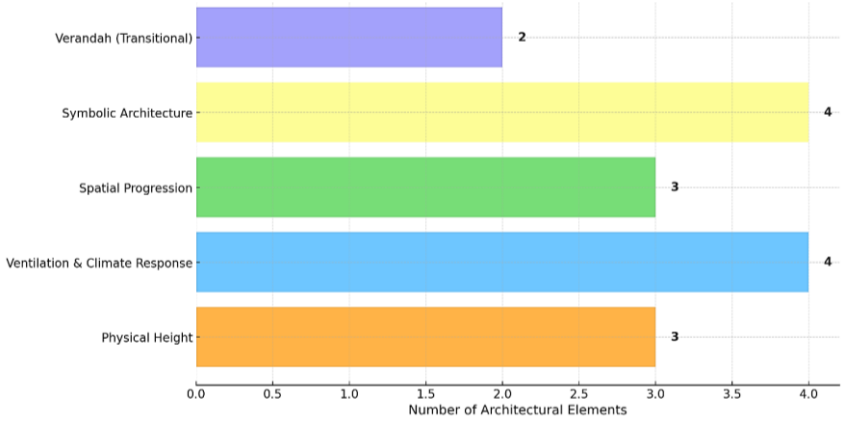


Figure 13. An infographic chart: Architectural elements shaping loftiness "Colonial Bengal Architecture".

The architectural character of colonial Bengal ultimately emerged from a hybridization of European classicism and Bengali domestic traditions. Classical elements Corinthian or Ionic columns, dentil cornices, cartouches, and symmetrical façades were selectively absorbed, reinterpreted, and often localized with brick-and-plaster craftsmanship. These motifs coexisted with deeply rooted Bengali features such as internal courtyards, which enabled light penetration and family-centric activities. The verandah became an adaptive space, functioning as a transitional room suited to the humid climate. Louvers, wooden screens, and jalis allowed filtered light and cross-ventilation, demonstrating a sensitivity to tropical environmental conditions.

This hybrid architecture was not merely aesthetic it reflected social aspiration, climatic intelligence, and cultural negotiation. By merging global stylistic symbols with indigenous spatial

logic, colonial Bengali homes produced a distinct architectural identity rooted in both tradition and modernity.

5. Conclusion and Recommendations

The study demonstrates that the sense of colonial loftiness in Narayanganj is not the result of ornamentation alone but a careful integration of architectural expression, climatic response, and social order. The examined houses consistently reveal three core characteristics. First, classical stylistic frontality provides a dignified and imposing façade that communicates authority. Second, climatic intelligence is embedded in the use of deep verandahs, elevated plinths, generous ceiling heights, and cross-ventilated interiors—elements that negotiate heat, humidity, and seasonal variation with remarkable efficiency. Third, spatial organization reflects social hierarchy, where circulation patterns, entry sequences, and room arrangements quietly articulate cultural values and domestic structures. Together, these components form a cohesive architectural identity that distinguishes colonial-era dwellings in the region.

Future preservation or adaptive reuse efforts must prioritize the intrinsic logics that shaped these buildings. Renovations should respect original volumetric proportions, maintain verandah depth and ceiling height, and safeguard the transitional thresholds that define movement and privacy. Climate-responsive strategies such as cross-ventilation and shading should be retained or sensitively enhanced rather than replaced with incompatible modern interventions. Documentation, community awareness, and regulatory guidance can further support conservation. By aligning contemporary needs with historical intelligence, Narayanganj's colonial houses can remain culturally meaningful and environmentally functional for generations to come.

Conserving colonial Bengali houses requires respecting their original spatial qualities and climatic logic. The height-to-void ratios and deep verandahs should be preserved to maintain natural ventilation, avoiding additions like false ceilings. Modern services must be inserted through reversible, non-destructive methods to protect historic materials. Plinths and damp-prone areas should be strengthened with breathable, lime-based finishes rather than synthetic coatings. During adaptive reuse, it is essential to retain the traditional circulation hierarchy, ensuring that new functions such as cafés, boutiques, or museums do not obstruct original movement patterns or visual axes. The façade and its classical elements, including columns, pediments, railings, and stucco details, must be carefully conserved through gentle cleaning and material-matched repairs. Overall, interventions should enhance usability while safeguarding the building's historical, climatic, and architectural character.

Thanks and Information Note

The authors thank local residents, caretakers, and Narayanganj heritage enthusiasts for their support and narratives. The researchers also acknowledge access to municipal archives and the guidance of conference organizers and reviewers.

The article complies with national and international research and publication ethics. "No external funding or support was received for this study." "All authors contributed equally to the preparation

of this article." "The authors declare that there is no conflict of interest regarding the publication of this article."

References

Ahmed, N. (1984). *Discover the Vernacular Architecture of Bangladesh*. Bangladesh Architectural Research Council.

Alam, M. S. (2019). Colonial urbanism and the transformation of Dhaka's zamindar houses. *Journal of Bengal Architecture*, 12(1), 45–63.

Afzal, M. (2019). Colonial Domestic Architecture in Bengal: Hybridity, Identity and Spatial Negotiation. *Journal of South Asian Built Heritage*, 5(2), 33–52.

Bengal Institute for Architecture, Landscapes & Settlements. (n.d.). *Architectural heritage studies and regional documentation reports*. Bengal Institute Publications.

Ching, F. D. K. (2014). *Architecture: Form, Space, and Order* (4th ed.). Wiley.

Hasan, M. (2010). *Vernacular Architecture of Rural Bengal*. University Press Limited.

Khan, H. (2006). *The Architectural Heritage of Dhaka: Houses and Urban Form*. Asiatic Society of Bangladesh.

Sengupta, A. (2007). *Living in the Periphery: Provinciality and Domestic Space in Colonial Bengal*. Routledge.

The Daily Star. (2018). Colonial architecture: Fusion of aesthetics and power. *The Daily Star*. (Original article published January 2018).

The Daily Star. (2018). Colonial architecture: Fusion of aesthetics and power. *The Daily Star*. (Published January 2018).

Tracing Colonial Footprints. (2024). *Heritage Houses of Barodi and Narayanganj Region: A Photographic and Spatial Survey*. Local Heritage Research Collective.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Healthy Cities in Environmental Protection

Belgin YILDIRIM[1]*

ORCID 1: 10000-0001-5451-5526
[1] Doç. Dr., Aydın Adnan Menderes University, Faculty of Nursing, Department of Public Helath Nursing, Aydın-Türkiye
byildirim@adu.edu.tr (Responsible Author)

Seher SARIKAYA KARABUDAK [2]

ORCID 2: 0000-0002-9039-5637
[2] Doç. Dr., Aydın Adnan Menderes University, Faculty of Nursing, Department of Child Health and Disease Nursing, Aydın-Türkiye
ssarıkaya@adu.edu.tr

Abstract

Creating Ideal Cities: Many architectural and urbanist works and ideas, such as those of Plato, Leone Battista Alberti, Filarete, and Vitruvius, have concerned themselves with creating and developing ideal living conditions for humanity. The concept of the ideal city, which gained widespread acceptance in Europe after Plato, can be said to have begun with Francesco Eiximenic's (1340-1409) introduction of the "planned city" (bastide) as the "ideal city" (la ville idéale). A review of numerous researchers throughout history reveals that they have worked on the importance of healthy and planned cities and have emphasized their importance. The concept of a healthy city was first introduced in 1987, and we see this concept in the literature at the same time. The Healthy Cities Project, which became a project, was implemented in a five-year phase in numerous countries around the world. Threats to public health—workplace conditions, deaths from infectious diseases, and sewage problems—have created a need for healthy cities. To this end, a healthy cities project network was envisioned, and parameters were established for this purpose. The WHO has parameters for this. For healthy cities, there are the slow city movement, the slow city concept, and the criteria for becoming a slow city. There are exemplary cities around the world that address these issues. Research is ongoing on this topic. The key here is to protect all living things, flora, and human health, and to create environmental conditions that support them.

Keywords: Environment, environmental protection, healthy cities

1. Introduction

Historical Development Process

Creating ideal cities: Many architectural and urbanist works and ideas, such as those of Plato, Leone Battista Alberti, Filarete, and Vitruvius, were concerned with creating and developing ideal living conditions for humanity. The concept of the ideal city, which gained widespread acceptance in Europe after Plato, can be said to have begun with Francesco Eiximenic's (1340-1409) introduction of the "planned city" (bastide) as the "ideal city" (la ville idéale). A review of numerous researchers throughout history reveals that they have explored the importance of healthy and planned cities and have striven to emphasize the importance of this concept. Creating an orderly, healthy, aesthetically pleasing, practical, easily accessible, and usable order throughout history has proven difficult. Efforts to achieve beauty and betterment have drawn not only from theoretical and applied sciences but also from art. The breadth of artists' imagination and beauty have inspired them. When we consider artists of the past, we see their interest in disciplines such

as mathematics, astronomy, biology, chemistry, medicine, and so on. And they proved to be exceptionally good in these areas. This provided them with a holistic perspective, helping and leading the world to a new level. For example, Albrecht Dürer was a pioneer of linear cities. Lonardo da Vinci and Piranes, who addressed the separation of social classes in his ideal city, continue to inspire and guide us even today by emphasizing the importance of creativity, imagination, and experimentation. Unfortunately, Lonardo da Vinci was unable to implement his ideal city plan in his lifetime. His theory remains a source of inspiration for academics. His geometric urban plan, particularly for infrastructure and sewage systems, is a prime example. Thomas More criticized city plans in 1517. These ideal city projects progressed slowly until the 19th century. The 19th century focused on the concept of the ideal city, and many researchers worked on it. However, these constructs remained limited to science fiction for metropolises. At the end of the Industrial Revolution, this concept resurfaced, and attempts were made to critically examine it. Researchers on this topic differed in their perspectives. For example, one group prioritized large natural areas and parks alongside tall skyscrapers, while another group also sought to design metropolises in the suburbs. Furthermore, in an effort to promote social justice in every aspect, parks and gardens were designed as rest areas, and common areas and living spaces, especially in nature, for everyone of all classes to use. These designs were also influenced by economics and politics. For example, Central Park in New York City, USA, was designed under the influence of this approach of the time (2,6,7,8).

2. Healthy City

Cities in developed, developing, and even at the very beginning of the world are constantly and rapidly transforming and changing. Living cities, like a puzzle, constantly evolve and respond to people's needs. Here, the two concepts of health and city are in constant relationship. This relationship is crucial for the health of animals and humans, nature, and plants (11).

If we examine the concept of health, it is a state of complete well-being in every aspect. If we look at the concept of city, we see the terms "city" and "city." Furthermore, for the population living here, it is a non-agricultural living space where industry, commerce, the service sector, and the people involved in its management are settled (22).

The health environment is the social context and daily activities within which organizational, environmental, and individual influences interact to influence health and well-being. It is here that people work, learn, play, create, and live healthily (11, 18, 19).

Considering the concept of urban health, we can say that it is a state of well-being in every aspect (11,21).

A healthy city is a concept that expands the resources of communities, creating and improving them, both positively and negatively (20, 22).

Sustainable healthy city is the concept that ensures the continuous development of people living in the city, their natural environments and systems, now and in the future (11,20).

The Healthy City Movement; Research on the concept of healthy cities emerged in 1987 with support from the WHO. The Healthy Cities Project, which became a project, was implemented in

a five-year phase in numerous countries around the world (5). Threats to public health in Western countries—workplace conditions, deaths from infectious diseases, and sewage problems—have led them to recognize the need for healthy cities in urban settings (14).

The Healthy Cities Network consists of five regions: the Western Pacific Network, the Eastern Mediterranean Network, the American Network, the European Network, and the Southeast Asian Network.

City Health Profile; A public health report. It is an analysis of the city's health and its determinants. It includes the city's health status, demographics, environmental conditions and differences, policies, and services (15,19).

Healthy City Ecosystem: The interaction between individuals and businesses within a city and their surroundings (11).

The Digital Healthy City Ecosystem is the transfer of the healthy city ecosystem to a digital service provider network. In other words, it is the technology platform that connects digital service provider systems and forms the digital backbone among ecosystem members (4, 22).

City Health Policies: The process of making cities healthy and evaluating them through public policies (3, 11).

The health of a city benefits both people and nature. It also supports the national economy. It contributes to the peaceful and prosperous life of people and institutions. There is no class distinction among the people. There is equality, balance, and justice. There is no administrative weakness. The rules are clear and applied equally and fairly to everyone. Most importantly, improving and developing health. The development of the city and its people is fundamental. This development encompasses human, social, economic, urban, and sustainable development. In the context of the healthy city vision, it represents people, prosperity, the earth, space, peace, and participation.

If we examine the fundamental characteristics of healthy cities, the most fundamental aspect is the health of people and the surrounding environment. This involves adopting and implementing healthy cities within the context of the social determinants of health. This will positively impact the interaction between people, nature, and the environment (31, 32, 33). In this sense, the fundamental characteristics of healthy cities are:

- Establishment of national and international networks, global governance, and collaboration.
- Monitoring and evaluation
- Transparency, the rule of law, and accountability.
- Intersectoral collaboration.
- Ensuring community participation in policy making and implementation.
- Improving and developing health requires good governance.
- Health equity and human development are at the core of government policies and actions.

• Strong political commitment to optimal health and human development.

3. Characteristics of Healthy Cities

Urban health is defined as a city that constantly interacts with, creates, and improves its physical and social environment, enabling its inhabitants to fulfill all their functions and develop their highest potential, while also supporting each other (1). In such a city, the lives of its inhabitants are facilitated by calm, peaceful, and healthy spaces where people can comfortably carry out their work. These are safe environments that provide people with easy access to community resources that regulate and improve the conditions in their environment (19). At the 1996 forum in Geneva, the consensus was that "individuals' physical health, psychological health, individual beliefs, and social relationships are directly affected by the health of the environment" (18, 29, 31, 33). There are several parameters for a healthy city. These are:

• ***Healthy City Planning:*** It's important to start with the neighborhood for this planning. Planning begins with neighborhoods, the smallest units in cities. It's crucial to secure policy, neighborhood capacity, and institutional support for this.

• ***Healthy Transportation:*** Transportation should be equitable and fair for everyone. Furthermore, everyone should be able to easily reach their workplace without using a vehicle.

• ***Security:*** All city streets, homes, and all areas of residence—women, children, the elderly, the disabled, and young people—in other words, all people and animals—are safe and secure within the vegetation. They are places where people can move freely.

• ***Housing and Transformation:*** They are environments that facilitate people's access to nature, parks, and gardens, and that provide a comfortable environment for their travels. They are healthy environments that protect and improve individuals' health, allowing them to travel easily.

• ***Creativity and Livability:*** It is important to develop policies that foster the creativity of people in cities, and to increase and diversify cultural activities.

• ***Exposure to Noise and Pollution:*** Protecting children, a special group in urban communities, against toxic substances and adverse health effects. For example, these include indoor and outdoor pollution, tobacco smoke in all areas, and various noises. It is important to protect these areas, improve action, and ensure their sustainability.

• ***Climate Change and Public Health Emergencies:*** The health impacts of climate change and its impact on urban health, the health of cities worldwide, and interventions to protect human health during human movement crises.

The characteristics of a healthy city are also mentioned in the sources (23,24,25, 26, 30). If we briefly review these:

High-quality, safe, clean housing and environments

• A sustainable and stable ecosystem

• A just and equitable society where communities support each other at all times, in all ways, and under all circumstances, where strong and trustworthy people support each other, and where there is no one exploiting or favoring the powerful

• A vibrant, diverse, progressive, and innovative urban ecosystem

• Easy access to a wide range of resources

• An environment where interaction and communication are easy

• Participation of urban residents in decision-making

• The well-being and well-being of participating residents are prioritized

• Meeting the basic needs of urban residents (food, water, shelter, income, security, workspaces, recreational areas, etc.)

• The city's ability to live with its past, as well as its cultural, biological, and physical heritage, while encouraging groups and people to do so

• A city that aligns with healthy city parameters and behaviors and possesses features that enhance and improve these

• Easy access to healthcare facilities

• A city where public health and patient care services are easily accessible and optimal service is provided

• A city where health status, especially positive health status, is enhanced and negative health conditions can be addressed immediately.

World Health Organization's Healthy City Criteria

The principles of Health for All, along with the Ottawa Charter for Health Promotion, form the basic framework of the WHO's Healthy City Project (27). If we examine the WHO's Healthy City Criteria in this context, we can list the following (16, 21, 27, 28).

• A safe, clean, high-quality physical environment

• A balanced and sustainable ecosystem

• A strong and collaborative, successful society

• Individual participation in and influence over decisions affecting their own lives, health, and well-being

• Meeting the basic needs of all city residents

• Access to all available experiences and resources through diverse communication, interaction, and connections

• A diverse, vital, and innovative city economy

• Citizens who embrace their cultural, historical, and biological past and heritage

• High-quality and high-quality healthcare

Today, some of our habits in our fast-paced, modern life lead to a number of health problems (such as joint diseases due to a sedentary lifestyle, obesity, depression, and asthma). The indoor spaces we live in are disconnected from the earth and have become oxygen-poor spaces. In addition to air pollution, potential risks related to environmental and noise pollution in living spaces should be identified and made conducive to healthy living. Of course, simply improving the physical environment and the space itself will be insufficient. The space and physical environment should be considered together with social parameters, and problems can be resolved through this perspective (12, 13, 17).

4. Healthy Cities in Environmental Protection

We all agree on the importance of protecting the environment we live in, but the question arises as to whether there are any healthy cities in the world that do. Yes, there are examples of cities around the world that meet the criteria for a healthy city. But first, as people walk down the street in their daily lives, they notice their surroundings, for example:

• It's so beautiful when you see the flowers along the side of the road.

• I wish I lived here.

• The city has fewer trees; I wish there were fruit trees here.

• There's a need for a bike path.

• This is exactly the city I want to live in.

• If the environment were clean, I'd love to walk around.

Similar thoughts about the city we live in and the cities we visit may float through our minds. While there are different ideas and opinions about how to achieve a healthy city in the cities we live in or visit, people are united by common desires. Living a happy, healthy, and meaningful life is everyone's common desire (9, 10, 11, 31).

It can be an example of healthy green spaces.



Figure 1. Izmir Culture Park

The children's street in the Esenler district of Istanbul has been specially designed. It is a good example of a children's playground.



Figure 2. Children's street

Adana Flavor Festival can be an example of street food.



Figure 3. Adana Flavor Festival

The regular collection point for household waste collected in Istanbul is a good example of storage in the sense of healthy cities.



Figure 4. Waste Storage Area

It is a good example of a bicycle path for a healthy city.



Figure 5. Bicycle path

We could multiply these examples. We could also point to Central Park as an example from around the world.



Figure 6. Central Park

There are several new urbanization trends around the world aimed at making urban life more sustainable (29, 33). These include:

- New Urbanism
- Smart City
- Eco-City
- Low-Carbon City
- Green City
- Smart Growth
- Ecological Settlements and Green Architecture
- Ideal City
- Compact City
- Symbio City
- Landscrapers (Built-in settlements)

- Arcological City (Architecture + Ecology)
- Livable City
- Intelligible City
- Digital City
- Slow City

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Terminology of the European Conference on Health, Society and Alcohol: A Dictionary with French, German, and Russian Equivalents (1995). WHO (EURO), Copenhagen,

Buchholz, E.L. (2005). *Leonardo da Vinci.* Ali Kurultay, (Trans.), Literatür Publications, 37, Italy, ISBN 975-04-02-98-7.

Belli, A. & Aydın A. (2017). Law No. 6360 and local centralization. *International Journal of Social Science,* 55, 401-413. Doi:http://dx.doi.org/10.9761/JASSS6945.

Belli, A. & Aydın, A. (2016). Evaluation of Aksaray Municipality within the Scope of the World Health Organization Healthy City Project, *1st International Aksaray Symposium,* October 27-29, 2016, Aksaray.

Belli, A. (2019). A Comparative Analysis of Healthy Cities and Metropolitan Municipalities in Turkey, *OPUS-International Journal of Society Research,* 10(17), 1930-1962.

Castelli, P. (2013). *Renaissance Aesthetics,* (Translator: Durdu Kundakçı, Gül Özaktürk), Dost Bookstore, Ankara.

Curl, J.S. (1970). *European Cities and Society: A Study of the Influence of Political Climate on Town Design.* Leonard Hill Books, London.

Da Vinci, L. (2007). *Boyut Publications,* Istanbul, 2007, Design: Bülent Ustaoğlu.

Healthy City Izmir, http://skpo.izmir.bel.tr/content.aspx?MID=11, E-Date: 12/19/2020.

Healthy City Gölcük, http://skb.golcuk.bel.tr/id3.html, E-Date: 08/17/2019.

Kenan, S (2016). Local Governments and Health. *Journal of Health Thought and Medical Culture,* 38, 36-39.

Kocaman, E. (2023). *Healthy City Management.* Chapter Title: What is a "Healthy City"? 1st Edition, Holistence Publications, Istanbul, 1-25.

Kürkçüoğlu, İ.E. (2010). A Turning Point in the Search for the Ideal: Star Cities, *Ideal City,* 1, 78-95.

Marten, K. (2011). Quadralectic Architecture – A Survey of Tetradic Testimonials in Architecture. Falcon Press, Nashville, TN, USA. See http://quadralectics.wordpress.com/ 4-representation/4-1-form/4-1-3-design-in-city-building/ 4-1-3-3-the-squarerectangular-model/ (accessed 02/25/2014).

Mazumdar, S. (2007). Urban Quality of Life and Sense of Place. University of California, Department of Planning, Policy and Design. Publication: *Architecture Magazine*, Issue: 335, 2007.

Turkish Healthy Cities Association. (TSKB). (2023). https://www.skb.gov.tr/ Access Date: 11.08.2023.

World Health Organization Healthy Cities. http://www.skb.gov.tr/dunya-saglik-orgutu-avrupa-saglikli-sehirler-agi/, E.Date: 09.10.2020.

World Health Organization. (1998). "City Health Profiles: A Review of Progress"

5. World Health Organization. (2014). "Health in All Policies: Helsinki Statement". Framework for Country Action

World Health Organization. (1986). "Ottawa Charter for Health Promotion". *Health Promotion*, 1 (4), 3-5.

World Health Organization Regional Office for Europe. (1997). Twenty steps for developing a healthy cities project. Yalova Governorship Provincial Directorate of Environment and Urbanization, http://yalova.csb.gov.tr/saglikli-kent-nedir-kriterleri-nedirhaber-169094, E.T.: 25.12.2018.

World Health Organization, https://www.who.int/healthpromotion/conferences/previous/-jakarta/declaration/en/index1.html, E.T.: 28.12.2018.

WHO. https://www.who.int/healthy_settings/types/cities/en/, E.T.: 21.12.2018

World Health Organisation. (1988). "The Adelaide Recommendations: Healthy Public Policy". WHO and The Commonwealth of Australia.

World Health Organization. (WHO). (2015). Healthy cities: good health is good politics: toolkit for local governments to support healthy urban development (No.WPR/2015/DNH/004). WHO Regional Office for the Western Pacific.

World Health Organization. (WHO). (2018). Copenhagen Consensus of Mayors: healthier and happier cities for all: a transformative approach for safe, inclusive, sustainable and resilient societies. Healh Cities Vision, World Health Organization. Copenhagen.

