BEYOND ALL LIMITS CONFERENCE 2025

3rd International Conference on Sustainability in Architecture, Planning, and Design

Proceedings Book of Papers

ÇANKAYA UNIVERSITY

Università degli Studi della Campania *Luigi Vanvitelli*

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FOREWORD

It is our great pleasure to welcome you to BEYOND ALL LIMITS 2025 – The 3rd International Conference on Sustainability in Architecture, Planning, and Design, jointly organized by Çankaya University (Türkiye), Università degli Studi della Campania "Luigi Vanvitelli" (Italy), Lund University (Sweden), and Azerbaycan Technical University (Azerbaijan). The conference will take place in the Congress Hall of Çankaya University, Ankara, Türkiye, on October 16–17, 2025, and is supported by SITdA – Società Italiana della Tecnologia dell'Architettura and GRID – Architecture, Planning and Design Journal.

The BEYOND ALL LIMITS conference series has established itself as an international platform where scholars, practitioners, and students converge to explore and challenge the evolving concept of sustainability. This year's theme continues this legacy by seeking to redefine sustainability across environmental, economic, and socio-cultural dimensions, while fostering cross-disciplinary dialogue and collaboration among architecture, urban planning, and design fields. The conference aspires not only to broaden the conceptual and methodological boundaries of sustainability but also to inspire transformative and practical approaches for shaping a more resilient, equitable, and regenerative built environment.

The scientific program of the conference includes a rich variety of sessions, featuring keynote lectures, and parallel paper presentations. Over two intensive days, nearly 200 academicians, experts, researchers, and professionals from various countries will share their studies, projects, and perspectives. The conference program includes 78 scientific presentations, offering a comprehensive overview of current research trends and innovative practices in the field.

We are honoured to host two distinguished keynote speakers whose contributions have greatly advanced the discourse on sustainable architecture and energy design: Prof. Dr. Susan Roaf, Emeritus Professor of Architectural Engineering at Heriot-Watt University (UK), renowned for her pioneering work on climate-responsive architecture and resilience and Prof. Dr. Pieter de

Wilde, Professor of Energy and Building Design at Lund University (Sweden), recognized internationally for his expertise in building performance modelling and simulation.

This Proceedings Book compiles the written contributions presented at the conference, including both peer-reviewed papers and keynote addresses. All authors submitted papers (ranging between 1500 and 3000 words), which were blind peer-reviewed by the Scientific Committee to ensure academic rigor and quality. The accepted papers published herein represent a diverse and inspiring collection of ideas that reflect the conference's central aim to go *beyond all limits* in reimagining sustainability for the built environment.

On behalf of the Conference Organization Committee, we would like to express our deepest gratitude to all members of Çankaya University, Università degli Studi della Campania "Luigi Vanvitelli", Lund University, and Azerbaycan Technical University for their invaluable contributions, dedication, and collaborative spirit in organizing this international event.

We would also like to extend our sincere appreciation to all authors, speakers, reviewers, and participants for sharing their research, insights, and visions. Your active participation and commitment to advancing sustainable design and planning make this conference a vibrant and meaningful academic platform.

We wish you all a productive and inspiring conference experience, filled with fruitful discussions, new collaborations, and lasting connections.

Conference Organization Committee
BEYOND ALL LIMITS 2025 – 3rd International Conference on Sustainability in Architecture, Planning, and Design

TABLE OF CONTENTS

COMMITTEES 1

Honorary Committee 1
Organizing Committee 2
Scientific Committee 3

FOREWORD 8

KEYNOTE SPEAKERS 25

Climate-Safe Design in Natural Energy Buildings 26
Susan Roaf

BIM 2 BEM: from Building Information Model to Building Energy Model 39
Pieter de Wilde

CONFERENCE PAPERS 46

CONFERENCE PAPERS 46

SUSTAINABILITY IN MATERIALS 47

Holistic Design Decision Making at the Nexus of Sustainability and Fire Safety Engineering: A Preliminary Review of Current Limits and Challenges 48
Asala Bandak, Brian Meacham, Ricardo Bernardo, and Pieter de Wilde

Sustainable Heritage Documentation of the Frigidarium Mosaics in the Great Bath Complex at Syedra 62
Başak Kalfa, Ayşe Nihan Avcı, Hatice Ergürer

Biomimetic Transformation in Pavilion Typology: Comparative Analysis of Nature-Inspired Materials for Sustainable Design 71
Dilara Güneş Kıratlı, Özgür Yakın

Towards the Definition of Circular Bio-Hybrid Building Materials. An Experimental Glossary Linking Research and Design 86
Gabriele Rossini, Paola Altamura, Serena Baiani

SUSTAINABILITY IN MODELLING, ASSESSMENT, AND DESIGN TOOLS 102

Sustainable Modelling of Historic Masonry: Learning from the Past 103
Claudia Cennamo, Luciana Di Gennaro, Giorgio. Frunzio, Luigi Massaro

Digital Models as a Tool for Sustainability in Museum Spaces 113
Gianluca Gioioso, Luigi Corniello

Optimizing Acoustic Performance of a Seminar Room in a Cultural Heritage Building 123
Işılsu Arık, Zeynep Sevinç Karcı, Cemre Uğurlu

Systematic Analysis of the Life Cycle Assessment Method in Renovation Works 133
Merve Nur Taşcı, Ayşegül Tereci

A Socio-Economic and Environmental Decision Support Model for The Implementation of Whole-Life Zero Carbon Office Buildings 143
Nuri Cihan Kayaçetin, Ayşegül Tereci, Gülsu Ulukavak Harputlugil, Başak Yüncü Karanfil, Merve Kılınç Gilisıralıoğlu, Diğdem Karaer

Computational Workflow for Energy-Efficient Building Design: Review of Current Challenges and Opportunities 152
Pouria Elahi, Carlos Martinez, Marie-Claude Dubois, Pieter de Wilde

Comparative Analysis of Life Cycle Assessment (LCA)-Process-Oriented Approach with Campus Sustainability Assessment Systems 163
Zeki Solmaz, Gökçe Tuna

SUSTAINABLE PLANNING AND DESIGN 172

Civic Use Landscapes as Resilient Infrastructure: Technological Strategies for Energy Communities 173
Antonella Violano

Evaluation of Solid-State Lighting According to Biophilic Design Principles 185
Aze Yıldız, Mine Yıldıran, Damla Tunçaylar, Serap Turan, Tamer Avcı, Ayşe Nihan Avcı

From Grey to Green: Rethinking Urban In-Between Spaces through Rooftop Agriculture and Climate Design 193
Maria Michaela Pani, Fabrizio Amadei, Giada Romano

SUSTAINABILITY IN THEORY 205

New life on M.A.A.R.T.E.Buildings 206
Concetta Tavoletta, Vittorio Vernazzani

From Screen to Skyline: How Cinema Imagines Biophilic Futures on Sustainable Cities 223
Çılga Günaydın

Project of Liberation. The critique of domestic space as a critique of power structures 234
Fabrizia Ippolito, Annalaura De Rosa

Collective space. Project of mobilization 244
Fabrizia Ippolito, Ilenia Mariarosaria Esposito

Architectural Resilience through Adaptive Reuse: Sala Beckett as a Model of Layered Sustainability 253
Michela Colucci

Oscillating Between Sustainable Utopia and Dystopia: NEOM City 259
Rabia Çiğdem Çavdar

SUSTAINABILITY CHALLENGES IN URBAN DESIGN AND PLANNING 266

The Role of Cultural Heritage at the Intersection of Circular Economy and Rural Development 267
Ayşe Manav

Being on the Edge: Searching the Continuity of Rural Characteristics in the Urban Periphery 277
Başak Demir, Deniz Altay Kaya, Damla Yeşilbağ

Indicators and Parameters of The Five Capitals in the Sustainable Livelihoods Framework: A Comprehensive Literature Review 287
Cengiz Yenikalaycı, Serap Kayasü

Caring for the Emergency City 300
Ludovica Gregori

Complex Systems for Sustainability and Representation of Infrastructure and Transport. From Photogrammetric Survey To 3D Modelling 310
Luigi Corniello, Andrea Maliqari, Alice Palmieri, Gianluca Gioioso, Manuela Piscitelli

Ecological Issues in Circular Cities Transformation 321
Rossella Franchino, Caterina Frettoloso, Francesca Muzzillo

SUSTAINABILITY IN PERCEPTION, EXPERIENCE, AND BEHAVIOUR 331

Observation-Based Experience of Delft: From Object(hood) Interfaces to Familiarity and Cultural Sustainability 332
Nilüfer Talu, Zeynep Oğrak

Beyond the Class Hours: Interior Architecture Students' Use of Faculty Spaces in Their Leisure-Time 346
Çetin Tünger, Zeyca Örer Söğüt

Urban Identity, Place Attachment, and Social Sustainability: The Case of Hasanpaşa Neighborhood 356
Deren Onur, Gülbin Lekesiz, Güliz Özorhon

Sustainable Playgrounds: Affordance-Based Approaches to Design and Play Engagement 368
Güniz Sağocak, Güler Ufuk Demirbaş