World Health Organization. (WHO). (2023). Healh Cities Vision, https://www.who.int/europe/news-room/fact-sheets/item/healthy-cities-vision Access Date 10.07.2023

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

The Place and Importance of Environmental Education in Nursing

Belgin YILDIRIM[1]*

ORCID 1: 10000-0001-5451-5526
[1] Doç. Dr., Aydın Adnan Menderes University, Faculty of Nursing, Department of Public Helath Nursing, Aydın-Türkiye
byildirim@adu.edu.tr (Responsible Author)

Seher SARIKAYA KARABUDAK [2]

ORCID 2: 0000-0002-9039-5637
[2] Doç.Dr. Aydın Adnan Menderes University, Faculty of Nursing, Department of Child Health and Disease Nursing, Aydın-Türkiye
ssarıkaya@adu.edu.tr

Abstract

Environmental education is critical for nursing students and nurses to develop ecological awareness, become more aware of environmental issues, and adopt sustainable living practices. Today, as environmental problems have become a global crisis, educational institutions play a strategic role in raising environmental awareness. Teachers and faculty members must emerge as key players in the effective implementation of environmental education. It has been stated that environmental knowledge and positive attitudes can only be imparted to students through environmentally conscious and responsible educators and peer leadership, and that environmental education can be ineffective in the absence of teachers and faculty. Environmental awareness and environmental literacy must be fostered in students and young people to foster a curiosity for understanding and examining the environment. Environmental education should not be limited to the mere transfer of theoretical knowledge. Critical thinking, questioning, and the development of an ethical attitude toward nature should be encouraged. Nature-based environmental education should be supported, and it is recommended that approaches such as place-based education, the forest school approach, the biophilia hypothesis and nature-connected learning, and the ecophobia hypothesis be incorporated into university environmental courses. Especially when viewed from the perspective of nursing, the relationship between health and the environment is fundamental, and it is thought that developing course curricula in this context will contribute to environmental education.

Keywords: Environment, environmental education, student nurse, student

1. Introduction

The Concept of Environment

The use of the concept of environment appears to date back to the 1970s (41). Since then, this concept has been used in various meanings across various disciplines and has undergone continuous development (10). The environment is the living environment of any living being (7). From an ecological perspective, the environment refers to all living and non-living entities. The definition of environment is "the totality of physical, chemical, biological, and social factors that may have a direct or indirect impact on human activities and living beings, either immediately or over a period of time" (25). The environment has been defined as the environments in which living beings and humans live, whether in nature or elsewhere (33). These are areas where living beings are connected to, influence, and influence other living beings (26). The environment is the ecosystem of a region (21). It is the environment and conditions in which living and non-living

beings exist (12). If we review all definitions, it is a very comprehensive area consisting of living and non-living beings. We can call this the environment.

The Emergence of Environmental Problems

Nature and humans, in other words, the environment and humans, are in constant communication and interaction. They cannot be separated or separated. The damage humans inflict on the environment has been recognized since the 21st century. The first humans appeared 5 million years ago, and the first living creatures 3.5 billion years ago. The Earth is approximately 4.6 billion years old. How sad it is that the damage humans inflict on the environment is only just beginning to be recognized (2). This recent awareness is quite significant. Climate change is rapidly threatening the Earth and its living creatures. Unfortunately, human awareness of this issue is very low.

Global population growth, the misuse of resources, and the exploitation of less developed countries, in particular, have not slowed down. Developed countries' constant use of global decisions to their advantage is unfortunately making the planet we live on uninhabitable. It is truly saddening that the lack of awareness in underdeveloped countries, the fact that developing countries are caught in the middle and trying to adapt to a rapidly changing world, is harming nature while doing so. Furthermore, the crucial problem of waste, clean water resources, and the pollution of soil are deteriorating the world we live in. The disconnection of people from nature in the developing world, coupled with their self-serving relationships with the environment, is unfortunately no longer tolerated by the planet and is increasingly prevalent. Unfortunately, rapid population growth and industrialization-based economies have led to the depletion of natural resources. The constant increase in technology, the resulting production and consumption, and people's desire for increased comfort are causing irreversible damage to nature (20).

Humanity, which has caused this situation, must solve the problem. Human interaction with nature is harmonious in the first stage because they are hunter-gatherers. It is a process of harmony with nature. The weapons of the people in this period were quite primitive. They struggled to avoid harm from animals and to find food. Their discovery and control of fire caused considerable damage to nature. However, in general, the first period is the stage of adaptation to nature and meeting their needs (3, 5).

The second stage involved the making and use of tools, particularly the learning to use iron. This period marked the transition to a settled life, the domestication of animals, and a continuation of the first period. The Neolithic period witnessed the first and most serious environmental degradation. Unfortunately, flaws in agricultural practices and the development of hunting methods began to degrade the fauna and flora—that is, the environment. During this period, the growth of the human population, the developing economy, and technology began to inflict damage on nature, from micro to macro (3).

The third stage was the industrial revolution. During this period, the human-environment relationship developed negatively. People's desire for dominance over their environment evolved into a passion for exploitation (4,11). It was during this period that humanity exploited the Earth. This process was accelerated by the idea of Bacon, Descartes, and Newton that "nature is a blessing bestowed upon humanity for a prosperous life and that humans have the right to consume it without

limit." Unfortunately, this idea not only sowed the seeds of the environmental crisis but also spread it. It led to serious global environmental problems and crises (27, 28). For example, the radioactive elements, DDTs, detergents, and synthetic plastics produced in the atomic bomb project during World War II can be exacerbated. Armament and wars, along with temporary economic interests, also initiated the search for solutions. The understanding of their detrimental global polluting effects on the environment coincided with the late 1950s and early 1960s. Development movements following wars, rapidly increasing global populations, shrinking living spaces, nuclear testing, the arms race, and the rapid depletion of natural resources, coupled with the rise of environmental problems, have all heightened political, economic, and artistic interest, as has the search for solutions (42). From a philosophical perspective, solutions are being proposed based on two opposing perspectives (ecological and mechanistic). However, the problems are worsening and persist.

2. Environmental Awareness and Mobility in the World and Turkey

Environmental awareness can be fostered through societies' recognition and understanding of the problems in their environment (8,17). Examples include the law enacted by Henry IV of England in 1534 to protect their wild birds. The French regulations on water quality in 1679 and the German "forest protection laws" (1). The Industrial Revolution was the beacon of awareness of environmental problems worldwide. The devastation caused by industrialization on the natural environment led some countries to become environmentally conscious.

The first legal development in Turkey on this issue was the 1982 Constitution. Article 56 of this law stated, "Everyone has the right to live in a healthy and balanced environment. It is the duty of the state and citizens to improve the environment, protect environmental health, and prevent environmental pollution..." (35) (37). The establishment of the Ministry of Environment in 1991 and the development of environmental awareness and sensitivity in schools affiliated with the Ministry of National Education were revisited (6). In subsequent processes, ministries and universities focused on this issue. The Paris Agreement was signed in 2015. In 2021, the Ministry of Environment and Urbanization changed its name to the Ministry of Environment, Urbanization and Climate Change (36).

3. Environmental Education

It emerged when people who harmed nature realized that these problems could be solved by themselves. Environmental education will enable people to solve these problems through cognitive, affective, and behavioral education and training methods (32). The cognitive dimension encompasses the ability to understand the functioning and structure of nature, human-nature interactions, and the consequences of human damage to nature. The affective dimension encompasses caring, empathizing with living and non-living things, demonstrating protective attitudes, and valuing others (31). The behavioral dimension is the process of acquiring the competence to transfer cognitive and affective gains to real life. Raising individuals with environmental awareness is the primary goal of environmental education (13,14,15). Demonstrating beneficial environmental behaviors and transforming these behaviors into attitudes is called environmental awareness (14). Solving these problems can be achieved through

environmental awareness and consciousness. The goal of environmental education is to raise environmental awareness and equip individuals, communities, and communities with knowledge and skills. In addition, it aims to support and encourage individuals to develop positive behaviors regarding the environment and its problems over time. Furthermore, it also aims to actively participate in environmental protection and conservation activities (19). The goal of environmental education is to acquire the knowledge and experience to work on the environment, to be concerned about problems occurring in the environment, and to engage in solution-oriented behaviors (16). To achieve these goals, the "International Environmental Conference" was held in Tbilisi in 1977. This was the first conference. This conference is very important for environmental education. The conference determined the principles, objectives, and methods of implementation. Five concepts were emphasized: awareness, knowledge, attitude, skills, and participation. All of these concepts are crucial and interconnected. The lack or deficiency of any one of these concepts affects the understanding of the other concepts.

The characteristics of environmental education are outlined in the Tbilisi Declaration. These are:

1. It is an educational approach.

2. It lasts a lifetime.

3. It involves active responsibility.

4. It is interdisciplinary.

5. It is holistic.

6. Nature and humans are intertwined and in constant interaction.

7. It has a spiritual, aesthetic, moral, technological, economic, political, and social integrity.

8. It actively encourages learning.

9. It is related to the establishment of environmental ethics.

10. It examines and uses teaching and learning techniques in a broad theoretical and practical context.

11. It supports the development of positive knowledge, attitudes, and behaviors toward the environment (22).

While the Tbilisi Declaration mentioned above provides the foundation, it is crucial to define an applicable environmental education approach with the right approach. In today's world, environmental problems are very complex, and the number of areas they affect has increased, leading to the questioning of the adequacy of environmental education currently in use (19,20). Therefore, especially in recent years, it is crucial to find solutions to environmental problems, increase the diversity of solutions, and choose an environmental education approach that meets the needs of society. Approaches to this issue seek solutions to different aspects of environmental degradation from different perspectives (32). Various approaches exist on this topic. These include nature pedagogy, ecological learning, ecopedagogy, sustainability, education for the environment, and education about the environment.

Nature pedagogy is the process by which people live isolated and alienated from nature due to environmental destruction. Education intertwined with nature is envisioned (19). It is crucial for students to learn and experience nature. Students observe nature here. They experience what they know through affective awareness (20,34).

Ecological learning focuses on individuals re-perceiving themselves and their environment in nature and their social environments, and reorganizing themselves and society (9,23). The proliferation of environmental movements brings this approach to the forefront. Environmental movements are a process of environmental education. It is an approach that allows individuals to see the bottom of the iceberg of environmental problems (20).

Ecopedagogy addresses the relationships and interactions of individuals with each other and society at the core of environmental education. This interaction and communication prioritizes human knowledge and behavior in both environmental degradation and environmental improvement (20). It aims to foster respect and understanding for people, their cultures, nature, and its diversity through a critical perspective (18,29,30). This approach aims to foster lasting attitude and behavioral transformation (5,29,30). Environmental education prioritizes individuals' understanding and awareness of nature through social interaction (32).

Sustainability refers to the capacity of nature to meet human needs without depleting its resources. Sustainability requires adopting a development model that is balanced both environmentally and economically (39). This concept was discussed extensively, particularly in the 1987 Brundtland Report, which emphasized the need to increase environmental responsibility so that future generations can benefit from natural resources (44).

Education for the environment, is the awareness of the biophysical conditions surrounding individuals and the consideration of their social and cultural environment. The aim is to bring individuals into harmony with nature (9, 32).

Education about the environment, stems from ignorance and a lack of knowledge. It involves acquiring knowledge in familiar, traditional learning environments. Environmental education is about acquiring knowledge about the structure, working principles, and functioning of nature. Implementing this approach in schools does not allow for a more detailed examination of the causes of environmental degradation. Therefore, it is limited (32).

4. The Place and Importance of Environmental Education in Nursing

Environmental education is crucial for raising nurses' and nursing students' awareness of their environmental sensitivity. In light of all the information mentioned above, it is critical for schools that train nursing professionals to raise their awareness of environmental issues and to adopt sustainable living practices. Unfortunately, today, when environmental problems have become a global crisis, educational institutions play a strategic role in raising environmental awareness, and teachers and faculty members stand out as key players in the effective implementation of environmental education (24,38). It is clear how essential it is for nurses to graduate as members of a profession who are sensitive to the environment and their surroundings, and how crucial it is for education that can influence and support them in adopting awareness, sensitivity, attitudes, and

ethical understanding towards their environment (40,43). An examination of nursing school curricula, both domestically and internationally, reveals that environmental issues are primarily addressed through the "Public Health Nursing" course. Elective courses such as Environmental Health, Fundamentals of Environmental Health, and Environmental Literacy are also available. While encouraging, this is not sufficient. It is important to increase activities in nursing education programs that will further develop students' environmentally oriented knowledge, skills, and attitudes toward the environment, enable them to transfer these attitudes to their personal and professional lives, and encourage them to take an active role in and support environmental organizations and their activities. Additionally, large-scale research should be conducted to examine the environmental knowledge, skills, attitudes, and behaviors of nursing academics, nurse clinicians, and nursing students.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Ada, S., Baysal, Z.N., & Şahenk Erkan, S.S. (2017). Environmental Education with Various Dimensions. Nobel Publishing.

Akarsu, B. (1997). Scientific Freedom and Environmental Ethics. In R. Keleş (Ed.), Human Environment and Society, İmge Publishing House, 18-40.

Akman, Y., Ketenoğlu, O., Kurt, L., Düzenli, S., Güney, K., & Kurt, F. (2000). Environmental pollution (environmental biology). Palme Publishing.

Alpak Tunç, G. (2016). Investigation of science teacher candidates' ethical approaches towards the environment and their attitudes towards a sustainable environment [Master's Thesis, Aydın Adnan Menderes University]. YÖK National Thesis Center.

Atasoy, E. (2015). Human-Nature Interaction and Education for the Environment (2nd Edition). Sentez Publishing.

Bozkurt, F. (2007). Environmental management in military housing. [Master's Thesis, Istanbul Commerce University]. YÖK National Thesis Center.

Çabuk, B. (2021). Environmental Education. Environmental Education and Sustainability in Early Childhood (12th Edition), Anı Publishing, 1-38.

Çabuk, B., & Karacaoğlu, C. (2003). Investigation of University Students' Environmental Awareness. *Ankara University Faculty of Educational Sciences Journal*, 36.1, 189-198.

Çelikbaş, A. (2016). The Effect of Sustainability-Based Environmental Education on Secondary School Students' Environmental Behaviors and Sustainable Environmental Attitudes [Master's Thesis, Mersin University Institute of Educational Sciences]. YÖK National Thesis Center.

Çobanoğlu, E., Karakaya, Ç., & Türer, B. (2012). Determination of Classroom Teacher Candidates' Environmental Values within the Framework of Ecocentric (Ecology-Centered) and Technocentric (Technology-Centered) Approaches. 5th National Science and Mathematics Education Congress, Niğde, Turkey.

Çüçen, A. (2011). Deep Ecology, (http://blog.aku.edu.tr/ometin/files/2011/12/derinekoloji.pdf), Access Date: 08.06.2014.

Doğanay, S. (2017). The role of local governments in the implementation of environmental policies: The example of Aksaray Municipality [Master's Thesis, Aksaray University Institute of Social Sciences]. National Thesis Center of the Council of Higher Education.

Erten, S. (2004). What are environmental education and environmental awareness? How should environmental education be? Environment and Human Journal, Publication Organ of the Ministry of Environment and Forestry, 65(66), 1-12

Erten, S. (2012). Environmental awareness among Turkish and Azerbaijani prospective teachers. *Körpeoğlu Journal,* 37(166).

Erten, S., Köseoğlu, P., & Gök, B. (2022). Environmental Education in Science Curricula: Examples from Turkey, Canada, and the USA. *Mehmet Akif Ersoy University Journal of Education,* (63), 220

Fang, W.T., Hassan, A., & Lepage, B.A. (2023). The Living Environmental Education. Singapore: Springer. doi: 10.1007/978-981-19-4234-1

Gadenne, D. L., Kennedy, J., McKeiver, C. (2009). An empirical study of environmental awareness and practices in SMEs. *Journal of Business Ethics*, 84(1), 45-63.

Gronemeyer, M. (1987). Ecological education a failing practice? "Or is the ecological movement an educational movement?", in Adult Education and the Challenges of the 1990s. WalterLeirman & LindaKulich (Eds.), pp. 70-83, New York: CroomHelm.

Gülersoy, A. E., Dülger, İ., Dursun, E., Ay, D., & Duyal, D. (2020). What kind of environmental education? Some suggestions within the framework of contemporary approaches. *Turkish Studies*, 15(5), 2357-2398.

Gülersoy, A. E., Yener, H., Turgut, T., Özşahin, D. M., & Açıkgöz, D. A. (2021). Some suggestions for an ideal environmental education policy in an age of chaos. *Turkish Studies*, 16(5), 1495-1552.

Hook, P. (2015). The Little Book of Environmental Terms. (Trans. Bahtiyar Kurt), TÜBİTAK Books Directorate, Ankara.

ICEET, 1977 https://ieeexplore.ieee.org/xpl/conhome/9943/proceeding

Kahn, L.M. (2010) Employment Protection Reforms, Employment and the Incidence of Temporary Jobs in Europe 1996-2001. *Labor Economics,* 17, 1-15.

Karahan Okuroğlu, G. (2012). The Effect of Nursing Education on Students' Attitudes Towards the Environment. *Journal of Research and Development in Nursing,* 3, 27-38. OKUROGLU

Keleş, R. & Hamamcı, C. (1998). Environmental Science. İmge Bookstore, Ankara.

Güney, E. (2004). Geography of Environmental Problems. Gündüz Education and Publishing, Ankara.

Karaca, C. (2008). Approaches to environmental problems and solutions within the framework of environment, humans, and ethics. *Çukurova University Journal of Economics and Administrative Sciences,* 1: 19-33. Karakoç, 2004

Keleş, Ö. (2015). Creative drama in the teaching of education for sustainable development: sample activity about sustainability and sustainable production. *Journal of Environmental Sustainability,* 4(4), 4.

Okur Berberoğlu, E. (2015). The effect of ecopedagogy-based outdoor environmental education on environmental awareness. *Hasan Ali Yücel Faculty of Education Journal,* 12(1), 67-81.

Özdemir, O. (2010). The effect of environmental education based on nature experience on the perception and behavior of primary school students towards their environment. *Pamukkale University Faculty of Education Journal,* 27(27), 125-138.

Özdemir, O. (2016). Ecological literacy and environmental education, 1st edition, Pegem Academy, Ankara.

Özdemir, O. (2024). Sustainable literacy and education, 6th edition, Pegem Publications, Ankara.

Özey, R. (2009). Environmental Problems, Istanbul: Aktif Publishing. Expanded 3rd edition.

Özdemir, O. (2025). A New Educational Paradigm Towards the Future: Sustainability Education. *Dokuz Eylül University Buca Faculty of Education Journal,* (64), 2525-2540.

Official Gazette, November 9, 1982 https://www.resmigazete.gov.tr/arsiv/17863_1.pdf

Official Gazette, October 29, 2021. https://www.resmigazete.gov.tr/eskiler/2021/10/20211029.pdf

Sancar, K. N. (2005). The Example of Turkey and Japan in Public Education for the Environment. [Master's Thesis, Ankara University, Institute of Educational Sciences].

Sattler, B. (2008). Environmental health risk. In: Ivanov LL, Blue CL, eds. Public Health Nursing, Leadership, Policy and Nursing. 1st ed. USA: Delmar Cengage Learning, 213-216.

Stern, N. (2006). Stern review: the economics of climate change. United Kingdom: N. p.,

Şenyurt, A., Temel, A., Özkahraman, Ş. (2011). Investigation of University Students' Sensitivity to Environmental Issues. *SDÜ Journal of Health Sciences,* 2,1, 8-15.

Uşak, M. (2006). What is Environment? Environmental Science (Aydoğdu, M. and Gezer, K., Eds.), Anı Publishing, Ankara, 1-9.

Ünder, H. (1996). Environmental Philosophy. Doruk Publishing.

Ünver, S., Avcıbaşı, İ. M., & Özkan, Z. K. (2015). Determination of Environmental Attitude and Awareness Levels of Nurses Working in a University Hospital. *Anatolian Journal of Nursing and Health Sciences*, 18,4, 282-6.

World Commission on Environment and Development, (1987). Report of the World Commission on Environment and Development: Our Common Future. http://www.ask-force.org/web/Sustainability/Brundtland-Our-Common-Future-1987-2008.pdf

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Computer Solution to Replacement Models for Items That Fails Suddenly

Alfa MOHAMMED[1*]

[1] Department of Cyber Security and Data Protection, Federal Polytechnic Bida, Nigeria

Abdulrahman MOHAMMED SABA[2]

[2] Department of Networking and Cloud Computing, Federal Polytechnic Bida, Nigeria

Abstract

Replacement theory is used in the decision-making process of replacing a used equipment with a substitute; mostly a new equipment of better usage. The problem of replacement arises when any one of the components of productive resources, such as; machinery, building and men deteriorates due to time or usage; therefore, the replacement might be necessary due to the deteriorating property or failure or breakdown of particular equipment. A program was then written in C++ to compute the replacement metrics. The number of unit replacement was accepted as 10000, the probabilities for p1 to p10 were considered. The value for the costs of replacement was accepted as ₦300. The mean life failure at long run was computed as 3.3 weeks and the average rate of failure in the long run was computed as 3030 per week. Individual replacement time was computed as 151.5 per week and the group replacement policy was then computed for week 1, 2, 3, and 4 as 300, 150, 133.33, and 150 respectively. The comparisons were done on the group replacement time for week 1 to 4, and the minimum cost replacement time is ₦133.33 per week. Therefore, the cost of replacement time is due at every three weeks.

Keywords: Replacement, policy, group replacement, individual replacement, paise, items, suddenly

1. Introduction

The problem of replacement arises when any one of the components of productive resources, such as; machinery, building and men deteriorates due to time or usage. For instance, a machine, which is purchased and installed in a production system, due to usage some of its components wear out and its efficiency is reduced, a building in which production activities are carried out, may leave cracks in walls, roof etc, and needs repair; a worker, when he is young, will work efficiently, as the time passes becomes old and his work efficiency falls down and after some time he will become unable to work. Thus the problem of replacement is experienced in systems where machines, individuals or capital assets are the main production or job performing units. The characteristics of these units is that their level of performance or efficiency decreases with time or usage and one has to formulate some suitable replacement policy regarding these units to keep the system up to some desired level of performance (Stephen, 2019).

Industries may have to take different type of decision such as: wait for complete failure of the item (which may result in some losses due to deterioration or to replace earlier at the expense of higher cost of the item; The expensive item may be considered individually to decide whether they should replace now or, if not, when it should be reconsidered for replacement; Whether the item is to be replaced by similar type of item or by different type for example item with latest technology. A separate but similar problem involves the replacement of items such as electric bulbs, radio tubes,

television parts, etc. of equipment which does not deteriorate with time but suddenly fails (Nwosu, 2020). The problem, in this case, is of finding which items to replace and whether or not to replace them in a group and, if so, when?

Different type of decision may be taken such as: Decision whether to wait for complete failure of the item (which may result in some losses due to deterioration or to replace earlier at the expense of higher cost of the item; The expensive item may be considered individually to decide whether we should replace now or, if not, when it should be reconsidered for replacement; Whether the item is to be replaced by similar type of item or by different type for example item with latest technology (Enogwe, 2021).

Almost all systems deteriorate with age or usage unless some of the corrective action is taken to maintain them. Repair and replacement policies are often implemented to reduce system deterioration and failure risk. Increasingly, complex systems have generated interest in the research of replacement theory. The ever increasing repair and maintenance cost necessitates the replacement of the equipment. However, there is sharp, clearly defined time which indicates the need for this replacement, the replacement policy, in this case, consist of calculating the increase operating cost, maintenance cost, forced idle time cost together with cost of replacing the new equipment (Gupta, 2016).

Failure Mechanism of Items

The word failure has got a wider meaning in industrial maintenance than what it has in our daily life. It is categorized in two classes. They are:

1. Gradual failure and

2. Sudden failure. (Progressive failure, Retrogressive failure and Random failure.

Gradual Failure: In this class as the life of the machine increases or due continuous usage, due to wear and tear of components of the facility, its efficiency deteriorates due to which the management can experience:

- Progressive increase in maintenance expenditure or operating costs,
- Decreased productivity of the equipment and
- Decrease in the value of the equipment i.e. resale value of the equipment/facility decreases. Examples of this category are: Automobiles, Machine tools, etc.

Sudden Failure: In this case, the items ultimately fail after a period of time. The life of the equipment cannot be predicted and is some sort of random variable. The period between installation and failure is not constant for any particular type of equipment but will follow some frequency distribution, which may be:

- Progressive failure: In this case probability of failure increases with the increase in life of an item. The best example is electrical bulbs and computer components.

- Retrogressive failure: Some items will have higher probability of failure in the beginning of their life, and as the time passes chances of failure becomes less. That is the ability of the item to survive in the initial period of life increases its expected life. The examples are newly installed machines in production systems, new vehicles, and infant baby (The probability of survival is very less in infant age, but once the baby get accustomed to nature, the probability of failure decreases).

- Random failure: In this class, constant probability of failure is associated with items that fails from random causes such as physical shocks, not related to age. In such cases all items fail before aging has any effect.

Replacement of Items that Fail Completely and Suddenly

There are certain items or systems or products, whose probability of failure increases with time. They may work with designed efficiency throughout their life and if they fail to act they fail suddenly. The nature of these items is they are costly to replace at the same time and their failure affect the functioning of entire system. For example, resistors, components of air conditioning unit and certain electrical components, if they are not replaced immediately, then loss of production, idle labour; idle raw materials, etc. are the results. It is evident failure of such items cause's heavy losses to the organization. Such situations demand the formulation of a policy, which will help the organization to avoid losses (Murthy, 2019).Sometimes it is better to replace the item before it fails so that the expected losses due to failure can be avoided. The following courses of action can be followed:

a) Individual replacement policy: This policy states that replace the item soon after its failure. Here the cost of replacement will be somewhat greater as the item is to be purchased individually from the seller as and when it fails. From the time of failure to the replacement, the system remains idle. More than that, as the item is purchased individually, the cost of the item may be more. In case, the component or the item is not available in the local market, one have to get it from other places, where the procurement cost may be higher for individual purchase. If the management wants to adopt this policy, it may have to waste its time and money also the losses due to failure. It is denoted with the equation below:

$$A_{(n)} = A_0 * C_i = \frac{N}{E(X)} C_i$$

b) Group replacement policy: If the organization has got the statistics of failure of the items, it can calculate the average life of the item and replace the item before it fails, so that the system can work without break. In this case, all the items, even they are in good working condition, are replaced at a stipulated period as calculated by the organization by using the group replacement policy. One thing is to remember is that, in case any item fails, before the calculated group replacement period, it is replaced individually immediately after failure. Hence this policy utilizes the strategy of both individual replacement and group replacement. The probability distribution of the failure of the item in a system can be determined by mortality tables for life testing techniques. It is denoted with the equation below:

$$A_{(n)} = \frac{C_n}{n} = NC_g + \frac{C_i \sum_{X=1}^{n-1} N(X)}{n}$$

2. Research Methods

The replacement of the items that fail suddenly was evaluated. Average rate of failure was computed. Individual and group replacements were obtained. The total number of items initially in the system (N), the probability of failure of items (P), and the expected life of the item (E(X)) were used as the input variables. A computer program was then written in C++. The outputs were presented as numerals, and tables.

Conceptual Framework

A conceptual framework illustrates the expected relationship between the research variables. It defines the relevant objectives for the research process and maps out how they come together to draw coherent conclusions.

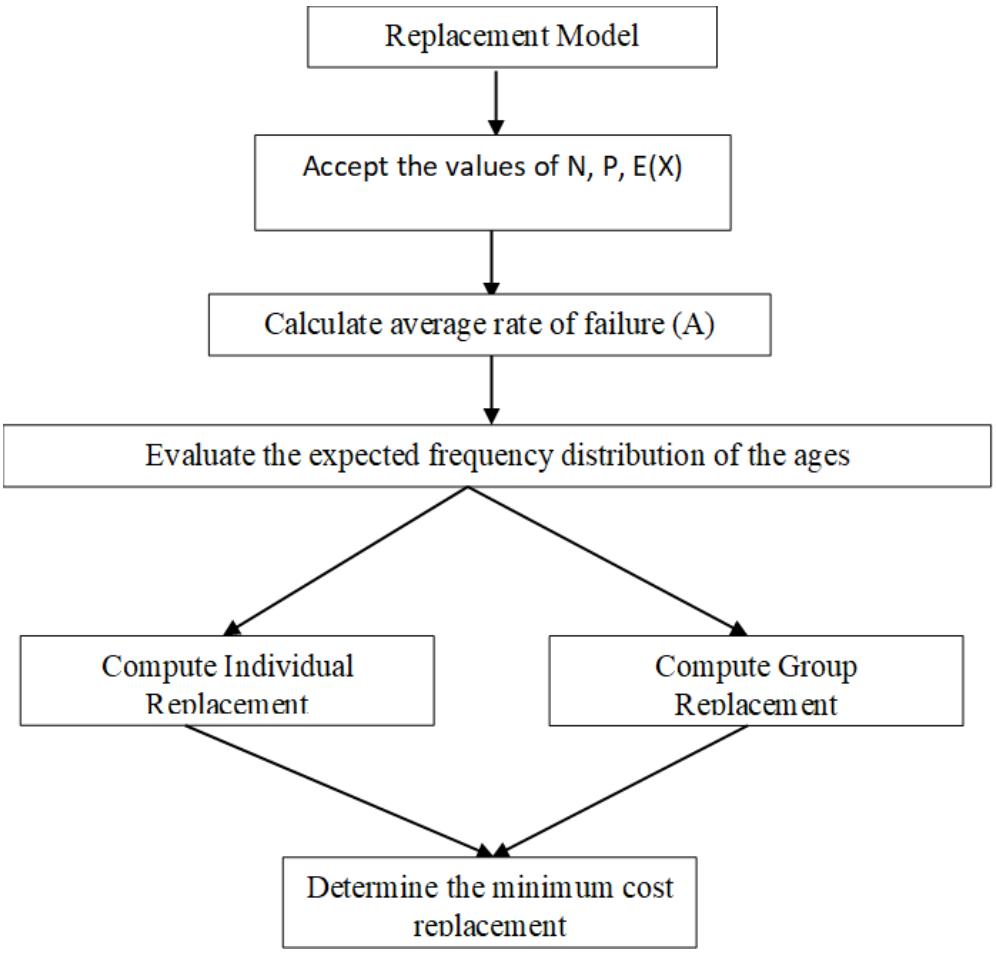


Figure 1. Conceptual Framework of the Model

Input Variables and Results Analysis

Replacement analyses for individual and group replacement policy were implemented in C++ programming language. When a user lunches the Dev C++ application, the user accepts the number of replacement unit, probabilities and the cost of replacement. The expected number of units to be replaced in each week 1 to 7, rate of failures expected in the long run, the expected frequency distribution in the long run, individual and group replacement on failure costs of 5 paise each would be display as output.

Table 1. Input variables for number of unit replaced, probabilities and cost of replacement

NUMBER OF UNIT REPLACED (N_0)	PROBABILITIES		COSTS OF REPLACEMENT (₦)
10000	P1	0.1	500
	P2	0.5	
	P3	0.2	
	P4	0.4	
	P5	0.9	
	P6	0.3	
	P7	0.0	
	P8	0.8	
	P9	0.7	
	P10	0.6	

Table 2: The output result of the mean life failure, average rate of failure, expected frequency distribution of ages, individual replacement policy and group replacement policy.

The Mean Life Failure At Long Run (Weeks)	Average Rate of Failure In The Long Run (Per Week)	Expected Frequency Distribution of Ages At The Beginning of 8th Week	Individual Replace-Ment Policy	Weeks	Group Replacement Policy
28.3	353	39507.4	17.65	1	500
				2	250
				3	251. 667
				4	226.375

3. Discussion and Findings

From table 1 above, the number of unit replacement was accepted as 10000, the probabilities accepted for p1, p2, p3, p4, p5, p6, p7, p8, p9 and p10 are 0.0, 0.2, 0.4, 0.3, 0.1, 0.0, 0.0, 0.0, 0.0 and 0.0 respectively. The value for the costs of replacement was accepted as ₦300. The mean life failure at long run was computed as 3.3 weeks and the average rate of failure in the long run was computed as 3030 per week.

From table 2 above, the average rate of failure was then multiply by the percentage of costs of 5 paise and the individual replacement time was computed as 151.5 per week. The group replacement policy was then computed for week 1, 2, 3, and 4 as 300, 150, 133.33, and 150 respectively. Therefore, the minimum cost replacement policy in group replacement is at every three weeks for a cost of ₦133.33 per week.

4. Conclusion

Analysis of replacement models for items that fails suddenly was computed using C++ program. The number of unit replacement, probabilities and the value for the costs of replacement were accepted in the program. The mean life failure at long run, average rate of failure, individual replacement time**,** and the group replacement time were computed.

The number of unit replacement was accepted as 10000, the probabilities for p1 to p10 were considered. The value for the costs of replacement was accepted as ₦300. The mean life failure at long run was computed as 3.3 weeks and the average rate of failure in the long run was computed as 3030 per week. Individual replacement time was computed as 151.5 per week and the group replacement policy was then computed for week 1, 2, 3, and 4 as 300, 150, 133.33, and 150 respectively. The comparisons were done on the group replacement time for week 1 to 4, and the minimum cost replacement time is ₦133.33 per week. Therefore, the cost of replacement time is due at every three weeks.

Recommendations

Based on the results from the analysis, it is recommended that:

1. Since the cost of replacement time is due at every three weeks, the group replacement should be done every three weeks.
2. There should be need to consider other values for the number of unit replacement to compare the above metrics.
3. More research should be conducted on the replacement analysis because of it significance to the society.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Alexander, O. (2015). Vehicle Repair and Maintenance Costs in Nigeria: Development of a Standard Model. *Global Journal of Mathematical Sciences*, 3, 1-4. https://doi.org/10.4314/gjmas.v3i1.21344

Christer, R. (2017). *"The Indian Economy and its Performance since Independence".* Delhi: Oxford University Press, 2017.

Derendra, C. (2018). "Vehicle Replacement in Government Parastatals": A Comparative Study of Major Government Policies. *Global Journal of Mathematical Sciences,* 2, 37-41

Dror, Z. (2019) "*Maintenance, Replacement and Reliability",* Pitman Publishing, London, 2019, pp 31-134

"A Modified Optimal Replacement Policy for Items That Fail Suddenly". An Unpublished M.Sc Thesis, Department of Statistics, Michael Okpara University of Agriculture, Umudike, Abia State-Nigeria

Gupta, S. and Kapoor, V. (2016). *Fundamentals of Mathematical Statistics.* 11th Edition. Sultan Chand and Sons, New Delhi, India

Hira, D. (2020). "Operations Research for Engineering, Computer Science, Commerce & Management Economics.

Kumar N., (2020). "Development of Vehicle Replacement Programme for a Road Transport Company". *International Journal of Applied Science and Technology*, 2, 31-35.

Lan, Y. (2016). "Study of Laplace and Related Probability Distributions and Their Applications". Unpublished Ph.D Dissertation, Department of Mathematics, College of Arts and Sciences, University of South Florida.

Massoub B. (2018). "Modified Goodness-of-Fit Test for the Laplace Distribution". *Communication Statistics A*, 17, 275-281.

Mingchich C. (2019). "Selection of a Probability Distribution Function for Construction Cost Estimation". In: Khorsrowshahi, F., Ed., *20th Annual ARCOM Conference on Association of Researchers in Construction Management*, Heriot Watt University, 1-3 September 2019, Vol. 1, 125-128.

Nwosu, R. (2020). "Selection of a Probability Distribution Function for Construction Cost Estimation". In: Khorsrowshahi, F., Ed., *20th Annual ARCOM Conference on Association of Researchers in Construction Management,* Heriot Watt University, 1-3 September 2020, Vol. 1, 125-128.

Rama M. (2019). "*Business Statistics for Management and Economics".* 5th Edition. Houghton Miffling Company, Boston, New Jersey USA.

Samuel, U. (2019). "A Unified Methodology of Maintenance Management for Repairable Systems Based on Optimal Stopping Theory". A Dissertation Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College.

Satoshi, M. (2021). "Development of Vehicle Replacement Programme for a Road Transport Company". *International Journal of Applied Science and Technology*, 2, 31-35.

Sobanjo, J. (2018). "*Operations Research: Theory and Applications".* 4th Edition, Macmillan India Ltd., New Delhi.

Stephen, O. (2019). *"Numerical Methods for Scientific and Engineering Computation".* 5th Edition, New Age International (P) Limited Publishers, New Delhi, India.

Tijanni, J.S. (2023). *"Introduction to Probability and Statistics Principles and Applications for Engineering and the Computing Sciences".* 3rd Edition, McGraw-Hill, New York.

Zhang, W.D. (2019). *"Simulation Modeling and Analysis".* McGraw-Hill, New York.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Evaluation of Users Preferred Biophilic Design Elements in Commercial Office Building, Abuja

Adeniji AHMED [1*]

[1] Department of Architecture, School of Architectural Technology, Federal University of Technology, Minna
adenijiadeolaahmed@gmail.com (Responsible Author)

Muhammad Isa BALA[1]

[2] Department of Architecture, School of Architectural Technology, Federal University of Technology, Minna

Abstract

Rapid urbanization has increasingly distanced individuals from natural environments, raising questions about the human experience within built spaces. Biophilic design, which integrates elements such as natural light, vegetation, water features, natural materials, and spatial configurations, offers a restorative approach to workplace environments. This study evaluated users' preferred biophilic design elements in commercial office buildings in Abuja, with the aim of understanding how natural features and spatial qualities influence comfort, well-being, and workplace satisfaction. A quantitative methodology was adopted using structured surveys to collect responses from office users across diverse professional and demographic backgrounds. Participants assessed biophilic elements categorized as direct experience of nature (light, vegetation, water), indirect experience of nature (natural materials, colours, patterns), and experience of space and place (variability, refuge, prospect). The findings revealed a strong preference for natural light and indoor vegetation, which were consistently ranked as the most impactful on comfort and productivity. In contrast, water features and highly variable spatial forms were less prioritized. Analysis underscored the importance of user engagement in workplace design, demonstrating that aligning design strategies with user preferences enhances well-being, satisfaction, and sustainable office practices. The study concludes that architects, designers, and facility managers should integrate user-preferred natural elements into both new and existing workplaces. Doing so fosters restorative, human-centred, and culturally meaningful environments that support long-term user satisfaction while contributing to sustainable building practices.

Keywords: Biophilic design, user preferences, office buildings, workplace well-being, indoor environmental quality, Abuja

1. Introduction

The concept of *biophilia*, derived from the Greek terms *bios* (life) and *philia* (love), encapsulates the innate human tendency to affiliate with life and natural systems. This notion forms the theoretical foundation of biophilic design, which promotes the deliberate integration of natural elements into architecture, urban planning, and governance (Cortina, 2024). Zhong et al. (2022) assert that biophilic design extends beyond the mere inclusion of greenery; it encompasses a wide range of experiences which are physical, sensory, morphological, material, and even spiritual that reconnect humans with their natural environment.

Empirical studies such as Aerts et al. (2018) and Hao et al. (2024) affirm that incorporating natural features such as daylight, vegetation, and ventilation yields significant benefits, including improved health, enhanced well-being, and greater productivity within the built environment. Conversely, technological progress and the increasing dominance of sealed, artificial environments have weakened human contact with nature, with adverse effects on physical, mental, and emotional well-being (Harper & Snowden, 2017; Bianchi et al., 2024). In Nigeria, for instance,

many office buildings in Abuja are characterized by heavily glazed façades and fully air-conditioned interiors, which often limit direct access to daylight, natural ventilation, and greenery, thereby exacerbating the disconnect between workers and their natural surroundings.

Research demonstrates that access to natural light, open spatial configurations, and visual or physical contact with greenery promotes restorative experiences, elevating mood, cognitive performance, and workplace satisfaction (Bolouki et al., 2025; Ergan et al., 2019). For example, Ergan et al. (2019) found that employees in offices with unobstructed views of green landscapes reported reduced stress levels and higher levels of job satisfaction compared to those in enclosed, windowless spaces.

Since the late 1980s, sustainability discourses have reintroduced nature as a vital inspiration in architectural practice, positioning biophilic design as a critical frontier in sustainable architecture (Zhong et al., 2022). The growing prominence of environmental responsibility, especially in the post-COVID-19 era, has amplified the demand for frameworks that integrate biophilia, ecology, and inclusive design principles. These frameworks not only promote physical and psychological health but also support social well-being in the built environment (Reinmueller, 2023).

Within contemporary workplaces, the paradigm has shifted from mere productivity to a broader emphasis on user experience, holistic development and well-being. The studies of Niza et al. (2024) and Felgueiras et al. (2023) highlighted that elevated stress levels in office settings are often linked to poor environmental quality, which diminishes productivity. Conversely, natural environments exhibit restorative potential, alleviating stress and fostering resilience (Gunawardena & Steemers, 2023). As a result, integrating biophilic strategies into workplace design is increasingly recognized as a pathway to healthier, more meaningful, and human-centred workspaces (Rao et al., 2025; Issac, 2024).

However, while research on biophilic design has expanded in Western and Asian contexts, limited studies have explored user preferences in African office environments. This gap is particularly significant given the rapid urban growth and evolving workplace cultures in cities such as Abuja. Consequently, this study evaluates users' preferred biophilic design elements in commercial office buildings in Abuja, Nigeria. Abuja is selected as the case study location due to its position as the nation's administrative capital, its concentration of high-rise office developments, and its representative role in shaping modern workplace design across the country. The aim is to identify features that most significantly influence workplace satisfaction, well-being, and performance.

2. Biophilic Design and Its Principles

According to Andreucci et al. (2021) and Panagopoulos et al. (2021), biophilic design is a holistic approach that prioritizes human well-being, minimizes environmental damage, and enhances the resilience of the built environment. Biophilic design is not a temporary trend but grounded in biophilia theory, which emphasizes humanity's innate affinity for nature and the need to reconnect people with natural systems. Consequently, as Barbiero and Berto (2021) explain, it responds to the growing demand for nature-integrated spaces in architecture, city planning, and sustainability practices.

The application of biophilic concepts spans a wide range of building typologies. Abdelaal (2019) highlights their use in residential, commercial, educational, and healthcare facilities, where eco-friendly technologies and green infrastructure enhance resilience. Similarly, Paul et al. (2024) emphasize that these strategies support long-term sustainability goals. Beyond functionality, Richardson and Butler (2022) note that biophilic principles foster continuous interaction with nature, strengthening emotional connections to the built environment. At multiple scales ranging from urban planning to architectural detailing, biophilic design employs human-centred strategies that appeal to the senses (Dalay & Aytaç, 2022).

Empirical evidence also demonstrates its psychological and physiological benefits. Soderlund and Newman (2015), for example, found that exposure to natural features reduces stress, enhances mental health, and improves productivity. More recent studies confirm these effects in workplace settings, showing that natural cues positively shape psychological responses and perceptions of quality (Song et al., 2022). Likewise, Ariyawansa et al. (2022) identify key biophilic triggers that enrich user experiences, while Ifebi et al. (2024) demonstrate how natural components foster tranquillity and well-being across offices, healthcare, and educational spaces.

Despite these benefits, Richardson and Butler (2022) caution that more comprehensive frameworks are required to maximize the potential of nature connectivity. This gap is particularly relevant to the present study, as it motivates the evaluation of user preferences for biophilic design in Abuja's commercial office buildings. In this context, even small-scale interventions, such as the integration of natural light, indoor plants, or water features can transform workplace environments (Khanzadeh, 2024). As Dalay and Aytaç (2022) argue, in an era of rapid urbanization where people are increasingly detached from nature, biophilic design is not only an ecological strategy but also a determinant of workplace quality. Its integration into commercial office buildings is therefore significant, offering the potential to improve user satisfaction, job performance, and overall well-being.

3. Biophilia and Office Design

Office design is widely recognised as a multidimensional construct encompassing building components, spatial layout, indoor environmental quality (IEQ), and organisational culture, all of which jointly influence users' wellbeing and productivity. Scholars argue that the workplace functions as a psychophysical system where physical conditions and users' perceptions interact to shape satisfaction and performance outcomes (Roskams & Haynes, 2021; Zhang, 2025).

Within this system, layout and IEQ have emerged as vital design factors. They facilitate efficient task performance, reduce stress, and support communication and supervision (Appel-Meulenbroek et al., 2018). Among IEQ parameters, daylighting, thermal comfort, air quality, acoustics, and visual access to nature are the most influential. According to Manfredini et al. (2023) and Negarestan (2025), natural light and views of greenery not only regulate circadian rhythms but also reduce stress and enhance job satisfaction and recovery rates. Similarly, indoor planting and biophilic cues have been shown to improve attention and lower absenteeism (Fadda et al., 2023; Altaf & Billington, 2025). Lighting quality more broadly has direct effects on mood and

performance, while poor acoustics and noise distractions consistently emerge as major contributors to reduced concentration and dissatisfaction (Kang et al., 2017; Kim & De Dear, 2013).

Thermal comfort is also strongly linked to productivity, with studies often identifying an optimal temperature range of 21–22°C (Seppänen et al., 2006; Wargocki et al., 2012). However, this benchmark largely derives from temperate-climate studies and requires contextual adjustment for tropical regions such as Abuja, where adaptive thermal comfort models suggest slightly higher ranges may be more suitable (Nimlyat et al., 2023). Similarly, adequate ventilation and low-emission materials significantly improve wellbeing and reduce sick-building symptoms.

These studies show workplace wellbeing depends not on single elements but on the integration of biophilic and IEQ features. Effective design strategies combine daylight and views, ventilation and thermal control, greenery and micro-restorative spaces, alongside acoustic and material considerations. Furthermore, providing occupants with adaptive control over these conditions is very important. Localised control allows employees to adjust to comfort variations in real time, while simultaneously supporting energy-efficient building management—an important consideration in climates like Abuja where cooling demands are high (Loengbudnark et al., 2023; De Dear et al., 2013). These empirical findings affirm the centrality of preferred biophilic elements, particularly daylight, vegetation, natural views, ventilation, and thermal comfort, in shaping job satisfaction and workplace performance within commercial office environments.