Sustainable Morphological Transformation in a UNESCO World Heritage Site: A Space Syntax Study of Bursa Khans District 378
İmran Gümüş Battal

Perception, Emotion, and Behavior in In-Between Spaces: A Neuroarchitectural Approach to Climate Neutrality 388
Maria Michaela Pani

Neuroarchitecture and Penal Rehabilitation: The Empathic and Sustainable Model of Halden Prison 398
Monica Santoro

SUSTAINABILITY FOR CULTURAL HERITAGE AND HISTORICAL STUDIES 404

Sustainable Conservation of UNESCO World Heritage Sites through Monitoring: Göreme National Park and the Rock Sites of Cappadocia 405
Bilge Çifci, Tuba Akar

Research Lines in the History of Environmental Architecture. The SME Power Station by Renato Avolio De Martino in San Giovanni A Teduccio, Naples 416
Chiara Ingrosso

Evaluation of Photovoltaic Potential in Ahmet Piristina City Archive and Museum 423
Derin Karaoğlu, Belgin Terim Çavka

Sustainable Design Principles in Traditional Gaziantep Houses 434
Ebru Yazgan Serinkaya

Towards Sustainable Heritage Conservation: An Examination Through Three Historic Districts in Ankara 448
Elif Bengi Uyan, Leyla Etyemez Çıplak

Performing Sustainability: The Venice Architecture Biennale as a Stage of Discourse, Display, and Dissonance 458
Emre Kazandere, Gülser Çelebi

Climate Change and Other Sources of Stress on Cultural Landscapes: The Case of Cappadocia 464
Fatma Gül Öztürk Büke

Between Preservation and Adaptive Reuse the Measurement of Resilience Towards Climate Neutrality of Cultural Heritage 471
Gaia Garofali, Gaia Turchetti, Serena Baiani

Preserving Cultural Heritage in Italian Inner Areas: The Key Role of Participatory Processes 485
Giada Limongi, Francesca Gasparetto, Adriana Galderisi, Ornella Zerlenga, Laura Baratin

Community-Centered Use Adaptations as a Means to Enhance Social Sustainability: The Case of Istanbul's Piers 495
Gülce Güleycan Okyay Bayazıt

Architectural Assessment and Conservation of the Ferhat Pasha Mosque 506
Handenur Özdemir, İlke Ciritci

Tabriz Bazaar as a Backbone Invaluable Heritage Site: Lessons for Green Adaptive Reuse 516
Leila Naserimohammadpour, Mohammadjavad Mahdavinejad, Somayeh Pourbagher, Nasreen Kauser Dummi, Ahadollah Azami

The Portuguese Cultural Heritage. Residences and Parks in Sintra 526
Luigi Corniello, Gianluca Gioioso

Reconstruction of Collective Memory through Antakya's Three Monumental Buildings 537
Meltem Bayram Açıkgöz, Ayça Özmen

Casertavecchia as a Laboratory of Sustainability: Documentation, Resilience and Inclusive Accessibility of Cultural Heritage 547
Ornella Zerlenga, Margherita Cicala, Rosina Iaderosa, Riccardo Miele

Cultural Heritage Documentation. The complex of Santa Maria della Vita in Naples (Italy) 562
Ornella Zerlenga, Vincenzo Cirillo, Domenico Iovane, Veronica Tronconi

Post- Disaster Sustainability of Intangible Cultural Heritage: A Spatial and Socio-Cultural Evaluation of Antakya Long Bazaar 573
Zubeyde Tugba Alkan Celik, Yelda Mert

CLIMATE CHANGE 588

Climate Change Adaptation: Current Status in Turkiye 589
Begüm Yelda Gür Karabulut, Gülsu Ulukavak Harputlugil

Sustainable Regeneration of Public Built Heritage for Climate Neutrality, Resilience and Social Value. A Comparative Assessment of Four Good Practices 599
Chiara Mastellari, Paola Altamura, Fabrizio Tucci

Small Open Spaces as Urban Climatic Refuges: The Networking Approach 612
Farah Lyna Chaib, Rossella Franchino, Caterina Frettoloso, Francesca Muzzillo

Depicting Factors and Parameters of UHI and UHI Intensity 623
Melike Berfin Karabacak, Ayşem Berrin Çakmaklı

BEST PRACTICES 633

Passive Building Design Strategies for Different Climatic Zones in Türkiye 634
Emine Hilal Arslan, Gülsu Ulukavak Harputlugil, Gülser Çelebi