4. Biophilic Design Elements in Commercial Office Buildings

Biophilic design advances the principle that human health and productivity are significantly enhanced when built environments reconnect occupants with nature. Kellert and Calabrese (2015) argue that this reconnection must be systematic and holistic, since fragmented or decorative applications diminish its effectiveness. In commercial office buildings, where employees spend extended periods in controlled environments, biophilic interventions are particularly valuable. They can reduce stress, foster cognitive restoration, and strengthen job satisfaction.

Kellert (2012) categorizes biophilic attributes into direct experience of nature, indirect experience of nature, and experience of space and place. Each provides distinct but complementary contributions to workplace well-being. Direct experiences, such as access to natural light, fresh air, vegetation, water, and outdoor views, are strongly correlated with improved concentration and reduced stress. Green walls, indoor planting, and rooftop gardens not only moderate indoor climates but also provide restorative micro-environments that mitigate the sterility of enclosed offices (Abdulkadir & Olagunju, 2023).

Indirect experiences operate through natural analogues such as textures, colours, and natural materials that elicit affective responses linked to ecological memory (Kellert, 2006). In commercial offices, finishes in timber, natural fibres, or biomorphic forms can create a calming ambience and enhance satisfaction, even in settings with limited direct access to nature.

The experience of space and place, by contrast, encompasses more abstract spatial strategies, including refuge and prospect, as well as complexity, order, and mystery (Duarte, 2017; Dosen & Ostwald, 2013). In office settings, this translates into layouts that balance open-plan expansiveness

with private nooks, alongside circulation paths that encourage curiosity and engagement. These spatial qualities resonate with evolutionary preferences for safety, exploration, and sensory stimulation. Moreover, multisensory cues such as the sound of water, the flow of air, and the tactile qualities of surfaces extend beyond visual perception to improve comfort, creativity, and overall cognitive well-being in office environments (Kellert & Calabrese, 2015).

Building on these conceptual foundations, Ryan et al. (2014) and Browning et al. (2015) identified 15 patterns of biophilic design organized across the three categories above, offering practical guidelines for application in contemporary workplaces. These patterns highlight the tangible links between nature-health interactions and workplace performance. In the present study, they provided the conceptual framework that informed both the analysis and interpretation of findings, ensuring that design recommendations are anchored in established biophilic theory.

5. Methodology

This study adopted a descriptive research design. The design enabled the examination of nine key biophilic attributes which include, natural lighting, ventilation, vegetation, water features, natural materials, and spatial variability, considered as independent variables influencing workplace well-being, stress reduction, and job satisfaction. A quantitative approach was employed, involving the administration of structured questionnaires to two groups: office users (N = 214) and building professionals (N = 103). The research focused on high-rise commercial office buildings in Abuja, Nigeria, selected through purposive sampling to capture buildings with significant occupancy rates, modern design features, and compliance with minimum building standards. Within these buildings, simple random sampling was used to administer questionnaires to occupants who spend at least 80% of their work hours in the offices, while auxiliary staff were excluded.

The survey instruments comprised predominantly closed-ended items rated on 5-point Likert scales, supplemented by targeted open-ended responses. Reliability testing using Cronbach's alpha yielded a coefficient of 0.97, indicating excellent internal consistency of the measures. Data analysis employed both descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, percentages, and graphical representations, were used to summarise demographic characteristics and highlight patterns in user and professional preferences for biophilic design elements. To examine associations between variables, inferential analyses were conducted. A chi-square test assessed the relationship between the perceived biophilic quality of office spaces and job satisfaction, while Spearman's rank-order correlation measured the strength and direction of relationships between specific biophilic features (such as natural light, ventilation, greenery, and water features) and workplace outcomes such as comfort, productivity, stress reduction, and satisfaction. These non-parametric tests were selected given the ordinal nature of Likert-scale data and the non-normal distribution of responses. All analyses were conducted using SPSS (Version 26.0).

6. Results And Discussion

To explore which biophilic design elements most resonate with office users in Abuja, the study examined respondents' understanding of what constitutes a biophilic workplace through selection of defining characteristics, including natural light, plant integration and views of nature. Building

on this foundational understanding, building practitioners and professionals indicated biophilic design elements considered most effective for enhancing job satisfaction and well-being in office settings. The demographic profile of respondents indicates a predominantly young workforce, with the largest age group being 26–35 years (46.7%), followed by under-25 (20.6%), while only 1.4% were over 65, suggesting that receptiveness to innovative workplace interventions such as biophilic design may be shaped by youth dominance. Gender distribution shows a male majority (62.2%), with females comprising 36.0% and 1.9% preferring not to disclose, a factor to be considered in interpreting gender-based differences in preferences.

General perception of biophilic design element

Table 1 summarises respondents' selections of biophilic features considered most effective for enhancing job satisfaction and well-being. Natural light emerged as the most endorsed element, with 85.98% of participants identifying it as significant. Natural ventilation and fresh air followed closely at 84.11%, while thermal comfort with high air quality was selected by 72.90%. Views of nature from windows (72.43%) and a strong visual connection with nature (65.89%) also ranked highly. Indoor plants and greenery (60.75%) and the use of natural materials such as wood or stone (60.28%) were each chosen by over 60% of respondents. Natural patterns and colours were cited by 51.40%, while nature-themed artwork (42.06%) and water features (31.71%) were less frequently selected.

When compared with international studies, these results show both convergences and divergences. For instance, the prioritisation of daylight aligns with findings from Kellert and Calabrese (2015) and Browning et al. (2014), who emphasise natural light as one of the most universally recognised drivers of well-being in workplace environments globally. Similarly, the high value placed on views of nature echoes evidence from Ohly et al. (2016), who demonstrated that visual access to greenery reduces stress and supports attentional restoration. However, Abuja respondents' comparatively lower emphasis on water features (31.71%) contrasts with findings from North American and European studies, where aquatic elements are often highlighted as restorative (Geist & Hawkins, 2016). This suggests that contextual and cultural factors may mediate the relative salience of certain biophilic elements in Nigerian workplaces.

Table 1. Selected biophilic features considered most effective for improving job satisfaction and well-being

Biophilic Feature	Count	Percentage (%)
Indoor plants and greenery	130	60.75
Natural Light	184	85.98
Views of nature from windows	155	72.43
Natural ventilation and fresh air	180	84.11
Natural materials	129	60.28

Water features	70	31.71
Nature-themed artwork	90	42.06
Visual connection with nature	141	65.89
Natural patterns & colours	110	51.40
Thermal comfort and air quality	156	72.90

Professional Perception of Biophilic Design Element

Table 2 presents the preferences of building professionals (N = 103), including architects, engineers, and facility managers, regarding the most important biophilic design elements for enhancing office user satisfaction and well-being. Providing access to outdoor nature (for example, courtyards or terraces) was ranked highest, with 76.7% identifying it as the top priority. Natural lighting and views followed closely at 72.8%, while indoor plants and greenery were selected by 70.9%. Just over half (50.5%) prioritised the use of natural materials such as wood or stone, while 40.8% highlighted water features such as fountains or aquaria. These preferences are broadly consistent with literature highlighting direct contact with nature as the most valued biophilic design strategy (Richardson & Butler, 2022). Yet, the prominence of outdoor courtyards and terraces in the Abuja context may reflect climatic and cultural conditions, differing from colder-climate studies where interior vegetation often dominates biophilic interventions.

Table 2. Most important biophilic design element in offices as identified by building professionals (N=103)

Biophilic Element	**Count**	**Percentage (%)**
Incorporates water features (such as fountains, aquariums)	42	40.78
Uses natural materials (wood, stone, bamboo)	52	50.49
Uses plants and greenery indoors	73	70.87
Makes use of natural lighting and views	73	72.82
Provides access to outdoor nature (courtyards, roof gardens)	79	76.70

Association between biophilic feel and job satisfaction

To examine how the exposure to and incorporation of biophilic elements influenced key workplace outcomes, including perceived comfort, productivity, stress reduction, and overall job satisfaction, respondents rated their agreement with related statements on a five-point Likert scale. Spearman's rank-order correlations were computed to assess associations between the overall implementation of biophilic elements in the office and each outcome index. Open-text responses were thematically analysed to identify whether design impacts were perceived as positive, negative, or neutral.

Table 3 cross-tabulates respondents' overall rating of the "biophilic feel" of their office (on a 1–5 scale) against their reported impact on job satisfaction (Negative, Neutral, Positive). A clear pattern emerges: as the biophilic feel score increases, the proportion of respondents reporting a positive impact rises sharply, from 37.5% at score 1 to 75.9% at score 3, while negative evaluations decline to zero at the highest biophilic rating.

Table 3. Contingency table

Biophilic feel of office / impact on job satisfaction	Negative	Neutral	Positive
1	4	6	6
2	8	16	41
3	5	16	66
4	2	13	22
5	0	2	7

As seen in Table 4, a chi-square test of independence confirmed that this distribution differs significantly from chance ($\chi^2(8) = 15.65$, $p = 0.048$, Cramer's $V = 0.21$), indicating a small-to-moderate effect size. In other words, employees who experience stronger biophilic elements are significantly more likely to report positive effects on their job satisfaction.

Table 4. Chi square test results

Chi Square Statistics	df	p-value
15.65	8	0.048

Correlation analysis of specific biophilic elements and perceived outcome

As revealed in Figure 1, to further explore the interrelationships between biophilic design features, a Spearman correlation heatmap was generated. The heatmap illustrates the strength and direction of associations across the ten survey items (Q1–Q10). Darker red shades denote stronger positive correlations, while lighter tones represent weaker associations; blue tones indicate negative correlations. Strong to very strong correlations ($\rho \geq 0.70$) are evident between Q2 (productivity with views of nature) and Q6 (indoor plants, $\rho = 0.71$), Q3 (water features) and Q7 (nature-themed artwork, $\rho = 0.74$), and Q6 (indoor plants) with Q10 (breakout spaces/indoor gardens, $\rho = 0.75$).

These results indicate that vegetation, natural views, and flexible restorative spaces tend to reinforce one another as integrated aspects of a biophilic workplace. Moderate to strong correlations ($\rho = 0.50–0.69$) were also observed, particularly between Q4 (natural materials) and Q5 (daylight, $\rho = 0.63$), and between Q5 (daylight) and Q8 (natural ventilation and air quality, $\rho = 0.69$), suggesting that materiality, daylight, and ventilation are perceived as mutually reinforcing

environmental qualities. These patterns resonate with Kellert and Calabrese (2015), who emphasise multisensory layering as a cornerstone of biophilic effectiveness.

By contrast, Q1 (overall biophilic feel of the office) exhibited weak and slightly negative correlations with individual features (ρ ranging from –0.17 to –0.05). The negative values indicate not merely weak but, in some cases, inverse associations, suggesting that employees' holistic sense of a "biophilic workplace" may not align directly with the presence of specific features. This supports the interpretation that biophilic feel is an emergent construct shaped by the cumulative integration of multiple features rather than any single dominant element (Andreucci et al., 2021). Consequently, workplace design strategies should avoid overemphasising one feature, such as greenery or daylight at the expense of holistic integration. This conclusion is reinforced by the chi-square results in Table 3.

Taken together, the correlation and chi-square findings highlight a critical distinction. On the one hand, individual features such as daylight, indoor plants, or breakout spaces are strongly interlinked and valued by employees; on the other hand, the global perception of biophilic quality and its predictive relationship with job satisfaction depends on the holistic integration of multiple features. This dual insight aligns with global evidence that piecemeal application of biophilic strategies is less effective than layered, multisensory design approaches (Yin et al., 2024). In the Abuja context, this suggests that organisations seeking to improve workplace well-being should prioritise integrated strategies that combine daylight, vegetation, ventilation, natural materials, and restorative spaces, rather than privileging a single element in isolation.

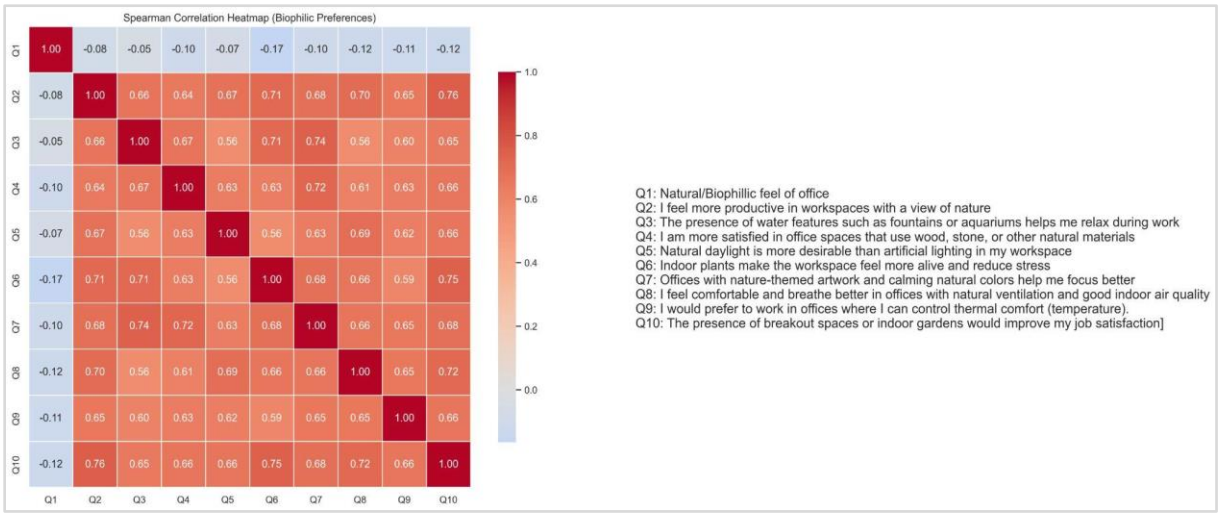


Figure 1. Heatmap of relationship between biophilic feel of offices and rating of job satisfaction

7. Conclusion

This study validates that biophilic design elements are highly valued by office users and building professionals in Abuja, with consistent evidence that natural light, ventilation, views of nature, and

indoor greenery are central to enhancing workplace comfort, productivity, and well-being. As such, these elements should be should be reflected in design strategies that maximize daylight, views, and ventilation while supporting acoustic comfort. The statistically significant association between the perceived biophilic quality of office environments and job satisfaction ($\chi^2(8) = 15.65$, $p = 0.048$, Cramer's $V = 0.21$) provides empirical support for the theoretical premise that human affinity for nature supports healthier and more fulfilling workplace experiences. Moreover, beyond significance, specific correlation patterns highlight how integrated strategies yield complementary benefits. For instance, the strong association between breakout spaces and productivity ($\rho = 0.76$) suggests that informal, socially supportive areas may reinforce the positive effects of nature views by providing restorative opportunities within the office. Similarly, the close links between ventilation, thermal comfort, and well-being ($\rho \geq 0.72$) highlighted that comfort-oriented design interventions do not function in isolation but collectively shape holistic user satisfaction.

While decorative features such as water elements and nature-themed artwork were not among the highest priorities, their positive associations with vegetation ($\rho = 0.74$) suggest they can enhance the sensory diversity of office environments when integrated thoughtfully. This echoes findings from biophilic design research emphasizing the cumulative impact of multisensory experiences in fostering vibrant and engaging environments (Ryan et al., 2014). Importantly, both office users and professionals highlighted outdoor access and natural light as critical to achieving optimal workplace outcomes, confirming their primacy across contexts. In conclusion, the findings reinforce the necessity of embedding a broad palette of biophilic elements into commercial office design in Abuja, advancing workplace satisfaction and productivity while simultaneously aligning with sustainable building practices and contributing to healthier, more resilient urban futures.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Abdelaal, M. S. (2019). Biophilic campus: An emerging planning approach for a sustainable innovation-conducive university. *Journal of Cleaner Production*, *215*, 1445–1456. https://doi.org/10.1016/j.jclepro.2019.01.185

Abdulkadir, J., & Olagunju, R. (2023). Biophilic design: Towards enhancing user's comfort via direct experience with nature in high-rise residential buildings, Abuja, Nigeria. *World*, *27*(4), 107-118.

Aerts, R., Honnay, O., & Van Nieuwenhuyse, A. (2018). Biodiversity and human health: Mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*, *127*(1), 5–22. https://doi.org/10.1093/bmb/ldy021

Altaf, B., & Billington, S. L. (2025). Biophilic Design Interventions for Indoor Environments: Exploring Nature Connectedness, Well-being, and Public Acceptance Through a Within-subjects Experiment. *Environment and Behavior*, *57*(5-6), 399-430.

Andreucci, M. B., Loder, A., Brown, M., & Brajković, J. (2021). Exploring challenges and opportunities of biophilic urban design: Evidence from research and experimentation. *Sustainability*, *13*(8), 4323.

Appel-Meulenbroek, R., Clippard, M., & Pfnür, A. (2018). The effectiveness of physical office environments for employee outcomes: An interdisciplinary perspective of research efforts. *Journal of Corporate Real Estate*, *20*(1), 56–80. https://doi.org/10.1108/JCRE-04-2017-0012

Ariyawansa, D. N., Perera, N. G. R., & university of Moratuwa, Sri Lanka. (2022). The Role of biophilic design in hotel architecture: A case study of Heritance Kandalama, Sri Lanka. *15th International Research Conference - FARU 2022*, 214–223. https://doi.org/10.31705/FARU.2022.24

Barbiero, G., & Berto, R. (2021). Biophilia as evolutionary adaptation: An onto-and phylogenetic framework for biophilic design. *Frontiers in psychology*, *12*, 700709.

Bianchi, E., Bencharit, L. Z., Murnane, E. L., Altaf, B., Douglas, I. P., Landay, J. A., & Billington, S. L. (2024). Effects of architectural interventions on psychological, cognitive, social, and pro-environmental aspects of occupant well-being: Results from an immersive online study. *Building and Environment*, *253*, 111293.

Bolouki, A., McAnirlin, O., HEM Browning, M., & Maynard, A. (2025). Optimizing virtual nature for psychological and physiological well-being: a systematic review of the moderating effects of duration, nature type, sample characteristics, and immersiveness and potential risks of bias. *International Journal of Human–Computer Interaction*, *41*(1), 775-791.

Browning, W. D., Ryan, C. O., & Clancy, J. O. (2015). *14 Patterns of Biophilic Design: Improving Health & Well-Being in the Built Environment* (p. 64). Terrapin Bright Green, LLC.

Cortina, M. (2024). Rethinking Erich Fromm's Humanism and His View of Human Nature. *Psychoanalytic Inquiry*, 44(1), 95-102.

Dalay, L., & Aytaç, G. (2022). Biophilic Design: Integrating Nature into the Urban Environment. In E. G. Özdamar & O. Tandoğan (Eds.), *Advances in Media, Entertainment, and the Arts* (pp. 1–19). IGI Global. https://doi.org/10.4018/978-1-7998-6725-8.ch001

De Dear, R. J., Akimoto, T., Arens, E. A., Brager, G., Candido, C., Cheong, K. W. D., Li, B., Nishihara, N., Sekhar, S. C., Tanabe, S., Toftum, J., Zhang, H., & Zhu, Y. (2013). Progress in thermal comfort research over the last twenty years. *Indoor Air*, *23*(6), 442–461. https://doi.org/10.1111/ina.12046

Dosen, A. S., & Ostwald, M. J. (2013). Prospect and refuge theory: Constructing a critical definition for architecture and design. *The International Journal of Design in Society*, *6*(1), 9.

Duarte, F. (2017). *Space, place and territory: A critical review on spatialities*. Routledge.

Ergan, S., Radwan, A., Zou, Z., Tseng, H., & Han, X. (2019). Quantifying Human Experience in Architectural Spaces with Integrated Virtual Reality and Body Sensor Networks. *Journal of Computing in Civil Engineering*, *33*(2), 04018062. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000812

Fadda, R., Congiu, S., Roeyers, H., & Skoler, T. (2023). Elements of biophilic design increase visual attention in preschoolers. *Buildings*, *13*(5), 1160.

Felgueiras, F., Mourão, Z., Moreira, A., & Gabriel, M. F. (2023). Indoor environmental quality in offices and risk of health and productivity complaints at work: A literature review. *Journal of Hazardous Materials Advances*, *10*, 100314.

Geist, J., & Hawkins, S. J. (2016). Habitat recovery and restoration in aquatic ecosystems: current progress and future challenges. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(5), 942-962.

Gunawardena, K., & Steemers, K. (2023). Assessing the influence of neighbourhood-scale vertical greening application. *Buildings and Cities*, *4*(1), 103–123. https://doi.org/10.5334/bc.282

Hao, S., Zhang, L., Hou, R., Lau, S. S., & Lau, S. S. Y. (2024). Research on the physiological and psychological impacts of extraordinary nature on emotions and restorative effects for young adults. *Journal of Environmental Psychology*, *97*, 102345.

Harper, C. L., & Snowden, M. (2017). *Environment and Society: Human Perspectives on Environmental Issues* (6th ed.). Routledge. https://doi.org/10.4324/9781315463254

Ifebi, O. C., Obi-George, L. C., Maduka, N. M., Nzewi, N. U., & Ochonogor, H. (2024). Integration of Biophilic Design Elements in Hotel Building Environment Towards Enhancing Users Wellbeing in Abuja, Nigeria. *International Journal of Innovative Environmental Studies Research*, *12*(4), 134–151.

Issac, A. L. (2024). The Human-Centred Workplace in Industry 4.0: Cultivating Well-Being and Engagement. In *Smart Cities and Circular Economy* (pp. 1-8). Emerald Publishing Limited.

Kang, S., Ou, D., & Mak, C. M. (2017). The impact of indoor environmental quality on work productivity in university open-plan research offices. *Building and Environment*, *124*, 78–89.

Kellert, S. R. (2006). Building for life: Designing and understanding the human-nature connection. *Renewable Resources Journal*, *24*(2), 8.

Kellert, S. R. (2012). *Birthright: People and nature in the modern world*. Yale University Press. https://books.google.com/books?hl=en&lr=&id=dFZt0lvxkjEC&oi=fnd&pg=PP2&dq=Kellert,+S.+(2012).+Birthright:+People+and+Nature+in+the+Modern+World.+New+Haven:+Yale+University+Press.&ots=GjLyMWGaSv&sig=xc10V7xQbK9M01KqmalcEYker9A

Kellert, S., & Calabrese, E. (2015). The practice of biophilic design. *London: Terrapin Bright LLC*, *3*(21). http://biophilic-design-course.s3.amazonaws.com/module-2/practice-of-biophilic-design-kellert-calabrese.pdf

Khanzadeh, M. (2024). Enhancing user experience in interior architecture through biophilic design: a case study of urban residential spaces. *New Design Ideas*, *8*(1), pp.137-168. https://doi.org/10.62476/ndi81137

Kim, J., & De Dear, R. (2013). Workspace satisfaction: The privacy-communication trade-off in open-plan offices. *Journal of Environmental Psychology*, *36*, 18–26. https://doi.org/10.1016/j.jenvp.2013.06.007

Loengbudnark, W., Khalilpour, K., Bharathy, G., Voinov, A., & Thomas, L. (2023). Impact of occupant autonomy on satisfaction and building energy efficiency. *Energy and Built Environment*, *4*(4), 377-385.