Integrating The Sustainable Development Goals Into Interior Architecture Education 643
Gülnar Bayramoğlu Barman, Tulû Tohumcu Kaya

Bridging Design and Performance: Teaching Passive Solar Architecture through Simulation-Based Student Projects 665
Gülsu Ulukavak Harputlugil, Sinem Sari, Şeyma Nur Demirhan, Gülüstan Coşgun Türe, Ahmet Salih Ertuğrul, Rabia Kocamiş

Community Engagement and Co-Design Processes for Sustainable Urban Regeneration. The Utopize Horizon Europe Project 673
Raffaella Riva, Giovanni Castaldo, Fabrizio Banfi

WATER SUSTAINABILITY 683

Multi-Scale Approach to Integrated Water Resource Management for Architectural and Urban Resilience in the European Context 684
Lidia Maria Giannini, Giada Romano, Fabrizio Tucci

ECONOMY AND SUSTAINABILITY 697

Financing the Energy Transition: A Comparative Analysis of Green Urban Development in Germany and Turkey 698
Dilay Kesten Erhart, Ayşegül Tereci

A Comparative Analysis in the Real Estate Market Between Naples and Istanbul 709
Fabiana Forte, Daniela Menna and Yvonne Russo

Reuse-Oriented Architectural Projects in the Context of Circularity: A Review 720
Fehmi Tığlı, Gökçe Tuna

INDOOR ENVIRONMENTAL QUALITY 732

Daylight Performance of Turkish Residential Buildings in the Context of EN17037 733
Ecenur Kızılörenli, Niko Gentile

Designing with Daylight: Natural Light Strategies in Louis I. Kahn's Educational Buildings 744
Fatmanur Atalay

Evaluating Daylight Performance in a Cultural Heritage Library: A Combined Simulation and Measurement Approach at APİKAM 755
Lâl Temizler, İlknur Uygun, Belgin Terim Çavka

Use of Daylight in Mimar Sinan's Şehzade and Selimiye Mosques: Functional, Symbolic, and LEED Certification Criteria Perspectives 767
Nagihan Özdemir, Mine Yazıcıoğlu

Building Materials and Indoor Air Quality: Emission Profiles, Environmental Sensitivity, and Pollution Age Concept 776
Zeinab Shojaei, Ahadollah Azami

SUSTAINABILITY AND CONSTRUCTION 793

Integrating Seismic Resilience and Circular Economy: The Role of Cold-Formed Steel in Sustainable Construction 794
Maria Antonia Barucco, Bensu Berk

From Internal Areas to Sustainable Buildings: A Framework for Integrating QGIS and LCA for their Planning and Regeneration 803
Marica Merola

A Nature-Based Approach for Regenerative Built Environments 812
Monica Cannaviello, Francesca Muzzillo

Building Technological Disaggregation Methodology to Improve Knowledge About the Existing Building Stock for Circularity 823
Roxana Georgiana Aenoai

SUSTAINABILITY IN EDUCATION 834

Re-Designing Fashion Sustainability: Bridging Academia and Industry in the Transition to Consciousness 835
Antonella Violano, Alessandra Avella, Monica Cannaviello, Roberto Liberti

Learning from Periurban. Laboratories in the Operational Landscape Between Napoli and Caserta 846
Giuseppe Guida, Chiara Bocchino

A Sustainable Education Model in Teaching Detail Design in Interior Architecture 855
Gökçe Atakan, Mine Çelebi Yazıcıoğlu, Serkan Mertyürek

Cultures of Glass. Heritage-Based Innovation and Sustainability in Education 869
Maria Antonia Barucco

NEED (New Empatich Educational Design) Sustainable Practices 879
Maria Dolores Morelli, Angela Caterini, Noemi Pardi

Tracing Multimedia Collaboration in Architectural Education: A Retrospective Forensic Study of a Student Competition Team 890
Ömer Can Bakan , Altuğ Kasalı

KEYNOTE SPEAKERS

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Sue Roaf – B.A. Hons, A.A. Dipl., PhD, FRIAS is Emeritus Professor of Architectural Engineering at Heriot Watt University, Honorary Professor at Deakin University, Melbourne and at the University of Queensland and Honorary Doctor of Engineering at Southampton Solent University. An award winning author, architect, teacher and solar energy pioneer. She spent ten years in Iran and Iraq, on archaeological excavations, nomadic migrations, and researching desert technologies. Her 24 books include those on The Ice-houses of Britain, Ecohouse design, energy efficient buildings, adapting buildings and cities for climate change, sustainability indicators, adaptive and resilient thermal comfort, natural energy buildings and transforming markets in the built environment. She has organised many conferences including www.plea2017.net and www.icarb.org and led the Scottish Government programme on Adaptation in the Built Environment from 2010 to 2016. She now leads the Comfort at the Extremes movement (www.comfortattheextremes.com) working since 2019 in Antarctica looking at marginalised communities in heating Australia.

Prof. Dr. Pieter de WILDE

Pieter de Wilde is a full professor at LTH in Sweden and visiting professor at Strathclyde in Scotland. He is Director-at-Large and vice-president of the International Building Performance Simulation Association (IBPSA), Associated Editor of Advanced Engineering Informatics, and member of the editorial board of Applied Energy, Energy and Buildings, the Journal of Building Performance Simulation, and Building Simulation Journal.

Pieter’s main research emphasis is on thermal building performance simulation, and its use in the building services and engineering community. He also has a track record in building performance monitoring in their actual day-to-day context which enables critical reflection on the validity of computational results, and their meaning in building operation and facility management practice. He has authored over 300 publications on various topics related to building performance, including the seminal academic book Building Performance Analysis which was published in 2018 by Wiley and which is the third book to be endorsed by IBPSA. He has been involved in the Beyond All Limits conference from its start, attending both BAL 2017 in Ankara and BAL 2022 in Caserta before joining BAL 2025.

BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

CLIMATE-SAFE DESIGN IN NATURAL ENERGY BUILDINGS

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Climate-Safe Design in Natural Energy Buildings

Abstract: Humanity is currently unprepared for the scale of adaptation required to survive in the extremes of heat and weather in the coming decades. Using ideas developed in our forthcoming book on Adaptive thermal Comfort at the Extremes[1] key lessons are presented around the need for populations to be able to remain thermally safe in the buildings they live and work in. In order for that to happen people to be able to adapt themselves and their surroundings as temperatures increase. This involves not only having the adaptive hardware to hand to do so but also the opportunities to make behavioural changes to restore comfort to themselves. Using a case study of an apartment block a range of small changes are presented that could improve comfort and enhance well-being to lower income inhabitants in Ankara

Keywords: Climate Change, buildings, comfort, adaptive opportunities

Introduction

The rate and scale of change in the climate is accelerating leading to ever more record breaking extreme weather events. The last time I gave a paper was on the 17th October 2018 six months after the Flash floods wrought havoc in Mamak district of the city on the 5th May, 2018[2]. Ankara. , Turkey, on Saturday 05 May, 2018 that injured six people were injured in the floods, with more than 160 cars and 25 businesses suffering damage. Two months ago on the 18th July 2025 flash flooding in the Keçiören district of Ankara caused extensive damage to homes, businesses and vehicles. Despite new tools for mapping and planning flooding[3] and major investments the flooding this year was worse in volume that seven years ago. However, the focus of this paper is not on such drought enhanced flood events but on the issue of thermal resilience in buildings. However, this paper only deals with the thermal performance of buildings that are on the front line of the challenge of surviving well in a heating climate by:

1) Making drastic emission reductions happen in practice
2) Adapting buildings to keep occupants thermally safe in the more extreme climates and weather of the future.

In 2018 we described our Adaptive viewpoint on what constitutes thermal comfort and outlined some then current trends in thinking around the provision of comfort in buildings[4].

1 Roaf, S., F. Nicol and M. Humphreys (2026). Adaptive thermal comfort at the extremes, Routledge, London

2 https://floodlist.com/asia/turkey-ankara-may-2018

3 Kocaman,S., C. Gokceoglu, and H. A. Nefeslioglu (2018). Considerations in the use of sentinel-1 data in flood mapping in urban areas: Ankara (Turkey)2018 Floods, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., Vol. XLII-5, pp. 575 – 581, Copernicus PublicationsDOI: 10.5194/isprs-archives-XLII-5-575-2018.

4 Roaf, S. (2018). How to design a comfortable building, Proceedings of the Beyond All Limits Conference, pp. 22-38, Çankaya University, Ankara, Turkey. ISBN: 978-975-6734-20-9. https://drive.google.com/file/d/1xpZfI_GxVQLMMJTr7NGN_cl9mtjnrnTa/view

Since then an extraordinary range of unprecedented and unpredicted occurrences have taken place including the accelerating pace of global heating and related severity of extreme weather events, the COVD pandemic[5], increasing scale of local and regional grid-failures, cost of energy and cost of living and the socio-economic and political histories occurring around us in this war-torn world. In the face of the enormity of such factors this paper focusses on relatively simple ideas around how to reinforce homes in Ankara against the higher temperatures occurring now and in the future. Just as one might use the cost of tomatoes or petrol at the pumps as key indicators of the economic stress levels felt by ordinary citizens in Turkey, the temperatures in summer occupied rooms in Turkish homes will provide a useful indicator of the scale of the social and political pressures from the quality of the built environment being felt across the nation. Ensuring people can be safe in their homes in hotter summers may be critical to maintaining political stability of societies in febrile times.