Manfredini, R., Cappadona, R., Tiseo, R., Bagnaresi, I., & Fabbian, F. (2023). Light, circadian rhythms and health. In *Therapeutic Landscape Design: Methods, Design Strategies and New Scientific Approaches* (pp. 81-92). Cham: Springer International Publishing.

Negarestan, A. (2025). Natural Light in Interior Architecture: Enhancing Mental Health. *Management Strategies and Engineering Sciences*, *7*(3), 66-76.

Nimlyat, P. S., Inusa, Y. J., & Nanfel, P. K. (2023). A literature review of indoor air quality and sick building syndrome in office building design environment. *Green Building & Construction Economics*, 1-18.

Niza, I. L., de Souza, M. P., da Luz, I. M., & Broday, E. E. (2024). Sick building syndrome and its impacts on health, well-being and productivity: A systematic literature review. *Indoor and Built Environment*, *33*(2), 218-236.

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *19*(7), 305-343.

Panagopoulos, T., Sbarcea, M., & Herman, K. (2021). A biophilic mind-set for a restorative built environment. *Landscape Architecture and Art*, *17*, 68–77. https://doi.org/10.22616/j.landarchart.2020.17.08

Paul A. O., Ahmad Nia, H., Müzeyyen Findikgil, M., & Goksel Yildirim, S. (2024). Assessing the effectiveness of biophilic design approach in contribution to sustainable architectural goals. *New Design Ideas*, *8*(SI), 144–169. https://doi.org/10.62476/ndisi144

Rao, S., Good, J., & Alavi, H. (2025, July). Designing Multisensory Biophilic Futures: Exploring the Potential of Interaction Design to Deepen Human Connections With Nature in Indoor Environments. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference* (pp. 357-374).

Reinmueller, P. (2023). *Towards Anthropotropic Architecture: Establishing a Framework for Integrating Human Flourishing into Building Design*. Stanford University.

https://search.proquest.com/openview/87085e2f05bd48bf60bdfac9468fd337/1?pq-origsite=gscholar&cbl=18750&diss=y

Richardson, M., & Butler, C. W. (2022). Nature connectedness and biophilic design. *Building Research & Information*, *50*(1-2), 36-42.

Roskams, M., & Haynes, B. (2021). Environmental demands and resources: a framework for understanding the physical environment for work. *Facilities*, *39*(9/10), 652-666.

Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic Design Patterns: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment. *International Journal of Architectural Research*, *8*(2), 62–76. https://doi.org/10.26687/archnet-ijar.v8i2.436

Seppanen, O., Fisk, W. J., & Lei, Q. H. (2006). *Effect of temperature on task performance in office environment*. https://escholarship.org/content/qt45g4n3rv/qt45g4n3rv.pdf

Soderlund, J., & Newman, P. (2015). Biophilic architecture: A review of the rationale and outcomes. *AIMS Environmental Science*, *2*(4), 950–969. https://doi.org/10.3934/environsci.2015.4.950

Song, C., Ali, F., Cobanoglu, C., Nanu, L., & Lee, S. H. J. (2022). The effect of biophilic design on customer's subjective well-being in the hotel lobbies. *Journal of Hospitality and Tourism Management*, *52*, 264–274. https://doi.org/10.1016/j.jhtm.2022.07.008

Wargocki, P., Frontczak, M., Schiavon, S., Goins, J., Arens, E., & Zhang, H. (2012). Satisfaction and self-estimated performance in relation to indoor environmental parameters and building features. *Proceedings of 10th International Conference on Healthy Buildings*, *1*(1), 1–6. https://escholarship.org/uc/item/451326fk

Yin, J., Zhu, H., & Yuan, J. (2024). Health Impacts of Biophilic Design from a Multisensory Interaction Perspective: Empirical Evidence, Research Designs, and Future Directions. *Land*, *13*(9), 1448.

Zhang, X. (2025). *Perceived Environmental Qualities and Occupants' Mental Health, Cognitive Performance, and Satisfaction at Workplaces in China: Survey and Experiment* (Doctoral dissertation, University of Liverpool).

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research*, *11*(1), 114–141. https://doi.org/10.1016/j.foar.2021.07.006

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Effect of Green Wall on Residential Property Values in Ibadan, Nigeria

Nnaemeka Bethel EZEOKOLI [1*]

ORCID 1: 0000-0002-2189-3464
[1] Dr., Federal University of Technology Akure, School of Environmental Technology, Department of Estate Management, Nigeria.
nbezeokoli@futa.edu.ng

Ayooluwa Adeboye ADELAKUN [2]

ORCID 2: 0009-0009-2475-3035
[2] Research Assistant, Federal University of Technology Akure, School of Environmental Technology, Department of Estate Management, Nigeria.
adelakunayooluwa19@gmail.com

Abstract

Despite the increase in recognition given to sustainable property innovations such as green walls for environmental, social and economic benefits, there has been a dearth in the study of the extent of impact of this innovation on residential properties' values particularly in Nigeria. As a result, this study assessed the impact of green walls in residential property development on the rental values of the properties in Ibadan, Oyo State, Nigeria. The study adopted survey design approach to illicit information from 230 respondents which comprises of registered estate surveyor and valuer's firms and residents of the residential properties in Ibadan. out of which, two hundred (200) responses were retrieved and analyzed using descriptive and inferential statistical tools such as Percentage Frequency table, Independent T-Tests and Stepwise Multiple Regression. The Findings revealed a high level of user satisfaction with aesthetics, thermal comfort and environmental benefits of green walls, while the stepwise regression confirms that green walls significantly influenced residential property values, explaining up to 20.5% of the variance in rental performance. The study recommends the incorporation of natural plants on residential properties by developers in the course of planning and execution of the project since it enhances users' satisfaction and property values.

Keywords: Green wall, residential property, sustainable, value

1. Introduction

Climate change has made the need for sustainable urban planning and green infrastructure highly necessary and increasingly urgent (Akpabio et al., 2019) and as a response, the integration of green infrastructure such as green walls has become a popular strategy in urban development most especially in developed nations of the world. Green walls, also called living walls (internal) or vertical gardens is regarded as vegetative systems that have been designed to enhance building facades through plant incorporation in vertical structures. These walls are usually created when interior or exterior surfaces of a building is covered with vegetation thereby promoting sustainability and at the same time serving as a shield against environmental hazards, and are therefore considered as important component of sustainable urban development (Perini et al. 2011, Susorova et al.2013; Perini & Rosasco. 2013).

The impact of green walls on rental values and property prices in Ibadan has not been systematically studied. The absence of clear data on whether properties with green walls command higher rental rates or sale prices compared to those without poses a challenge for stakeholders. The level of satisfaction among users of green walls in residential properties remains unknown. User

experiences with green wall whether positive or negative can influence future adoption rates and perceptions of value. Without understanding how satisfied residents are with these features, it is challenging to determine their long-term viability and appeal. The difference in rental values between properties with and without green walls has not been explored in the study area. While green features are often associated with higher property values in other regions, it is unclear whether this trend holds true in Ibadan's real estate market. Beyond rental income, the overall effect of green walls on residential property values in Ibadan is not well understood. While studies in developed countries have demonstrated that green infrastructure can increase property values (Deng & Wu, 2014), these findings may not be directly applicable to the Nigerian context. This lack of information makes it difficult for property developers and investors to assess whether green walls provide a financial return on investment. Thus, this study aims to examine level of satisfaction of users with green walls in residential properties, measure the difference in rental values of residential properties with and without green walls between 2015-2025 and assess the impact of the green walls on residential property values in Ibadan.

Understanding how green walls impact property values in Ibadan will not only shed light on consumer behavior in a developing city but also provide data-driven recommendations for developers and policymakers. This study seeks to assess the impacts of green walls on property values in Ibadan, Oyo State. It examines how green walls influence buyer and tenant preferences market demand, and overall property valuation in the context of a developing city. By addressing these questions, the research aims to provide valuable insights for property developers, urban planners, and policymakers on the role of green infrastructure in promoting sustainable development and enhancing real estate value. The findings from this study will also contribute to the broader discourse on sustainable urban design in emerging economies.

This study focuses on residential property values within selected areas in Ibadan, Oyo state, Nigeria. Ibadan was chosen as the study location due to its unique blend of historical, environmental, and urban development characteristics that make it an ideal context for analyzing the value implications of sustainable building features such as green walls. The study is limited to selected residential neighborhoods within Ibadan where green walls have been observed or implemented. These areas include neighbourhood such as Bodija, Agodi GRA, Oluyole Estate, and Jericho, all of which are characterized by a mix of medium to high-income residential developments and a growing prevalence of eco-conscious architectural features.

2. Literature Review

2.1. User Satisfaction with Green Walls in Residential Properties

Francis and Lorimer (2011) argued that living walls create biophilic connections that can enhance occupant's psychological wellbeing, reporting that more than 80% of surveyed respondents in Melbourne housing estates experienced increased life satisfaction and perceived tranquility after the installation of vertical greenery. Quantitative reviews further reinforced these findings. Molla (2015) synthesized over forty empirical assessments of urban green infrastructure and reported that green walls consistently scored above 4 on a 5-point satisfaction scale for parameters such as noise reduction, privacy enhancement and sense of community, although scores varied by climate

zone and maintenance regime. Despite positive satisfaction indicators, other researchers caution that poor system performance can erode support. Ottelé, Perini, Fraaij, Haas, and Raiteri (2011) document cases in temperate Europe where malfunctioning irrigation and plant mortality led to satisfaction scores below 3, prompting early decommissioning in two of five pilot sites.

2.2. Difference in Rental Value of Residential Properties with and without Green Walls

Investigating how green wall installations influence rental values is essential for understanding their economic viability in residential markets. While substantial literature documents the sale-price premiums associated with landscape features, the specific effect of vertical greenery on rent remains underexplored. For instance, Rosen's (1974) hedonic pricing theory provides the foundational framework, positing that property attributes both structural and environmental are capitalized into the market prices. However, Rosier (1999) was unable to disaggregate sale from rental markets. Meanwhile, Aigbavboa, Thwala, Ademiloye, and Oshodi (2024) applied random forest algorithm to predict monthly rentals from data elicited from 2,500 online listings of green features such as facades and living walls in Cape Town. The results revealed that vertical greenery appeared in fewer than 5% of listings and on an average, contributed less than 1% premium to predicated rent values attributing this muted effect to both the novelty of the technology and weak market recognition of green walls as a value-adding amenity. On the other hand, insights from Nigeria and comparable West African contexts further underscore the need for localized rental analyses. Ayodele and Olawande (2018), using a similar hedonic approach combined with homeowner questionnaires in Abeokuta, observed that respondents perceived green walls as experimental and beyond typical maintenance capacities. Consequently, rental listings in these markets rarely highlight green wall benefits, leaving landlords with little incentive to invest.

2.3. Effect of Green Walls on the Values of Residential Properties

Early hedonic-pricing studies demonstrated that landscape features in general such as mature trees, manicured lawns, and decorative shrubbery tend to be capitalized into higher sale prices (Rosiers, 1999; Morley, 2008). Building on this foundation, researchers have been able to isolate the contribution of vertical greenery systems. Jim and Chen (2010) conducted a post-occupancy survey in Hong Kong on high-rise condominiums. Results revealed that the units adjacent green façades have achieved price/m^2 increases of 3.5% relative to matched comparators, attributing this gain to enhanced visual amenity and reduced façade-surface temperatures during summer months. Their spatially explicit hedonic model incorporated distance-decay functions to account for the diminishing effect of greenery visibility with increasing floor height.Perini and Rosasco (2013) conducted a cost-benefit analysis comparing living wall systems to conventional façades in Italy and Spain using market sales data from over 200 properties. Hedonic regression techniques were applied and findings revealed that homes with professionally installed green walls commanded sale price premiums of 4-6%, after controlling for floor area, age, location and horizontal landscaping. Their results held under sensitivity tests for maintenance cost variations, suggesting that buyers valued the environmental and aesthetic benefits sufficiently to pay a notable premium. Meanwhile, Manso and Castro-Gomes (2015) extended the work though the meta-analysis of 17 hedonic pricing publications on green façades and living walls. The survey reported an average sales price uplift of 5.2% (95 % CI: 3.8 – 6.6 %), with higher premiums in temperate climates

where green walls deliver pronounced thermal comfort improvements. Their review also highlighted methodological consistency in controlling for structural attributes and neighbourhood characteristics, reinforcing the robustness of the observed premium.

3. Methodology

The study adopts the survey research design approach to elicit data from a large number of respondents within a relatively short period. This survey research design would facilitate the use of structured instruments such as questionnaires to elicit responses from participants which comprises of principal stakeholders in Ibadan residential property market and classified into two categories; registered estate surveying and valuation firms and residential property owners/tenants in Ibadan. For the purpose of this study, 70 practicing professionals gotten from the Nigerian Institution of Estate Surveyors and Valuers (NIESV) Oyo state directory and 160 residential property owners who have installed or currently installing green walls in their buildings complied from Oyo State Ministry of Lands and Housing is adopted as the sample size while data obtained would analyzed using Weighted Mean Score (WMS), Independent T-test and Stepwise Regression.

The Study Area

Ibadan city, with an estimated population of about 3 million people, is one of the largest urban centers in Africa renowned for its rich cultural heritage and rapid urbanization (Raheem & Adebayo, 2016). This population growth, coupled with the sprawling nature of urban development has led to increased pressure on residential infrastructures and environmental resources. The dynamic mix of traditional and modern housing in Ibadan provides a unique context to assess the factors influencing the rate of adoption of green walls in residential property development in Ibadan.

4. Results and Discussion

Table 1. User satisfaction with green wall in residential property developments in Ibadan

	Agodi GRA		**Bodija Area**		**Jericho Area**		**Oluyole Area**	
User Satisfaction	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
The green wall contributes to a quieter, more peaceful space	3.58	1st	3.22	2nd	3.00	8th	2.57	12th
The green wall is easy to maintain	3.42	2nd	3.03	5th	2.93	12th	3.10	4th
I am satisfied with the overall appearance of the green wall	3.28	3rd	2.92	7th	2.97	10th	3.40	1st
The green wall promotes a healthier indoor environment	3.22	4th	3.00	6th	3.25	1st	3.26	2nd
I would recommend green walls to others	3.17	5th	3.08	4th	3.25	1st	2.81	9th

The installation process of green wall was satisfactory	3.17	6th	3.56	1st	3.03	5th	2.90	7th
The green wall has enhanced the aesthetic appeal of my home	2.97	7th	2.56	12th	3.25	1st	2.74	10th
The green wall reduces indoor heat in my home	2.92	8th	2.89	8th	2.98	9th	2.71	11th
The green wall has improved indoor air quality	2.86	9th	2.75	11th	3.02	7th	2.93	6th
The green wall gives me a sense of pride in my residence	2.78	10th	2.83	9th	2.95	11th	3.14	3rd
The green wall has increased the value of my property	2.72	11th	2.83	9th	3.03	5th	3.10	4th
The green wall makes me feel more connected to nature.	2.72	12th	3.17	3rd	3.25	1st	2.88	8th

Source: Field Survey, 2025

The findings presented in Table 1 provide insights into user satisfaction with green walls in selected residential neighbourhoods of Ibadan; Agodi Bodija, Jericho and Oluyole Area. The Table revealed that in Agodi GRA, overall satisfaction levels were moderate to high, with mean values ranging from 3.58 to 2.72 across the 12 satisfaction indicators, all statistically significant at $p < 0.001$. This indicates that residents consistently recognize multiple benefits of green walls, though the degree of satisfaction varies depending on the specific dimension assessed with the most highly rated satisfaction factor as the green wall contributes to a quieter, more peaceful space (Mean = 3.58, Ranked 1st). This finding highlights the role of green walls in providing sound insulation and enhancing tranquility in residential environments. It is consistent with studies that emphasize the noise-buffering potential of green facades, particularly in urban areas where external noise pollution is a key concern (Azkorra et al., 2015). The second- ranked factor, ease of maintenance (Mean = 3.42), further demonstrates that residents value practicality, and when maintenance demands are manageable, satisfaction is significantly enhanced while deeper affective or long-term benefits such as sense of pride (Mean = 2.78), increased property value (Mean = 2.72), and connectedness to nature (Mean = 2.72) were rated lowest as 10th, 11th and 12th respectively. This indicates that residents are less convinced of the symbolic, financial, or emotional value of green walls compared to their functional contributions.

Overall, the analysis reveals a layered pattern of satisfaction: functional benefits (peace and maintenance) dominate, aesthetic and ecological benefits occupy the middle tier, while symbolic and long-term values are perceived as least impactful. The differences in mean values (from 3.58 to 2.72) illustrate that while residents are broadly satisfied, satisfaction is uneven across dimensions. In relation to the study objective, the findings demonstrate that users of green walls in Agodi GRA are moderately satisfied, with the strongest appreciation for functional performance

and ease of upkeep, but with lower satisfaction in areas tied to environmental performance, symbolic value, and economic return.

Also, Table 1 presents the level of user satisfaction of green walls in Bodija. The results show a moderate level of satisfaction with mean values ranging from 3.56 to 2.56 and all statistically significant at $p<0.001$, thus, indicating that while residents recognize the benefits of green walls, satisfaction is uneven across the different dimensions assessed. It was discovered that the most highly rated indicator is the satisfaction with the installation process (Mean = 3.56, Rank 1st), suggesting that respondents were positively impressed with how green walls were introduced into their properties. This score is notably higher than the lowest-ranked factor, aesthetic appeal of homes (Mean = 2.56, Rank 12th), showing a mean gap of 1.0 point. This suggests that while users in Bodija value the process of implementation, they are less convinced of the visual or aesthetic transformation green walls provide. Overall, the analysis of Bodija demonstrates that satisfaction is strongest with the installation process and functional benefits (peace and connectedness to nature), while aesthetic and long-term economic impacts are less convincing to users. The difference in mean scores (from 3.56 to 2.56) reflects a full one-point variation, underscoring a moderate but uneven pattern of satisfaction. In relation to the study objective, the findings suggest that users in Bodija are moderately satisfied, particularly with the installation and experiential benefits, but display lower satisfaction with symbolic, visual, and property value contributions of green walls.

Furthermore, Table 1 shows that in Jericho Area, the top ranked indicators were clustered at the same mean score of 3.25, including recommendations to others, enhanced aesthetic appeal, healthier indoor environment and connectedness to nature and all ranked 1st. This clustering shows that users strongly associate green walls with visible, experiential, and ecological benefits while the willingness to recommend to others further suggests a positive general disposition toward green wall systems among residents. This finding aligns with previous research that highlights social endorsement and peer influence as important drivers of technology diffusion in sustainable housing (Darko & Chan, 2018). The results also show that the mean values were ranged from 3.25 to 2.93, all statistically significant at $p < 0.001$, indicating a relatively narrow satisfaction range compared to Agodi and Bodija. This suggests that residents in Jericho reported more uniform levels of satisfaction, with no single factor standing out as overwhelmingly high or low. Overall, the analysis of Jericho demonstrates that satisfaction is strongest in aesthetic, ecological, and experiential dimensions, with a consistently moderate appraisal across functional, economic, and symbolic benefits. The narrow range of mean scores (3.25–2.93) implies a balanced satisfaction profile, where no aspect of user experience is considered extremely weak but also none are rated exceptionally high. In relation to the study objective, the findings suggest that users in Jericho are moderately and consistently satisfied, particularly valuing the aesthetic appeal, environmental benefits, and connectedness to nature provided by green walls, with less emphasis placed on property value, maintenance, and symbolic pride.

Finally, the Table reveals the dimensions of the level of user satisfaction of green walls in residential properties in Oluyole. The findings revealed that mean scores of the indicators ranged from 3.40 to 2.57, with all being statistically significant at $p < 0.001$. Thus, suggesting that users

generally express moderate satisfaction but with notable variation across different aspects of green wall experience. The Table further reveals that the highest rated factor was overall appearance of the green wall (Mean = 3.40, Rank 1st), highlighting that residents in Oluyole place strong emphasis on the visual and aesthetic contribution of green walls to their homes. This was followed by promotion of a healthier indoor environment (Mean = 3.26, Rank 2nd) and sense of pride in residence (Mean = 3.14, Rank 3rd). These results suggest that users in this area are particularly appreciative of the symbolic and ecological benefits of green walls, which enhance both personal satisfaction and perceived well- being. In the long run, the overall analysis of Oluyole indicates that satisfaction is strongest in aesthetic and ecological dimensions (appearance, healthier indoor environment, pride in residence), while thermal, acoustic, and advocacy-related benefits are perceived less positively. The difference of 0.83 points between the top-ranked and lowest-ranked indicators (3.40 vs. 2.57) highlights a broader variation in satisfaction compared to Jericho, where responses clustered more narrowly. In relation to the study objective, the findings suggest that users in Oluyole are moderately satisfied overall, with clear appreciation for visual and symbolic value, but with weaker satisfaction in relation to environmental performance and broader social endorsement of green walls.

Table 2. Independent Sample T-test Results on Rent of Residential Properties with or without Green Wall in Ibadan from 2015-2025

	Agodi GRA			Bodija			Jericho Area			Oluyole Area		
Property Type	GWMR	NGWMR	p-value	GWMR	NGWMR	p-value	GWMR	NGWMR	p-value	GWMR	NGWMR	p-value
2-bed	472,727	287,273	0.03	477,273	409,091	0.54	804,545	510,901	0.17	368,182	260,000	0.25
3-bed	631,818	495,455	0.18	913,636	600,000	0.13	945,455	727,273	0.43	509,091	477,273	0.85
4-bed	859,091	568,182	0.14	1,040,909	890,909	0.65	1,572,727	1,262,636	0.32	669,091	618,182	0.77
Duplex	877,273	745,455	0.59	1,290,909	1,109,091	0.58	1,718,182	1,469,091	0.43	868,182	709,091	0.54

Source: Field Survey, 2025
Key: GWM- Green Walled Mean Rent, NGWM – Non-Green Walled Mean Rent, Sig. – Significance Level, S – Significant, N.S – Not Significant

Table 2 presents the statistical independent t-test results to compare the mean rental values of residential properties (2-bedroom, 3-bedroom and 4-bedroom flats and duplex) with and without green walls in selected residential neighbourhoods in Ibadan from 2015-2025 and to also determine the significant differences existing between the two groups. The Table reveals that in Agodi GRA, only 2-bedroom flats showed a statistically significant difference in rental values between properties with and without green walls ($p=0.03 <0.05$), thereby suggesting that in the lower-to-middle rental segment, tenants were more sensitive to the added benefits of green walls, which may include improved comfort, aesthetics, and perceived modernity. However, for 3-Bedroom, 4-Bedroom, and Duplex categories, the observed rental premiums, though visible in raw figures, were not statistically significant ($p > 0.05$). This implies that higher-income tenants may

prioritize size, luxury finishes, and location over sustainable features when negotiating rents.

The Table also presented the results from Bodija and it shows that there is no statistically significant rental difference across all property types ($p<0.05$) surveyed. Although mean rental differences were positive ₦68,182 for 2-Bedroom, ₦313,636 for 3-Bedroom, ₦150,000 for 4-Bedroom, and ₦181,818 for Duplexes, the p-values show that these differences are not strong enough to conclude a consistent rental premium attributable to green walls in Bodija. This suggests that while green walls added aesthetic and functional appeal, other rental determinants such as location within Bodija, structural features, and market demand dynamics had greater influence on rent levels. The lack of statistical significance highlights that Bodija's rental market, although responsive to sustainability features, does not yet consistently capitalize green walls as a decisive factor in determining rental values. In comparison with findings from Agodi, where smaller units showed significant rental differences, the Bodija results indicate a slower pace of acceptance. This may be explained by the socio-economic profile of Bodija tenants, who prioritize larger housing and prestige features over eco-friendly designs.

Meanwhile, in Jericho Area, a similar result was presented as there is no statistically significant rental difference across all property types as all p-values were found to be > 0.05. This outcome suggests that although tenants in Jericho recognized and appreciated the aesthetic and environmental benefits of green walls, these features did not yet carry sufficient weight to significantly alter rental pricing dynamics. In comparison to Agodi, where smaller units showed significant differences, Jericho reflects a market segment where tenants may prioritize broader prestige features and location advantages over sustainable design elements.

The results on Oluyole presented in Table 2 reveals that the observed differences were not statistically significant across all property types (all p-values > 0.05). This suggests that although green walls were associated with higher rents in some cases, the effect was inconsistent and not strong enough to be generalized statistically within Oluyole. These findings highlight an important hint, while tenants in Oluyole may appreciate the environmental and aesthetic benefits of green walls, other factors such as property location within the estate, design features, and economic conditions appear to play a stronger role in determining rents. Comparatively, Oluyole's results align more closely with Bodija and Jericho than with Agodi. Whereas Agodi's 2-Bedroom market demonstrated significant rental differences, Oluyole's results confirm that tenants in this location have not yet attached strong financial value to sustainable features like green walls. For developers, this suggests that while green walls can serve as a marketing tool, their impact on rental returns remains limited in Oluyole.

These findings are consistent with hedonic pricing theory (Rosen, 1974), which posits that property rents reflect the bundle of attributes each unit offers. Green walls serve as functional and aesthetic amenities, but their relative weight in rental determination differs by market segment. The results also mirror Rogers' (2003) diffusion-of-innovation framework: adoption and appreciation begin with early segments (smaller units), while higher-end markets take longer to integrate such innovations as defining value drivers. In comparison with international studies, the Ibadan findings are partially aligned. Perini and Rosasco (2013) in Italy and Aigbavboa et al. (2024) in South Africa observed consistent rent premiums across a wider range of property categories. In contrast,

the Agodi case shows selective significance, reflecting the still-evolving nature of sustainability awareness in Nigeria's residential rental market.

Table 3. Model Summary of Stepwise Regression

Model	Predictors Entered	R	R^2	Adjusted R^2	Std. Error of Estimate (₦)
1	Green wall	0.262	0.069	0.064	930,706.18
2	Green wall, Improve neighbourhood prestige	0.355	0.126	0.117	903,866.71
3	Green wall, Improve neighbourhood prestige, High-cost maintenance	0.429	0.184	0.172	875,693.97
4	Green wall, Improve neighbourhood prestige, High cost of maintenance, Reduced Indoor Heat	0.470	0.221	0.205	857,770.39

Source: Field Survey, 2025.

Table 3 above present the model summary of the stepwise regression on effect of green wall on values of residential properties in the study area. The stepwise regression produced four models, gradually adding predictors that significantly improved the explanation of rental value. Model 1, containing only the presence of green walls, explained approximately 6.9% of the variance in rental value ($R^2 = 0.069$). Adding "improve neighborhood prestige" in Model 2 increased the explained variance to 12.6% (Adjusted $R^2 = 0.117$), while Model 3, which added "high cost of maintenance," raised it further to 18.4% (Adjusted $R^2 = 0.172$). The final model (Model 4) including "reduced indoor heat" explained 22.1% of the variance (Adjusted $R^2 = 0.205$) with a standard error of ₦857,770. This indicates that as additional variables were incorporated, the predictive power of the model increased, confirming the multi-factorial nature of rental value determination in Ibadan.

Table 4. ANOVA Result for Stepwise Regression

Model	Sum of Squares	Df	Mean Square	F-value	Sig. (p)
1	12,675,655,468,473.90	1	12,675,655,468,473.90	14.633	<0.001
2	23,241,945,948,770.30	2	11,620,972,974,385.20	14.224	<0.001
3	33,888,833,366,091.00	3	11,296,277,788,697.00	14.731	<0.001
4	40,710,869,689,724.40	4	10,177,717,422,431.10	13.833	<0.001

Source: Field Survey, 2025.

The ANOVA results for the stepwise regression models is presented in Table 4 and it reveals that each model is statistically significant at $p < 0.001$. The F-values, which range from 13.833 to 14.731 across the four models, confirm that the predictors collectively explain a significant proportion of the variance in residential rental values compared to the null model. This provides strong evidence that the inclusion of variables such as Green Wall presence, improve neighborhood prestige, High Cost of maintenance, and reduced indoor heat improves the explanatory power of

the model, thereby validating the use of stepwise regression to identify the key determinants of rental value.

Table 5. Stepwise Regression Coefficients Predicting Average Rental Value

Model	Predictor	B (₦)	Std. Error	Beta	t	Sig. (p)
4 (Final)	Constant	384,201.56	299,215.99	–	1.284	0.201
	Green Wall	602,584.24	126,186.77	0.304	4.775	<0.001
	Improve Neighbourhood Prestige	184,076.36	45,691.80	0.257	4.029	<0.001
	High Cost of Maintenance	-179,146.00	41,865.99	-0.276	-4.279	<0.001
	Reduced Indoor Heat	133,477.07	43,834.97	0.196	3.045	0.003

Dependent Variable: Average Rental Value (₦)
Source: Field Survey, 2025

To identify the key factors influencing the rental values of residential properties and the impact of green walls on residential properties across Ibadan, a stepwise multiple regression analysis was conducted, with average rental value serving as the dependent variable and a range of predictors including the presence of green walls, value-related factors, and tenant satisfaction measures. This approach enabled the systematic isolation of the strongest predictors of rental value from a broader set of variables. The final model achieved an adjusted R^2 of 0.205, indicating that approximately 20.5 per cent of the variance in rental values could be explained by the combined predictors. Within this evolving model, it was observed that the presence of green walls consistently emerged as the most important predictor of rental value. In the final model, green walls were associated with an increase of approximately ₦602,584 in annual rent, holding other factors constant ($p < 0.001$). Similarly, the standardized coefficient (Beta = 0.304) shows that green walls exert a moderate positive influence on rental values. This finding dovetails with previous studies that highlight the premium placed on environmentally friendly and aesthetically appealing features in urban housing markets, thereby reinforcing the market relevance of green infrastructure.

Complementing this, "Improve Neighbourhood Prestige" was identified as another significant positive predictor of rental value (B = ₦184,076, Beta = 0.257, $p < 0.001$). This variable captures respondents' perceptions of the economic and social benefits of green walls, including enhanced image, energy savings, and long-term maintenance advantages. The inclusion of this factor demonstrates that beyond the physical presence of green walls, the perceived improvement in neighbourhood prestige also drives higher rental values. This finding builds on the earlier analysis and signals the importance of intangible, perception-based attributes in rental decision-making. However, the model also revealed that "High Cost of Maintenance" exhibited a significant negative relationship with rental values (B = –₦179,146, Beta = –0.276, $p < 0.001$). This suggests

that certain conditions represented by this factor such as increased upkeep, technical complexity, or perceived inconvenience could reduce the rental premium associated with green walls. This observation adds an important layer to the analysis by illustrating that the benefits of green walls may be partially offset if their maintenance requirements are seen as excessive, thereby influencing market demand.

Further reinforcing the model's comprehensiveness, "Reduced Indoor Heat" contributed positively to rental values (B = ₦133,477, Beta = 0.196, p = 0.003), indicating that higher levels of tenant satisfaction with indoor comfort are linked to higher rents. This is consistent with the literature on residential property markets, which shows that satisfaction with environmental quality, comfort, and aesthetics translates into a greater willingness to pay. In this way, the model connects physical features, perceived value, and tenant satisfaction, underscoring the integrated drivers of rental outcomes.

5. Conclusion and Recommendation

The study has been able to show that users of green walls in residential properties across all four selected residential neighbourhoods are moderately satisfied with its adoption in their residential buildings. Although, the level of satisfaction is shaped by local priorities, it is evident that functional benefits dominate in some areas, aesthetic and ecological benefits in others, while economic and environmental performance factors weakly endorsed across board. Similarly, the comparative analysis of rental values between 2015 and 2025 established that properties with green walls generally commanded higher rents, even though the effect varied across neighbourhoods. On the other hand, the independent t-test results provide nuanced evidence: while green walls clearly enhance rental values in Agodi, their influence is presently strongest in smaller other residential units. Finally, the regression analysis confirmed that green walls exert a measurable and statistically significant effect on residential property values in Ibadan with the presence of green walls alone explaining about 6.9% of the variation in rental values. The study therefore recommends the incorporation of natural plants on residential properties by developers in the course of planning and execution of the project since it enhances users' satisfaction and property values by promoting public-private partnerships (PPPs) to further enhance this essential sustainable adoption of green walls in residential property development.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Akpabio, E. S., Akeju, K. F., and Duruji, M. M., (2016). Climate Change Education in West Africa: Prospects and Problems. *Practices, Perceptions and Prospects for Climate Change Education in Africa*, 317- 334

Azkorra, Z., Perez, G., Coma, J., Cabeza, L. F., Bur**és**, S., Álvaro, j. e., Erkoreka, A., Urrestarazu, M. (2015). Evaluation of Green Walls as a Passive Acoustic Insulation System for Buildings. *Applied Acoustics*, 89(2015), 46-56

Aigbavboa, C. O., Thwala, W. D., Ademiloye, A., & Oshodi, O. (2016). Drivers of sustainable housing development in emerging economies. *Proceedings of the International Conference on Sustainable Built Environment*, 3(1), 67–75.

Ayodele, T., & Olawande, S. (2018). Landscaping features and property values in Abeokuta, Nigeria. *Journal of Environmental Studies*, 12(1), 44–59.

Blanc, P. (2008). *The vertical garden: From nature to the city.* New York: W. W. Norton.

Darko, A., Chan, A. P. C., Yang, Y., Tetteh, M. O., & Adabre, M. A. (2017). Building green: Drivers and barriers in developing countries. *Journal of Cleaner Production*, 145, 482–494.

Deng, Y., & Wu, J. (2014). Economic Returns to Residential Green Building Investment: The Developers' Perspective. *Regional Science and Urban Economics*, 47(2014), 35-44

Francis, R. A., & Lorimer, J. (2011). Urban reconciliation ecology: The potential of living roofs and walls. *Journal of Environmental Management*, 92(6), 1429–1437.

Jim, C. Y., & Chen, W. Y. (2010). External effects of neighbourhood parks and landscape elements on high-rise residential value. *Land Use Policy*, 27(2), 662–670.

Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable and Sustainable Energy Reviews*, 41, 863 - 871.

Molla, M. B. (2015). The value of urban green infrastructure and its environmental response in urban ecosystem: A literature review. *International Journal of Environmental Sciences*, 4(2), 89– 101.

Morley, M. (2008). The value of landscaping on residential property values. *Journal of Environmental Horticulture*, 26(4), 234–240.

Ottelé, M., Perini, K., Fraaij, A. L. A., Haas, E. M., & Raiteri, R. (2011). Comparative life cycle analysis for green façades and living wall systems. *Energy and Buildings*, 43(12), 3419–3429.

Perini, K., Ottele, M., Frarajj, A. L. A., Hass, E. M., and Raiteri, R., (2011). Vertical Greening Systems and the Effect on Air Flow and Temperature on the Building Envelope. *Building and Environment*, 46(2011), 2287-2294

Perini, K., Ottele, M., Frarajj, A. L. A., Hass, E. M., and Raiteri, R., (2011). Vertical Greening Systems and the Effect on Air Flow and Temperature on the Building Envelope. *Building and Environment*, 46(2011), 2287-2294

Perini, K., & Rosasco, P. (2013). Cost–benefit analysis for green façades and living wall systems. *Building and Environment*, 70, 110 - 121.

Raheem, W. M., & Adeboyejo, A. T., (2016). Urban Greening and City Sustainability in Ibadan Metropolis. *Ethiopian Journal of Environmental Studies & Management*, 9(3), 287-302.

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1), 34–55.

Rosiers, F. (1999). Impact of landscaping on residential property values. *Landscape and Urban Planning*, 45(2–3), 91–104.

Susorova, I., Angulo, M., Bahrami, B. and Stephens, B. (2013). A model of Vegetated exterior Facades for evaluation of wall thermal performance. *Journal of Building and Environment*, 67, 1-13.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Factors Influencing the Adoption of Green Walls in Residential Property Development in Ibadan, Nigeria

Nnaemeka Bethel EZEOKOLI [1*]

ORCID 1: 0000-0002-2189-3464
[1] Dr., Federal University of Technology Akure, School of Environmental Technology, Department of Estate Management, Nigeria.
nbezeokoli@futa.edu.ng (Responsible Author)

Ayooluwa Adeboye ADELAKUN [2]

ORCID 2: 0009-0009-2475-3035
[2] Research Assistant, Federal University of Technology Akure, School of Environmental Technology, Department of Estate Management, Nigeria.
adelakunayooluwa19@gmail.com

Abstract

Globally, in developed nations, the integration of green infrastructure, including green walls have become a popular strategy for urban development. However, they often appear unplanned and uncontrolled in African nations, including Nigeria. As a result, this study sought to assess the factors influencing the adoption of green walls in residential property development in Ibadan, Oyo State, Nigeria. The study adopted survey design approach to illicit information from 230 respondents which comprises of estate surveyors and valuers and residents in Ibadan out of which two hundred (200) responses were retrieved and analyzed using descriptive statistical tools such as Percentage Frequency and Weighted Mean Score. Findings revealed a relatively high level of awareness of green walls at 60%, while level of adoption remains moderate. The study further revealed aesthetic appeal, environmental benefits and improved neighbourhood as the major drivers of green wall adoption as they fall within the agree and strongly agree range, while high installation and maintenance costs, limited technical expertise and weak policy support are being considered as the key barriers to green wall adoption in residential property development. The study recommends targeted awareness campaigns, financial incentives, professional capacity building to enhance green wall adoption in residential property developments.

Keywords: Adoption, factors, green wall, residential property

1. Introduction

Green walls, according to Perini and Rosasco (2013) are living vertical walls, vertical gardens or vegetative systems that have been designed to enhance building facades through plant incorporation in vertical structures; which is to cover the interior and/or exterior of a building with vegetations thereby promoting sustainability and defense against environmental hazards. According to Susorova et al. (2013), vegetations installed on interior walls are referred to as living walls while the ones integrated on external walls are regarded to as green facades as a system put in place to offer wide range of environmental, economic, and aesthetic benefits, including improved air quality, noise reduction, thermal insulation, and increased biodiversity as well as an important component of sustainable urban development.

The increase in demand for sustainable housing has been necessitated by the rapid pace of urbanization and population growth in several cities across the globe. In response to this call, green infrastructure such as green walls have become so pertinent as a strategy in urban development

most especially in developed nations of the world (Ezema et al., 2016; Kamil and Fanneh 2023; Oduwaye et al. 2024). However, in Ibadan, Nigeria adoption rate on residential green walls has been low.

In Ibadan, Nigeria compared to the rest of the world, the true scale of adoption on green walls is minimal, thus, reflecting how the real estate market embraced these sustainable facades despite the sudden interest in green infrastructure incorporation in residential buildings in a bid to resolve urbanization and environmental challenges. This trend has been a result of the cost-benefit ratio, maintenance burdens, and a web of bureaucratic hurdles. Despite the potential of green walls in the enhancement of property values and sustainability, there is limited information on the level of adoption of green walls in Ibadan and the factors influencing their adoption among homeowners and property developers. Thus, this study aims to examine the level of adoption of green walls in Ibadan residential property developments and the factors influencing the rate of adoption in the study area.

This study focuses on residential property development within selected areas in Ibadan, Oyo state, Nigeria. Ibadan was chosen as the study location due to its unique blend of historical, environmental, and urban development characteristics that made it an ideal context for analyzing the value implications of sustainable building features such as green walls. The study is limited to selected residential neighborhoods within Ibadan where green walls have been observed or implemented such as Bodija, Agodi GRA, Oluyole Estate, and Jericho. These areas are characterized by a mix of medium to high-income residential developments and a growing prevalence of eco-conscious architectural features.

2. Literature Review

2.1. Concept of Green Walls

The concept of green walls first emerged in the late twentieth century and started gaining prominence after Blanc's seminal treatise The Vertical Garden: From Nature to the City, which chronicled early experiments in assimilating plant life with architectural form and have since then evolved from mere decorative installations into multifunctional systems recognized for their environmental, social and economic benefits (Blanc, 2008; Manso & Castro-Gomes, 2015). Perini et al (2011) described green walls as an innovative building element which integrates vegetation directly onto the vertical surfaces or structures of a building and are unlike the traditional gardens because it involves the utilization modular systems or climbing plants to create self-sustaining vegetated façades that provide functional and aesthetic enhancements to the built environment. Furthermore, green walls are categorized into two principal types called living walls or green facades/vertical gardens. While the green facades rely on climbers and trellises fixed to the building envelope; plants root at ground level and ascend by natural means or engineered supports, they often tend to be less complex and less expensive; living wall systems on the other hand consist of pre-vegetated panels or trays containing substrate, irrigation and drainage mechanisms mounted directly onto the wall and are often of greater diversity, denser coverage and enhanced control over water and nutrient delivery (Francis & Lorimer, 2011; Perini et al 2011; Perini & Rosasco, 2013; Manso & Castro-Gomes, 2015).

2.2. Level of Adoption of Green Wall in Residential Buildings

Green wall systems have attracted considerable scholarly attention, yet their penetration into mainstream residential construction remains limited. Early works such as Madushika, Ramachandra, and Geekiyanage (2022) employed a PRISMA-based systematic review of 103 publications (15 retained for in-depth analysis) to map global economic and implementation trends. They found out that less than 8 percent of surveyed residential developments worldwide incorporate any form of green wall or vertical façade system and that despite demonstrable benefits, uptake rates are restrained by high installation and maintenance costs, fragmented performance data and low practitioner awareness. This Wong, Tan, Tan, Chiang and Wong (2009) collaborated by stating that one of the principal drivers for adopting green walls is their environmental performance since vertical vegetation can moderate building temperatures by shading façades and promoting evaporative cooling, leading to reduced energy demand for air conditioning.

Studies in Nigeria revealed that incorporation of green walls in real property developments remain largely at the pilot - project stage. For instance, Ayodele and Olawande (2018) surveyed 35 developers and 200 residents in Abeokuta. It was revealed that 84% of respondents perceived green walls as an experimental technology beyond their maintenance capacity, while Oladokun (2019) in exploring the landscape design of Lagos indicated there is low adoption of vertical greening.

2.3. Factors Influencing Adoption of Green Walls in Residential Developments

Several researchers have looked into the reasons why green wall systems gained or failed to gain traction in the residential sector. For instance, Perini and Rosasco (2013) and Madushika, Ramachandra and Geekiyanage (2022) sought to identify the factors influencing green wall adoption. The studies discovered that persistence of cost, technical and informational barriers, high upfront installation and lifecycle maintenance costs are the foremost barriers to adopting green walls despite clear evidence of environmental and economic advantages. The studies observed that payback periods often exceed five years even when energy savings and stormwater benefits are accounted for. On the other hand, Safikhani, Abdullah, Ossen, and Baharvand (2014) further stress that local climate variability such as Ibadan's distinct wet and dry seasons necessitates adaptive irrigation regimes that many installers and homeowners find difficult to calibrate. Meanwhile, in Hong Kong, Rauniyar, Singh, Unluer, Abadi, Banihashemi, and Mohandes (2024), while conducting a two-phase study identified twelve critical adoption factors. The study employed exploratory factor analysis to group the factors into the following dimensions such as; technical challenge, perceived cost-benefit balance and maintenance complexity. It was however discovered that, maintenance expense scored highest in deterrence, with 72% of respondents indicating that ongoing irrigation and plant replacement costs dissuaded them from specifying green walls in residential towers.

3. Methodology

The study adopts the survey research design approach which is a quantitative approach often used in the social sciences to gather data from a large number of respondents within a relatively short period. This survey research design would facilitate the use of structured instruments such as

questionnaires to elicit responses from participants which comprises of principal stakeholders in Ibadan residential property market and classified into two categories; registered estate surveying and valuation firms and residential property owners/tenants in Ibadan. For the purpose of this study, 70 practicing professionals gotten from the Nigerian Institution of Estate Surveyors and Valuers (NIESV), Oyo state directory and 160 residential property owners who have installed or currently installing green walls in their buildings compiled from Oyo State Ministry of Lands and Housing is adopted as the sample size. The data obtained was analyzed using Percentage Frequency Table and Weighted Mean Score (WMS).

The Study Area

Ibadan city, with an estimated population of about 3 million people, is one of the largest urban centers in Africa renowned for its rich cultural heritage and rapid urbanization (Raheem & Adeboyejo, 2016). This population growth, coupled with the sprawling nature of urban development has led to increased pressure on residential infrastructures and environmental resources. The dynamic mix of traditional and modern housing in Ibadan provides a unique context to assess the factors influencing the rate of adoption of green walls in residential property development in Ibadan.

4. Results and Discussion

Table 1. Questionnaire administered and retrieved

Respondent	Number Distributed	Number Retrieved	Percentage (%)
Real Estate Firms	70	56	80
Residential Property Owners	160	144	**90**
Total	**230**	**200**	**86.96**

Source: Field Survey, 2025

Table above shows the number of questionnaires administered to the two respondent groups in Ibadan and the number retrieved. A total of two hundred and thirty (230) questionnaires were administered, out of which two hundred (200), representing 87.0% of the total questionnaires distributed, were successfully retrieved and used for the validity of this study. This suggests that the percentage of questionnaires retrieved from the respondents is statistically adequate to make inferences for the research. Consequently, the results of the findings can be considered reliable and sufficient for drawing conclusions on the objectives of this study.

Table 2. Social Economic background of Estate surveying and valuation firms in Ibadan

		Frequency	Percentage (%)
Highest Academic Qualification	Diploma/HND	14	25
	BSc	28	50
	MSc	8	14.3
	PhD	6	10.7
	Total	56	100
Years of Professional Service	1-5 years	9	16.07
	6-10 years	15	26.80
	Over 10 years	32	57.13
	Total	56	100
Residential Property Type Managed by Firm	2-Bedroom Flat	12	21.43
	3-Bedroom Flat	18	32.14
	4-Bedroom Flat	11	19.64
	Duplex	15	26.79
	Total	56	100
Property Location	Agodi GRA	15	26.79
	Bodija	17	30.36
	Jerico	11	19.64
	Oluyole	13	23.21
	Total	56	100.0

Source: Field Survey, 2025

Table 2 above shows the socioeconomic background of 56 estate and operating firms within Ibadan. The educational qualification section reveals that all professionals engaged are duly educated in the practice of estate management with majority having their first degree in Estate

Management (50%). The professional experience shows that the largest share of representatives had over 10 years of professional practice (57.13%) which indicates a long serving period of dominance in professional practice. Meanwhile the types of residential properties managed by the firms reflect the diversity of their operations with majority managing 3-bedroom flats (32.14%) and thus indicates that the firms catered to a wide range of property types, spanning medium-sized family units to higher-end residential developments while the distribution for the locations of the property managed by the firms reveals their spatial coverage with Bodija accounting for the largest share at 30.36%. The interrelation of these characteristics illustrates and further strengthens the validity of the responses of the representatives of each firm in accessing the factors influencing green wall adoption in residential buildings.