Accelerating Climate Change

The world is heating rapidly now making evidence-based decision-making essential and driving the need for timely and accurate information. Recent indicators developed for the IPCC show that human activities are increasing the Earth's energy imbalance and driving sea level rise at an ever faster rate that is unprecedented in the instrumental record. Data shows global surface temperatures (GST) for the 2015–2024 decade average, observed warming relative to 1850–1900 was 1.24 °C with the alarming 2024-observed best estimate of GST of **1.52 °C**[6]. While the Copernicus study did now claim that the Mean Global Temperature will reach 3^0C as early as 2050 as reported it focussed is on the need for drastic emissions cuts to avoid reaching 2°C in the next decade following high emission scenarios.

5 Roaf S. (2022). COVID-19: Trust, windows and the psychology of resilience, in The Routledge Handbook of Resilient Thermal Comfort, Edited by F. Nicol, H. Bahadur Rijal and S. Roaf, London: Routledge, ISBN 9781032155975

6 Forster, Piers, M., Chris Smith, Tristram Walsh, et al (2025). Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence, ESSD, Vol.17, pp. 2641–2680, DOI: 10.5194/essd-17-2641-2025. Accessed 26/9/2025 at: https://essd.copernicus.org/articles/17/2641/2025/

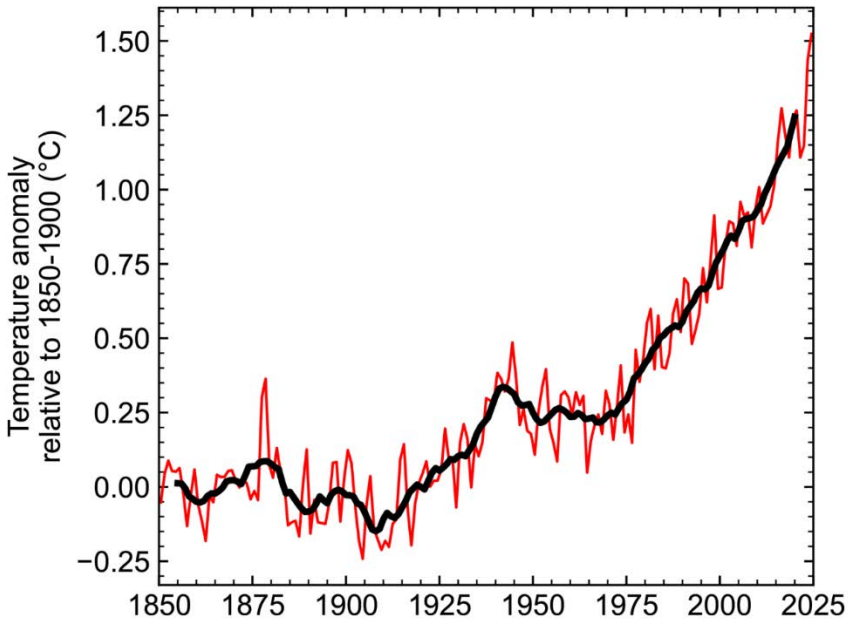
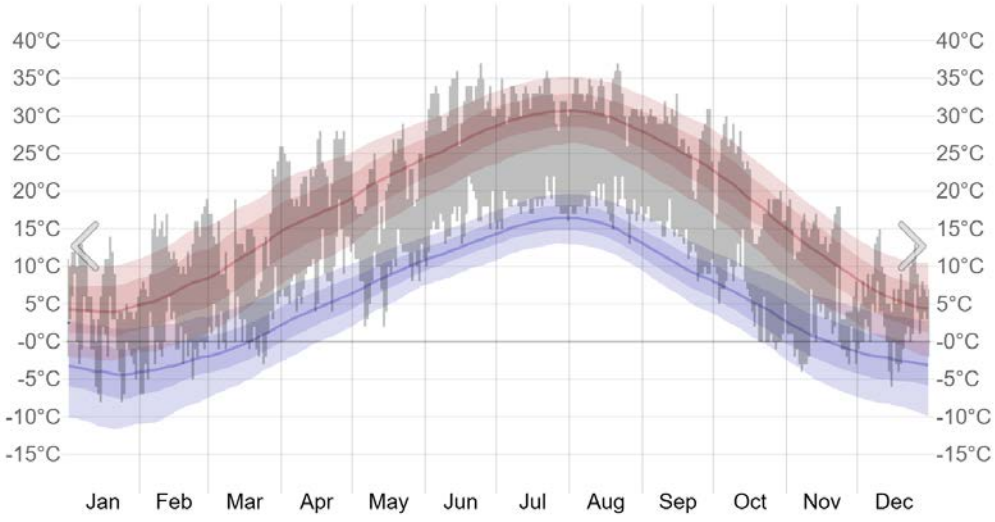
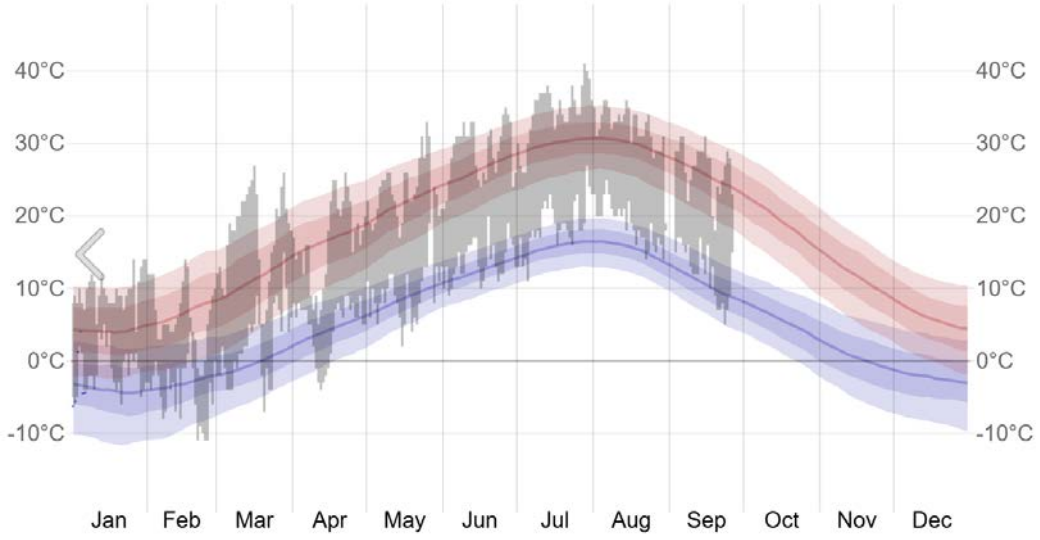