Table 3. Social economic background of residents

		Frequency	Percentage (%)
Years of Residing in Property	1-5 years	57	39.58
	6-10 years	44	30.56
	11-15 years	21	14.58
	16-20	22	15.28
	Total	144	100
Residential Property Type Managed by Firm	2-Bedroom Flat	23	15.97
	3-Bedroom Flat	55	38.19
	4-Bedroom Flat	47	32.64
	Duplex	19	13.20
	Total	144	100
Property Location	Agodi GRA	30	20.83
	Bodija	29	20.14
	Jerico	51	35.42
	Oluyole	34	23.61
	Total	144	100.0

Source: Field Survey, 2025

Table 2 above shows the socioeconomic background of 144 occupants of residential properties across selected neighborhood in Ibadan, either as a property owner or tenant. The year of residence in property section reveals that majority have been residing in their properties for a period between 1-5 years (39.58%) while the other percentage have maintained a longer period of stay for more than 5 years. This indicates that respondents can provide information on property market trends, rent and sales history, and experiences with the durability and maintenance of green walls based on their period of stay. Meanwhile the types of residential properties occupied by the respondents reflects that majority reside in 3-bedroom flats (38.19%) and thus collaborates the response of the firms on the type of property managed and further indicates that green wall adoption is been reported across a broad range of housing categories; while the distribution for the locations property occupation by the respondents reveal that majority reside at Jericho (35.42%) apart from other selected locations. This suggests that green wall awareness and adoption are not restricted to

a single enclave but cut across different social and economic contexts. The interconnection of these characteristics illustrates and further strengthens the validity of the responses of the representatives of each firm in accessing the factors influencing green wall adoption in residential buildings.

Table 4. Level of adoption of green wall in selected neighbourhood in Ibadan

		Agodi GRA		Bodija		Jericho		Oluyole	
		Freq	%	Freq	%	Freq	%	Freq	%
Heard of Green Wall	Yes	18	43	22	48	40	65	30	65
	No	24	57	24	52	22	35	16	35
	Total	**42**	**100**	**46**	**100**	**62**	**100**	**46**	**100**
Adoption of Green Wall on Residence	Yes	16	38	19	41	30	48	22	48
	No	26	62	27	59	32	52	24	52
	Total	**42**	**100**	**46**	**100**	**62**	**100**	**46**	**100**
Date of Adoption	2010-2015	8	19	3	7	2	3	2	4
	2016-2020	13	31	3	7	13	21	9	19
	2021-2025	14	33	13	28	15	24	11	27
	None	7	17	27	59	32	52	24	50
	Total	**42**	**100**	**46**	**100**	**62**	**100**	**46**	**100**
Location of Adoption	Building Wall and fence	6	14	3	7	4	6	3	7
	Fence only	6	14	6	13	5	8	5	11
	Front of the building	5	12	2	4	4	6	3	7
	Rear of the building	6	14	4	9	4	6	3	7
	Side of the building	5	12	2	4	5	8	3	7
	Whole building	7	17	2	4	8	13	5	11
	None	7	17	27	59	32	52	24	52
	Total	**42**	**100**	**46**	**100**	**62**	**100**	**46**	**100**

Source: Field Survey, 2025

Table 4 presents the pattern of adoption of green walls in selected residential neighbourhoods of Ibadan; Agodi GRA, Bodija, Jericho and Oluyole Area. Across all four areas, adoption remains at the early diffusion stage, with awareness consistently higher than actual adoption, and most installations limited to partial applications rather than full-building integration.

The Table 4 revealed the level of awareness of green walls varied across the study area. Agodi recorded the lowest awareness (43%), followed by Bodija (48%), while Jericho and Oluyole both reported relatively higher awareness (65%). This indicates a clear divide between locations, with Jericho and Oluyole demonstrating greater exposure to sustainable housing innovations, possibly due to socio economic advantages or stronger information dissemination. The gap between awareness and nonawareness was widest in Agodi, where a majority of residents (57%) had never heard of green walls, reinforcing earlier findings such as Ayodele and Olawande (2018) that informational barriers play a key role in adoption delays.

On the other hand, it was discovered that the adoption rate remained below 50% in all four areas, though with notable variation. Agodi reported the lowest adoption rate at 38%, followed by Bodija at 41% while Jericho and Oluyole both recorded the highest level of adoption at 48% each. These results show that even in the areas with relatively high awareness (Jericho and Oluyole), adoption remains partial, with a slight majority of residents (52%) still not adopting. The contrast between Agodi (38%) and Jericho/Oluyole (48%) indicates that while adoption is progressing, it has yet to cross the threshold of majority acceptance in any location.

Furthermore, the timing of adoption reflects a gradual but uneven growth trend. In Agodi, adoption has been spread fairly evenly across the three periods, with stronger growth between 2016–2025. In Bodija, adoption was heavily concentrated in recent years, with 28% adopting between 2021–2025, but a larger percentage (59%) reported no adoption at all. Jericho recorded steady adoption growth (21%) between 2016–2020 and 24% between 2021–2025, while Oluyole showed a similar trend, with 19% adoption period between 2016–2020 and 27% between 2021–2025. These patterns confirm that adoption momentum has increased most strongly in the past five years, though late uptake is particularly evident in Bodija.

Meanwhile, the part of the residential building where green walls are located were also observed and it was discovered that adoption across locations was largely fragmented and partial. In Agodi, adoption was spread across fences, rears, sides, and building walls, with 17% reporting whole building installation. Bodija showed the weakest adoption diversity, with 59% reporting no adoption and very few residents implementing whole-building applications (4%). Jericho stood out with 13% reporting whole-building adoption, the highest among the study areas, suggesting that once adoption occurs, some residents are willing to invest more fully. Oluyole followed closely, with 11% whole-building adoption, but partial adoption (fences, sides, fronts, and rears) remained common. Across all areas, the high percentages of “none” (Agodi: 17%, Bodija: 59%, Jericho: 52%, Oluyole: 52%) confirm that non-adoption is still the dominant outcome.

Table 5. Factors affecting adoption of green wall in residential property developments in Ibadan

	Agodi GRA		Bodija		Jericho		Oluyole	
Factors	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
High Cost of Installation	3.56	1st	3.62	1st	2.72	17th	2.86	10th
High cost of maintenance	3.38	2nd	3.56	2nd	3.39	2nd	2.94	6th
Multi-Criteria Design Approaches	3.24	3rd	3.44	3rd	3.06	8th	2.89	8th
Lack of Research on Green Wall	3.18	4th	3.33	4th	2.64	19th	2.50	20th
Technical Complexity	3.13	5th	3.31	5th	2.72	17th	3.42	1st
Zero Budget allocation for green wall system	3.11	6th	3.22	6th	2.81	13th	3.39	2nd
Lack of information	3.11	7th	3.20	7th	3.33	5th	2.89	8th
Information barrier about green wall	3.07	8th	3.13	8th	2.78	14th	2.86	10th
Provision of ecosystem services	3.07	9th	3.11	9th	3.39	2nd	2.83	13th
Difficulties in maintenance	3.04	10th	2.91	10th	3.17	7th	3.28	3rd
Complicated approval process	2.84	11th	2.91	11th	2.94	11th	3.00	5th
Thermal performance	2.84	12th	2.80	12th	3.19	6th	2.64	18th
Government law and policies	2.82	13th	2.76	13th	3.03	9th	2.69	16th
Fire safety concerns	2.80	14th	2.76	14th	3.36	4th	2.92	7th
Financial incentives	2.78	15th	2.73	15th	2.36	20th	3.06	4th
Sophisticated implementation	2.76	16th	2.73	16th	2.88	12th	2.56	19th
Green technology	2.64	17th	2.69	17th	3.53	1st	2.86	10th
Lack of green building codes and regulation	2.64	18th	2.56	18th	2.75	16th	2.83	13th
Low practitioner awareness	2.56	19th	2.56	19th	2.97	10th	2.83	13th
Planning recommendation	2.49	20th	2.47	20th	2.78	14th	2.67	17th

Source: Field Survey, 2025

Table 5 presents the factors influencing the adoption of green walls in Agodi and it reveals that economic constraints constitute the most significant barriers to the adoption of green walls in Agodi GRA with high cost of installation (Mean = 3.56) and high cost of maintenance (Mean = 3.38) emerging as the top two ranked factors, both statistically significant at $p < 0.001$. These mean scores are noticeably higher than those of the lowest-ranked factors, such as planning recommendation (Mean = 2.49) and low practitioner awareness (Mean = 2.56), representing a mean gap of more than 0.9 points. This disparity underscores that financial burdens are not only

the most frequently cited barriers but also perceived as substantially more pressing than regulatory or awareness-related issues. This aligns with prior studies emphasizing that affordability is a key determinant in the diffusion of sustainable housing technologies, particularly in developing economies where household budgets are stretched (Darko & Chan, 2018). Overall, the analysis reveals a distinct hierarchy of barriers. Economic factors dominate with the highest mean values, technical and informational barriers occupy a middle tier, while policy and awareness constraints fall toward the bottom of the ranking. The differences in mean scores ranging from 3.56 at the top to 2.49 at the bottom demonstrate that adoption of green walls is shaped by a complex interplay of constraints, but financial considerations weigh heaviest. Addressing these barriers requires a holistic strategy that couples financial incentives and subsidies with technical training, public awareness campaigns, and robust regulatory frameworks to create an enabling environment for sustainable building innovations in Ibadan and similar urban context.

Also, Table 5 presents the factors influencing the adoption of green walls in Bodija and it reveals that economic constraints constitute the most significant barriers to the adoption of green walls in Bodija with high cost of installation (Mean = 3.62) and high cost of maintenance (Mean = 3.56) emerging as the two most critical factors as they are both statistically significant at $p < 0.001$. These mean scores are noticeably higher than those of the lowest-ranked factors, such as planning recommendation (Mean = 2.47) and low practitioner awareness (Mean = 2.56), representing a mean difference of over 1.0 point. This gap highlights the perception of the stakeholders on affordability has been more pressing than policy or awareness related constraints. This result aligns with prior studies reinforcing affordability as a key determinant in the diffusion of sustainable housing technologies, particularly in developing economies where institutional and household budgets are limited (Darko, Chan, Yang, Shan, He, & Gou 2018). Overall, the analysis reveals a distinct hierarchy of barriers, while economic factors dominate with the highest mean values, technical and informational barriers occupy a middle tier, policy and awareness constraints fall toward the bottom of the ranking. The differences in mean scores ranging from 3.62 at the top to 2.47 at the bottom reveals that adoption of green walls is shaped by financial considerations.

Furthermore, Table 5 presents the factors influencing the adoption of green walls in Jericho and it reveals a distinct shift in the hierarchy of adoption barriers compared to Agodi and Jericho. In Jericho, technological and environmental performance factors emerged as the most significant critical barriers to the adoption of green walls with green technology (Mean = 3.53) being ranked first, and then followed by high cost of maintenance and provision of ecosystem services (Mean = 3.39 respectively) and are all statistically significant at $p < 0.001$. These mean scores are noticeably higher than those of the lowest-ranked factors, such as financial incentives (Mean = 2.36), lack of research (Mean = 2.64) and technical complexity (Mean = 2.72), reflecting a mean difference gap of over 1.0 point. This indicates that, unlike in Agodi and Bodija where cost of installation was the dominant concern, residents of Jericho view the technological suitability and functional benefits of green walls as equally decisive to their adoption. This finding aligns with prior studies showing that in more affluent or policy-sensitive urban areas, perceptions of performance and environmental value weigh heavily in adoption decisions (Häkkinen & Belloni, 2011; Darko et al., 2017). Overall, the analysis of Jericho highlights a distinct pattern: green technology,

environmental performance, and maintenance considerations dominate, while economic costs and regulatory frameworks fall into secondary positions. The range of mean values (from 3.53 at the top to 2.36 at the bottom) illustrates a more diversified perception of barriers compared to Agodi and Bodija. Addressing adoption challenges in Jericho therefore requires strategies that emphasize technological reliability, system performance, and effective maintenance support, complemented by targeted awareness campaigns and institutional reforms to sustain long-term uptake.

Finally, the findings presented in Table 5 reveal that in Oluyole, technical and institutional barriers constitute the most significant challenges to the adoption of green walls. Technical complexity (Mean = 3.42) ranked first, followed closely by zero budget allocation for green wall systems (Mean = 3.39) and difficulties in maintenance (Mean = 3.28), all statistically significant at $p < 0.001$. These mean scores are considerably higher than those of the lowest-ranked barriers, such as sophisticated implementation (Mean = 2.56) and lack of research (Mean = 2.50), representing a mean gap of about 0.9 points. This suggests that stakeholders in Oluyole perceive the practical challenges of technical design, institutional funding gaps, and maintenance issues as the most pressing adoption barriers, in contrast to locations such as Agodi and Bodija where cost of installation dominated. Overall, the analysis of Oluyole underscores that technical design, institutional support, and maintenance issues dominate the adoption landscape, while financial, policy, and awareness related factors occupy secondary positions. The range of mean scores (from 3.42 at the top to 2.50 at the bottom) reflects a narrower perception gap compared to other areas, suggesting that respondents view multiple barriers as interconnected but place greatest emphasis on technical and systemic shortcomings. Addressing adoption barriers in Oluyole therefore requires a strategy that prioritizes capacity building, institutional budgetary support, and maintenance solutions, alongside gradual policy reforms and awareness campaigns to strengthen the enabling environment for green wall adoption.

5. Conclusion and Recommendation

Conclusively, this study identified a complex interplay of factors affecting the adoption of green walls across selected residential neighbourhoods in Ibadan viz; Agodi, Bodija, Jericho, and Oluyole. While economic constraints such as high installation and maintenance costs dominated in Agodi and Bodija, Jericho highlighted concerns over technological reliability and environmental performance, and Oluyole emphasized technical feasibility and institutional budgetary gaps. Informational and policy-related barriers, though consistently significant, were ranked lower across all sites, suggesting that stakeholders prioritize immediate financial, technical, and institutional challenges over regulatory frameworks. Collectively, these findings confirm that adoption of green walls in the study area is context dependent, shaped by the socioeconomic realities, institutional capacities, and technical infrastructure of each location. Addressing these barriers will therefore require a multidimensional strategy that combines financial incentives in cost-sensitive areas, technological support in performance-driven contexts, and institutional capacity-building where systemic gaps prevail. This synthesis fulfills the study objective by clearly identifying the primary and secondary factors influencing adoption and by providing insights for tailored policy and practical interventions to enhance the uptake of green walls in Ibadan and similar urban environments. The study therefore recommends that sensitization campaigns and

public enlightenment through seminars, community engagements and demonstration projects in strategic neighbourhood are intensified by professional bodies such as the Nigerian Institution of Estate Surveyors and Valuers (NIESV) in collaboration with environmental agencies and local councils since awareness of green walls is now growing. Furthermore, to address the identified barriers of high installation and maintenance costs, government agencies and financial institutions should introduce targeted incentives such as tax rebates, low-interest green loans, and subsidies on planting materials and installation costs as such measures will not only encourage private homeowners but would also enable estate developers to incorporate green walls into new housing schemes, thereby mainstreaming sustainability in the property market.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article. There is no conflict of interest.

References

Ayodele, T., & Olawande, S. (2018). Landscaping features and property values in Abeokuta, Nigeria. *Journal of Environmental Studies*, 12(1), 44–59.

Blanc, P. (2008*). The vertical garden: From nature to the city.* New York: W. W. Norton.

Darko, A., Chan, A. P. C., Yang, Y., Tetteh, M. O., & Adabre, M. A. (2017). Building green: Drivers and barriers in developing countries. *Journal of Cleaner Production,* 145, 482–494.

Darko, A., Chan, A. P. C., Yang, Y., Shan, M., He, B., & Gou, Z., (2018). Influences of Barriers, Drivers and Promotion Strategies on Green Building Technologies Adoption in Developing Countries: The Ghanian Case, *Journal of Cleaner Production,* 200(2018), 687-703.

Ezema, I.C., Ediae O.J. and Ekhaese, E.N. (2016). Prospects, Barriers and Development Control Implications in the use of Green Roofs in Lagos, Nigeria. *Covenant Journal in Research and Built Environment (CJRBE),* 4 (2), 54 – 70.

Francis, R. A., & Lorimer, J. (2011). Urban reconciliation ecology: The potential of living roofs and walls. *Journal of Environmental Management*, 92(6), 1429–1437.

Kamil, H., & Fanneh, M. (2023). Challenges of Urbanization in Post-Colonial Ogbomos0, 1990 – 2019. *Awka Journal of History (AJOH),* 1 (1), 104 – 128.

Madushika, U. G. D., Ramachandra, T., & Geekiyanage, D. (2022). Economic performance of green walls: A systematic review. *University of Salford Repository*.

Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable and Sustainable Energy Reviews*, 41, 863 - 871.

Oduwaye, L. (2009). Challenges of sustainable physical planning and development in metropolitan Lagos. *Journal of Sustainable Development*, 2(1), 159 – 171.

Oladokun, V. O. (2019). The nexus between property value and landscape design: Case study of selected housing estates in Lagos, Nigeria. *International Journal of Real Estate Studies,* 13(1), 41 - 57.

Perini, K., Ottele, M., Frarajj, A. L. A., Hass, E. M., & Raiteri, R. (2011). Vertical Greening Systems and the Effect on Air Flow and Temperature on the Building Envelope. *Building and Environment,* 46(2011), 2287-2294.

Perini, K., & Rosasco, P. (2013). Cost–benefit analysis for green façades and living wall systems. *Building and Environment*, 70, 110 - 121.

Raheem, W. M., & Adeboyejo, A. T. (2016). Urban Greening and City Sustainability in Ibadan Metropolis. *Ethiopian Journal of Environmental Studies & Management,* 9(3), 287-302.

Rauniyar, A., Singh, A. K., Unluer, C., Abadi, M., Banihashemi, S., and Mohandes, S. R. (2024). Unpacking Factors Behind Green Wall Adoption in Sustainable Buildings. *Springer, Key Themes in Energy Management,* 100, 315-334.

Safikhani, T., Abdullah, A. M., Ossen, D. R., & Baharvand, M. (2014). Thermal impacts of vertical greenery systems on building surfaces. *Energy and Buildings*, 67, 587 - 597.

Susorova, I., Angulo, M., Bahrami, B. and Stephens, B (2013). A model of Vegetated exterior Facades for evaluation of wall thermal performance. *Journal of Building and Environment*, 67, 1-13.

Wong, N. H., Tan, A. Y. K., Tan, P. Y., Chiang, K., & Wong, N. C. (2009). Energy simulation of vertical greenery systems. *Building and Environment*, 44(12), 2438–2445.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Integrating Sustainable Construction Practices Into Building Design Without Compromising Cost and Quality

Timothy AMUSAN[1]*

ORCID 1:0009-0004-9720-2035
[1]Research Assistant, Joseph Ayo Babalola University, Faculty of Environmental Sciences, Department of Architecture, Osun State – Nigeria
architectdele@gmail.com (Responsible Author)

Abstract

The construction industry is a significant contributor to environmental degradation, resource depletion, and greenhouse gas emissions globally, including in Nigeria. As the demand for infrastructure and buildings continues to grow, integrating sustainable construction practices into building design has become imperative for mitigating environmental without compromising cost and quality. This abstract explores the strategies, benefits, challenges, and opportunities associated with embedding sustainability into the building design process. In the Nigerian context, sustainable construction practices can address pressing issues like energy scarcity, resource constraints, and climate resilience while supporting economic development. Strategies like incorporating natural ventilation, solar energy harnessing, rainwater harvesting, and use of sustainable local materials (like bamboo, compressed earth blocks) are pertinent. Cost consideration and quality is maintained through adherence to robust design and construction standards coupled with sustainable innovations. Challenges include limited awareness, skills gaps, higher initial costs for some technologies, and regulatory frameworks needing enhancement for sustainability mainstreaming. Collaboration among stakeholders—architects, engineers, contractors, policymakers—is vital for driving adoption. Adopting sustainable construction practices positions stakeholders to address pressing environmental challenges profitably, ensuring Nigeria's built environment therefore contributes positively to national development aspirations and global climate objectives without sacrificing economic viability or built quality.

Keywords: Building design, cost-effectiveness, eco-friendly materials, sustainable development goals

1. Introduction

The construction industry is a vital sector globally. However, the industry is at a critical juncture, where the imperative to reduce environmental impacts converges with the need for economic viability and quality assurance (Alexander, 1979). With the challenges of climate change, resource depletion, and urbanization, the built environment plays a significant role in shaping the sustainability of our future. Buildings account for a substantial portion of global energy consumption, greenhouse gas emissions, and waste generation. This makes it essential to integrate sustainable construction practices into building design.

However, the misconception persists that sustainability and cost-effectiveness are mutually exclusive, and that pursuing green building practices inevitably compromises quality or increases costs. In reality, integrating sustainable construction practices into building design can yield numerous benefits, including reduced energy consumption, improved occupant health and productivity, and enhanced market value (Ao et al., 2022). By adopting a holistic approach to building design, considering factors such as energy efficiency, water conservation, waste reduction, and material selection (Gausa & Fernández, 2010). The construction industry can minimize its environmental footprint while creating healthier, more productive, and sustainable spaces for occupants. This paper explores the integration of sustainable construction practices into building design, highlighting strategies, benefits, and opportunities for achieving cost-effective and high-quality sustainable buildings.

2. Sustainable Construction Practices

- **Design Phase:**

The design phase entails the incorporation of sustainable design principles, considering natural light, ventilation, and insulation. It also involves the use of building information modeling (BIM) and optimization of building performance to reduce waste.

- **Material Selection:**

The use of materials such as recycled materials, sustainably sourced wood, and low-carbon, specifying materials with environmental product declarations (EPDs), and considering material reuse and recyclability is away to integrating sustainable construction practices without compromising the cost implication (Egwabo et al., 2004).

- **Energy Efficiency:**

Optimizing the use of building orientation layout and maximizing natural lightning and passive heating/cooling, use of energy-efficient systems such as LED lighting, solar panels, and high-performance HVAC and Implementation of energy-efficient building envelope design (Egwabo et al., 2004).

- **Water Conservation:**

Installation of low-flow fixtures such as toilets, sinks, and showerheads and implementation of rainwater harvesting through Collection and reuse of rainwater for non-potable purposes.

- **Waste Reduction:**

Implementation of construction waste management and minimize waste. Designing for deconstruction and plan for building disassembly with material reuse.