Figure 1. Annual (thin line) and decadal (thick line) means of global surface temperature (expressed as a change from the 1850–1900 reference period). Temperatures are based on an average of four datasets following AR6 (Source: Copernicus.org)

Overheating of buildings in Ankara



a)



b)

Figure 2. The daily range of reported temperatures (grey bars) and 24-hour highs (red ticks) and lows (blue ticks), placed over the daily average high (faint red line) and low (faint blue line) temperature, with 25th to 75th and 10th to 90th percentile bands for a) 2024 and b) 2025 (Source: © WeatherSpark.com)

Figure 2 a) and b) of the annual temperatures in Ankara show a sharp increase in the recorded maximum temperatures in the city even in a year, with warm and hot events starting earlier and finishing later and a significant rise in night time temperatures in the city over the hotter months. With the massive increase in buildings of flats in and around Ankara the need to ensure that occupants in new and existing buildings are better protected in future against more extreme heat, cold and weather in the future.

Understanding Comfort

My Beyond All Limits 2018 paper covered basic tenets of comfort in buildings and the different ways people adapt to temperatures including physiological comfort, behavioural changes and psychological adaptations to expectations and sensory norms. Understanding how to design for safe indoor climates is hugely important as maximum temperatures around the world break records and continue on an unstoppable upward trend. Buildings are our first line of defence against the more extreme weather events not machines nor the decarbonized grid. Architects and engineers urgently need to get a grip on the fundamentals of what temperatures real people in real buildings can and do find acceptable but also to remain healthy and alive in buildings in a rapidly heating climate.

It is important to understand that there are two very different comfort models as explained in 2018. The Heating, Ventilating and Air-Conditioning (HVAC) industry needed a system to set their air-conditioning machines at and Ole Fanger eventually developed the

Predicted Mean Vote and PMV and predicted percentage of dissatisfied (PPD) system to determine comfort temperatures based on limited numbers of laboratory experiments in the mid twentieth century, mainly on small cohorts of male college students in laboratories[7]. The resulting standards loosely mandate that people of whatever race, gender, age, culture or economic or social status are comfortable only at temperatures between c. 20^{0}C -25.5^{0}C. The science underlying the method has long been discredited[8] Even leaders in the HVAC field admit that there is no proven correlation between the calculation outputs and comfort as experienced by real people in real buildings[9]. Refutations of many of the premises associated with the PMV method are contained in our 2022 Routledge Handbook on Resilient Thermal Comfort, particularly in the final chapter of that book[10].