- **Quality Assurance:**

Specification of quality control measures by ensuring sustainable materials and systems are installed correctly, conducting regular inspections through verification compliance with sustainable design and construction standards.

- **Cost Management:**

This involves Life-cycle cost analysis and evaluation of long-term costs and benefits of sustainable design elements. However, value engineering identifies cost-saving opportunities without compromising sustainability goals.

- **Collaboration and Communication:**

Engaging and educating stakeholders, and the involvement of building occupants, owners, and construction teams on sustainable design and operation. Collaboration with experts, specialists such as architects, engineers, and contractors to ensure integrated design. By incorporating these strategies, you can achieve sustainable construction practices without compromising cost and quality.

3. Opportunities and Challenges Associated with Sustainable Construction Practices

3.1. Opportunities

- Policy Incentives: Government policies promoting sustainable construction
- Capacity Building: Training professionals in sustainable design
- Public-Private Partnerships: Collaborations for sustainable infrastructure development
- The use of digital technologies in design sustainability has the potential to transform the field building construction, enabling architects to create structures that are not only visually stunning but also highly functional and sustainable (Gausa and Fernández, 2010).

3.2. Challenges

- Higher Initial Costs: Perception of increased upfront costs

- Limited Awareness: Low adoption of sustainable practices
- Skills Gaps: Need for capacity building among professionals (Alexander, 1979).

4. Discussion and Conclusion

Integrating sustainable construction practices into building design offers numerous benefits without compromising cost and quality. Addressing challenges through awareness, capacity building, and policy support can drive the transition to sustainable construction. The goal is to create buildings that are not only functional and sustainable but also aesthetically pleasing and culturally significant. As the world continues to evolve, it will be exciting to see how these trends continue to shape the field of building construction in the years to come.

References

Alexander, C. (1979). *The timeless way of building.* Oxford University Press.

Ao, H., Dylan, K., Jose, L., Adam, J. M., Uziel, M., Giovanni, M., T. Z., & David, B. (2022). Green Buildings: The Future of Sustainable Living. *Journal of Civil Engineering & Architecture,* 16: 195-199 Doi: 10.17265/1934-7359/2022.04.003.

Egwabo, J., Alokun, A., Olodeoku, M. E. & Mosopeoluwa, E. (2024). Optimizing Building Orientation for Passive Cooling: A Comparative Study of Museums in Lagos. *African Journal of Environmental Sciences & Renewable Energy,* 16(1):1-16. DOI:10.62154/ajesre.2024.016.010372

Gausa, M. & Fernández, E. (2010). *Smart Architecture: From Vision to Reality*. Barcelona: Links International.

V. International Architectural Sciences Congress
October 29 30-31, 2025, Demre (Antalya, Türkiye)
https://www.iarcsas.org/

Cost and Risk Management in Ukrainian Construction Projects through International Project Management Standards

Volodymyr MESHCHERIAKOV [1*]

ORCID 1: 0000-0002-4709-5436
[1] PhD in Economics, Associate Professor, State Biotechnological University, Faculty of Economic Relations and Finance, Department of Global Economy, Kharkiv, Ukraine
vmeshch@gmail.com (Responsible Author)

Anastasiia CHORNONOH [2]

ORCID 2: 0009-0004-9340-9266
[2] Bachelor's degree, State Biotechnological University, Faculty of Mechatronics and Engineering, Specialty: Architecture and Urban Planning, Kharkiv, Ukraine
styyyche@gmail.com

Abstract

The construction industry is one of the fastest-growing sectors in Ukraine, yet it remains among the most high-risk. It faces challenges such as insufficient control over unforeseen expenses, lack of clear planning, resource shortages, complex organizational processes, and numerous stakeholders. To prevent such risks, it is crucial to apply international project management standards. Modern project management relies on globally recognized frameworks. The "Big Three" standards include the Project Management Body of Knowledge (PMBOK), Projects in Controlled Environments (PRINCE2), and Scrum. In Ukraine, PMBOK and Scrum are the most widely implemented. Each framework provides effective tools for achieving project success and minimizing risks. Integrating these standards in construction enables structured planning, cost control, and continuous risk management, helping to reduce cost overruns and enhance overall performance. Special attention should be given to accurate cost estimation and realistic budgeting during the early stages of a project. Regular monitoring of financial indicators and transparent reporting facilitate timely detection of budget deviations. Risk management should be regarded as an ongoing process throughout the entire project life cycle rather than a one-time action at the beginning. The adoption of international standards forms a transparent and efficient system for cost control and risk management in construction, improving predictability, efficiency, and reliability of project implementation.

Keywords: Project management, construction industry, cost control, risk management, PMBOK, PRINCE2, Scrum, budgeting, Ukraine

1. Introduction

Over the last decade, Ukraine's construction industry has experienced unprecedented growth, fueled by a combination of public and private investments, large-scale reconstruction programs, and dynamic urban expansion initiatives. The sector now encompasses a wide spectrum of projects, from residential and commercial buildings to major infrastructure developments, including transport networks, energy facilities, and public institutions (Networking Technologies, 2020). This growth has significantly increased the complexity of project environments, often involving multi-level governance structures, numerous stakeholders with divergent interests, and high expectations for quality, efficiency, and sustainability. Despite these positive developments, the construction industry in Ukraine remains particularly vulnerable to various types of risks, including financial overruns, scheduling delays, resource shortages, and organizational inefficiencies (Tarataiko, 2024). These risks are amplified in the context of post-conflict reconstruction, where projects must balance urgent timelines, limited funding windows, and the necessity to restore critical urban infrastructure while ensuring compliance with both domestic regulations and international standards (Shulyk, 2022). The interplay of capital-intensive operations, complex contractual arrangements, and external socio-economic pressures creates a high degree of uncertainty, which emphasizes the need for

systematic, standardized, and robust project management approaches capable of mitigating potential failures.

Globally, internationally recognized project management frameworks such as PMBOK, PRINCE2, and Scrum are considered essential for improving predictability, enhancing decision-making, and reducing the likelihood of project deviations. PMBOK provides a knowledge-based, structured methodology for managing key project components, including costs, schedules, scope, quality, communication, and risk. It enables project managers to establish standardized processes, define knowledge areas, and implement continuous monitoring and control throughout the project lifecycle (Tarataiko, 2024). PRINCE2 complements this approach by emphasizing stage-gate control, clearly defined accountability structures, and formalized decision-making processes. By identifying critical control points and assigning responsibilities at every stage, PRINCE2 ensures that organizational complexities, regulatory requirements, and stakeholder expectations are effectively managed (Networking Technologies, 2020). Scrum, as an agile methodology, introduces iterative development cycles, short sprints, daily stand-ups, and incremental delivery, fostering collaborative teamwork, flexibility, and rapid adaptation to evolving project conditions (FlexiProject, n.d.). Integrating these approaches within Ukrainian construction projects allows organizations to combine the predictability and structure of PMBOK and PRINCE2 with the adaptability and responsiveness of Scrum, improving planning accuracy, stakeholder communication, cost control, and risk management.

Ukraine is gradually modernizing its project management ecosystem through legal and regulatory reforms, implementation of state programs, and professional training initiatives aligned with international standards. Universities and professional education institutions are increasingly offering specialized courses on PMBOK, PRINCE2, and Scrum, enabling project managers to apply globally recognized methodologies in local contexts (Shulyk, 2022). Despite these advancements, there remains a lack of empirical research on the practical effectiveness of these standards in Ukrainian construction projects, particularly concerning cost management, risk mitigation, and hybrid adoption of structured and agile frameworks. Challenges include the multi-level approval processes, regulatory inconsistencies, limited availability of skilled personnel, and uneven distribution of financial resources, all of which can exacerbate project risks (Tarataiko, 2024). By conducting a systematic analysis of these challenges and evaluating case studies of applied project management standards, this study aims to provide a comprehensive understanding of how international frameworks can optimize costs, reduce risks, and enhance overall project performance in Ukraine. Special attention is given to the practical application of hybrid methodologies, which integrate the controlled, structured processes of PMBOK and PRINCE2 with the flexible, iterative approaches of Scrum, thereby enabling construction projects to achieve both regulatory compliance and operational adaptability (FlexiProject, n.d.; Shulyk, 2022).

This expanded perspective highlights the importance of early-stage planning, transparent reporting, and continuous risk assessment in mitigating the uncertainties inherent in Ukrainian construction projects. Furthermore, it emphasizes the role of international standards in fostering a culture of systematic project management, promoting professional accountability, and enhancing organizational resilience (Networking Technologies, 2020; Tarataiko, 2024). By examining the intersections between structured frameworks and agile methodologies, the study contributes to the understanding of best practices for implementing internationally aligned

project management approaches in emerging economies facing high levels of uncertainty, resource constraints, and post-conflict reconstruction demands.

2. Materials and Methods

The study is grounded in a comprehensive comparative analysis of internationally recognized project management frameworks, specifically PMBOK, PRINCE2, and Scrum, and their practical application within the construction sector. The research aimed to evaluate the effectiveness of these frameworks in structuring project processes, assigning responsibilities, controlling budgets, and managing risks across a variety of project types, including large-scale infrastructure, residential developments, and reconstruction initiatives. The methodological approach combined both qualitative and quantitative techniques to assess applicability, challenges, and benefits of adopting international standards in the Ukrainian context (Networking Technologies, 2020; Tarataiko, 2024).

PMBOK Analysis: The study conducted an in-depth examination of the PMBOK framework, focusing on its ability to classify risks across knowledge areas, define comprehensive cost and schedule management processes, establish structured stakeholder communication channels, and integrate proactive risk response strategies. PMBOK serves as a foundational methodology for developing a systemic approach to cost estimation, risk identification, quality management, and process standardization throughout the entire project lifecycle. The framework enables construction organizations to develop detailed risk registers, scenario-based budget forecasts, and structured monitoring tools that allow early detection of deviations, thereby mitigating financial and operational uncertainties (Tarataiko, 2024). Additionally, PMBOK's emphasis on knowledge integration and continuous improvement supports iterative feedback loops, which are critical for managing complex construction projects with multiple interdependencies.

PRINCE2 Application: The application of PRINCE2 was analyzed for its effectiveness in structured decision-making, stage-gate control, and allocation of clear responsibilities among project participants. This methodology was evaluated for its suitability in Ukrainian construction projects, where multi-level approval processes, regulatory requirements, and complex stakeholder hierarchies present significant challenges. PRINCE2 allows project managers to define control points, develop responsibility matrices, and implement formalized review mechanisms, which facilitate early identification of deviations, reduce miscommunication, and improve adherence to regulatory standards. Its focus on controlled project stages provides a systematic approach to managing uncertainties in both planning and execution phases, ensuring that critical decisions are made based on accurate and timely information (Networking Technologies, 2020; Shulyk, 2022). Moreover, PRINCE2 promotes accountability by clarifying the roles of project boards, team managers, and project assurance functions, which is particularly relevant in Ukrainian projects characterized by complex organizational structures and high stakeholder involvement.

Scrum Assessment: Scrum was examined as an agile methodology enhancing adaptability, responsiveness, and iterative problem-solving in project environments with dynamic requirements. The analysis focused on its emphasis on iterative sprints, daily stand-up meetings, continuous progress evaluation, and early detection of deviations. Scrum is particularly effective in reconstruction projects, modernization works, and the implementation of BIM-based technologies, where frequent adjustments and rapid feedback are essential. By fostering collaborative teamwork, promoting transparency, and enabling incremental delivery of project outputs, Scrum mitigates the risk of delays, improves coordination between contractors and

designers, and enhances the quality of technical solutions (FlexiProject, n.d.). The study also highlighted the importance of Scrum artifacts such as product backlogs, sprint reviews, and retrospectives in maintaining adaptive planning and early risk identification.

Content Analysis: To contextualize the application of these frameworks, the study conducted an extensive content analysis of Ukrainian regulatory frameworks, public administration publications, and contemporary industry research. This analysis enabled a comparison between current local project management practices and international standards, identifying gaps, best practices, and potential areas for methodological integration. The research examined regulatory compliance challenges, project documentation procedures, budget approval workflows, and reporting mechanisms, providing insights into how PMBOK, PRINCE2, and Scrum could enhance efficiency, transparency, and accountability in Ukrainian construction projects (Shulyk, 2022; Networking Technologies, 2020).

Hybrid Framework Development: Building on these analyses, the study explored the integration of structured (PMBOK/PRINCE2) and agile (Scrum) methodologies to develop a flexible, hybrid project management model. This hybrid approach aims to combine the predictability, control, and documentation rigor of PMBOK and PRINCE2 with the adaptability, iterative planning, and rapid responsiveness of Scrum. By leveraging the strengths of both structured and agile frameworks, Ukrainian construction projects can achieve improved cost optimization, risk mitigation, stakeholder coordination, and schedule predictability. Preliminary applications of this hybrid model demonstrated potential for a 20–25% reduction in financial risks, improved resource allocation, and enhanced project completion reliability (Tarataiko, 2024; FlexiProject, n.d.). The comprehensive evaluation of this hybrid methodology underscores its suitability for managing complex, capital-intensive, and multi-stakeholder projects in Ukraine’s evolving construction landscape.

In conclusion, the combination of PMBOK, PRINCE2, and Scrum in a hybrid framework provides a robust methodological foundation for systematic project management in Ukraine. This approach facilitates early risk identification, structured budget monitoring, adaptive planning, and effective stakeholder communication, offering a practical solution to the challenges posed by complex construction projects in a post-conflict, rapidly developing environment.

3. Findings and Discussion

Empirical analysis of Ukrainian construction projects reveals persistent systemic challenges, including budget overruns, schedule delays, and resource shortages. These difficulties are primarily rooted in inadequate early-stage cost estimation, unstructured planning processes, and the absence of standardized risk management protocols (Networking Technologies, 2020). For example, initial project budgets often omit contingency allocations for inflation, material cost fluctuations, or unforeseen logistical issues, while timeline assumptions frequently underestimate the impact of regulatory approvals, permit delays, and contractor availability. Additionally, multi-stakeholder involvement in Ukrainian projects introduces organizational complexity, contributing to communication gaps and decision-making delays.

PMBOK Findings: Application of the PMBOK framework demonstrates significant potential for improving project predictability and cost control. By integrating knowledge areas such as cost, scope, quality, communications, risk, and stakeholder management, PMBOK enables systematic planning, real-time monitoring, and early identification of potential deviations

(Tarataiko, 2024). Risk registers, scenario-based forecasting, and structured reporting mechanisms allow project teams to preemptively address financial and operational uncertainties. Case studies indicate that PMBOK adoption in Ukrainian mid- to large-scale construction projects has resulted in approximately 15–20% reduction in cost overruns and improved schedule adherence. For instance, in a residential development project in Kharkiv, PMBOK-based processes enabled early detection of subcontractor delays, allowing reallocation of resources and mitigation of potential budget deviations. Furthermore, PMBOK's structured integration of lessons learned across project phases enhances organizational knowledge, leading to incremental improvements in subsequent projects.

PRINCE2 Findings: The PRINCE2 methodology provides a structured, stage-gate approach to project governance, emphasizing accountability, formal decision-making, and clearly defined responsibilities. In the Ukrainian construction context, where multi-level approvals and regulatory complexities are prevalent, PRINCE2 facilitates the identification of control points and early detection of deviations (Shulyk, 2022). Empirical evidence shows that projects employing PRINCE2 experience faster approval cycles, reduced errors in regulatory documentation, and better alignment with stakeholder expectations. A case example includes a public infrastructure project where PRINCE2 implementation enabled the coordination of multiple contractors and governmental agencies, minimizing miscommunication and reducing the risk of delays by nearly 18%. PRINCE2's focus on defined management stages, exception reporting, and structured review points provides transparency and enables proactive intervention, ensuring that resources are allocated efficiently and decisions are traceable.

Scrum Findings: Scrum supports rapid adaptation in environments with evolving requirements, making it particularly suitable for reconstruction, modernization, and BIM-based projects in Ukraine. Iterative sprints, daily stand-up meetings, sprint reviews, and retrospectives allow teams to detect deviations early, adapt workflows, and optimize coordination between contractors, designers, and engineers (FlexiProject, n.d.). Case studies of renovation and modernization projects in Kyiv and Lviv demonstrate that Scrum improved response time to unforeseen challenges, facilitated collaboration across multi-disciplinary teams, and reduced technical errors by approximately 15%. Scrum's iterative planning also enhanced forecasting accuracy, enabling teams to adjust resource allocation dynamically and maintain project momentum despite shifting external conditions.

Hybrid Framework Evaluation: Combining structured approaches (PMBOK/PRINCE2) with agile methodologies (Scrum) creates a hybrid project management model that leverages the strengths of each framework. Structured frameworks provide predictability, documentation rigor, and stage-gate controls, while Scrum adds flexibility, iterative planning, and rapid responsiveness. In Ukrainian projects, hybrid adoption has demonstrated the potential to reduce financial risks by 20–25% and improve schedule predictability by approximately 15% (Tarataiko, 2024; Networking Technologies, 2020). For example, in a mixed-use urban development project in Kharkiv, the hybrid model enabled precise cost tracking using PMBOK, controlled approvals and stage-gates via PRINCE2, and adaptive task management through Scrum, resulting in smoother coordination among five contractors, two design firms, and multiple governmental agencies.

The analysis also highlights challenges unique to Ukraine, including funding gaps, irregular resource allocation, extended intervals between project documentation and construction commencement, and delays in obtaining expert approvals and budget releases. Standardized

risk assessment and cost control mechanisms reduce the impact of these external factors, ensuring smoother execution and higher predictability. Furthermore, the gradual integration of international standards in Ukraine, through regulatory updates, educational programs, and public management initiatives, demonstrates growing institutional support for systematic project management practices (Shulyk, 2022).

The findings underscore that integrating international standards in Ukrainian construction projects provides multiple benefits: enhanced financial and operational discipline, improved stakeholder coordination, early detection and mitigation of risks, and increased adaptability to unforeseen changes. The use of a hybrid framework combining PMBOK, PRINCE2, and Scrum ensures both rigorous control and flexibility, enabling construction companies to navigate complex, multi-stakeholder projects in a post-conflict, rapidly developing environment. This approach promotes a culture of continuous improvement, transparency, and accountability, ultimately contributing to more predictable project outcomes, reduced cost overruns, and timely completion of construction initiatives.

4. Conclusion and Recommendations

The findings of this study demonstrate that the effectiveness of Ukrainian construction projects is highly dependent on the maturity of cost and risk management systems. Persistent challenges such as budget overruns, project delays, and fragmented decision-making often arise at early project stages due to insufficiently structured planning, inaccurate resource estimations, and inadequate change control mechanisms.

Application of internationally recognized project management standards—PMBOK, PRINCE2, and Scrum—significantly enhances the capacity of organizations to anticipate and mitigate risks, maintain financial discipline, and achieve coordinated decision-making. PMBOK provides systematic approaches for cost control, risk identification, and quality assurance throughout the project lifecycle. PRINCE2 establishes a structured, stage-gate decision-making environment with clearly defined responsibilities and accountability. Scrum ensures flexibility, iterative planning, and rapid team responsiveness to changing project conditions. The combined use of these methodologies in a hybrid framework enables both predictability and adaptability, crucial for complex, multi-stakeholder construction projects in Ukraine’s post-conflict reconstruction and modernization context.

Key Recommendations:

Enhance Early-Stage Planning:

Apply structured cost estimation techniques, incorporating contingency planning for inflation, material price volatility, and unforeseen delays.

Conduct comprehensive risk assessments, both qualitative and quantitative, to identify potential threats and develop mitigation strategies.

Integrate lessons learned from past projects to inform realistic scheduling, budgeting, and resource allocation.

2. Implement Continuous Monitoring:

Establish systems for real-time tracking of financial and operational indicators.

Use key performance indicators (KPIs) and variance analysis to detect deviations early.

Combine automated reporting tools with human oversight to improve decision-making speed and accuracy.

3. Adopt a Hybrid Project Management Approach:

Integrate structured frameworks (PMBOK, PRINCE2) with agile methodologies (Scrum) to optimize communication, adaptability, and error reduction.

Use PMBOK to maintain consistent cost and risk management practices, PRINCE2 to enforce stage-gate controls and accountability, and Scrum for iterative, team-oriented problem-solving.

Promote cross-functional collaboration and iterative validation of project outputs to reduce rework and enhance quality.

4. Strengthen Managerial and Professional Competencies:

Provide targeted training programs in international project management standards, including materials translated into Ukrainian.

Encourage professional certification (e.g., PMP, PRINCE2 Practitioner, Scrum Master) to enhance skill levels.

Facilitate knowledge-sharing and mentorship programs to build internal expertise.

5. Integrate International Standards into National Regulatory Frameworks:

Align national project approval, monitoring, and reporting procedures with internationally recognized standards to improve transparency, predictability, and accountability.

Develop regulatory incentives for construction companies adopting hybrid project management methodologies.

Encourage public-private partnerships that adhere to standardized management practices to promote sector-wide best practices.

6. Promote Financial Stability and Resource Planning:

Implement phased funding and resource allocation strategies linked to stage-gate approvals to minimize budget gaps and uneven resource distribution.

Develop financial models that account for potential delays in state funding and procurement processes.

Encourage risk-sharing agreements among stakeholders to reduce the financial impact of unforeseen events.

7. Foster Organizational Learning and Continuous Improvement:

Maintain knowledge repositories for project lessons learned, risks encountered, and mitigation outcomes.

Encourage feedback loops at each project stage to refine processes and enhance organizational maturity.

Support research and pilot projects to evaluate the effectiveness of hybrid frameworks in diverse project types.

The integration of international project management standards establishes a transparent, predictable, and efficient system for construction project management in Ukraine. It strengthens

the capacity to deliver projects on time, within budget, and at the expected quality level. Furthermore, hybrid adoption of PMBOK, PRINCE2, and Scrum mitigates operational and financial risks, enhances stakeholder coordination, and fosters adaptive capacity in complex project environments. For Ukraine, the implementation of these recommendations represents a critical pathway toward sustainable growth, competitiveness, and resilience in the construction industry.

Thanks and Information Note

The article complies with national and international research and publication ethics.

The authors express gratitude to specialists and consultants who contributed to the theoretical and methodological foundation of the research, as well as organizations providing access to analytical and regulatory materials in construction project management. The study received no external funding, grants, or sponsorship.

Author contributions: 1st author 50%, 2nd author 50%. There is no conflict of interest.

References

Networking Technologies. (2020). Project Management Standards [Electronic resource]. Retrieved November 15, 2025, from: https://nt.ua/ru/blog/project-management-standards

Tarataiko, I. (2024). PMBOK Methodologies: A Modern Approach to Project Management* [Electronic resource]. Retrieved November 15, 2025, from: https://www.linkedin.com/pulse/методології-pmbok-сучасний-підхід-до-управління-igor-tarataiko-wk6he

FlexiProject. (n.d.). Scrum Methodology: Introduction to Agile Project Management* [Electronic resource]. Retrieved November 15, 2025, from: https://flexi-project.com/uk/методологія-scrum-вступ-до-гнучкого-управ

Shulyk, Y. (2022). Application of Project Management in Public Administration in Ukraine* [Electronic resource]. Retrieved November 15, 2025, from: https://journals.oa.edu.ua/Economy/article/view/3442/3141