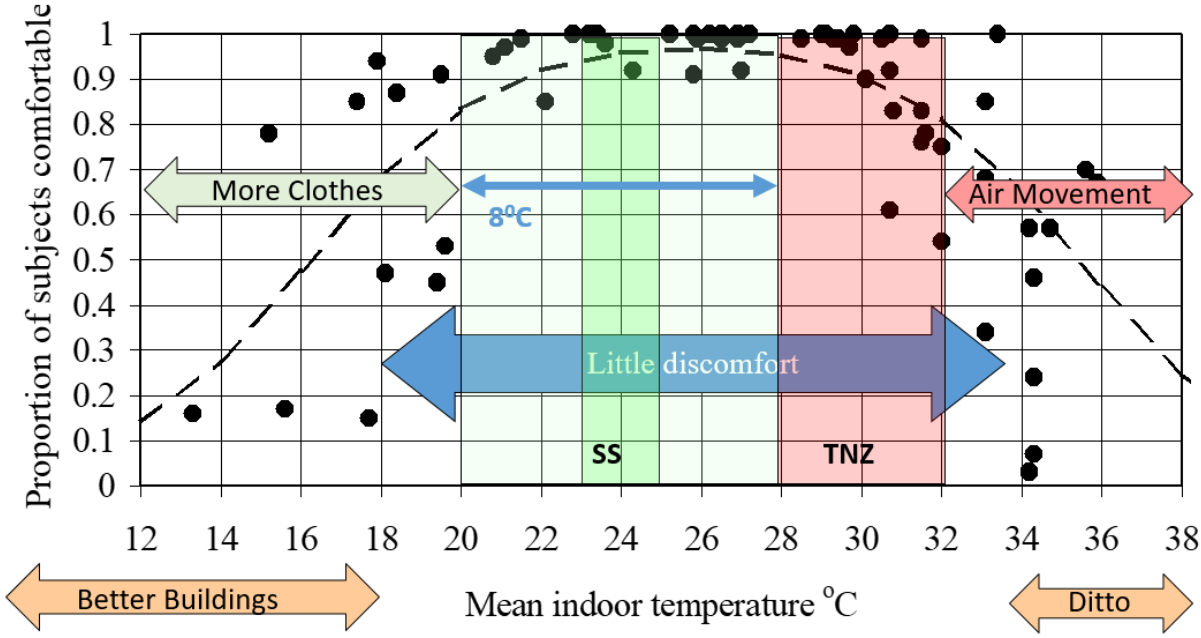


Figure 3. Comfort temperatures for real people in real buildings. Appropriately clothed, adapted people can experience little discomfort between c. 18^{0}C and 33^{0}C with a recorded sweet spot (SS) for clothed people between c. 23^{0}C – 26^{0}C. The Thermo-Neutral zone (TNz) for physiological neutrality for a naked person is around 27^{0}C – 33^{0}C. In colder temperatures more clothes are worn and better buildings needed and above around 32C fewer clothes and more air-movement improves comfort. Temperatures in and below the TNz are ideal for sleeping.

7 Fanger, P.O. 1970. Thermal Comfort: Analysis and Applications in Environmental Engineering. Malabar, FL: Krieger, Copenhagen.

8 Humphreys, M.A., Nicol, F. and Roaf, S. 2016. Adaptive Thermal Comfort Foundations and Analysis. London New York Routledge, Taylor & Francis Group.

9 Olesen, B.W. and Parsons, K.C. 2002. Introduction to thermal comfort standards and to the proposed new version of EN ISO 7730. Energy and Buildings, 34(6), pp. 537–548.

10 Nicol, F., H. Rijal and S, Roaf(Eds) (2022). Resilient comfort standards, in The Routledge Handbook of Resilient Thermal Comfort, London: Routledge, ISBN 9781032155975.

The way to understand what constitutes real comfort for real people in real buildings is via the Adaptive Thermal Comfort approach, as outlined in our 2018 paper. It is fully explained in our comprehensive compendium on *Adaptive Thermal Comfort at the Extremes* to be published in April 2026[11]. It demonstrates that there is no one comfort temperature that suits everyone and across the spectrum of comfort cultures, climates and countries people can adapt to finding indoor temperatures ranging from at least 10^0C to 35^0C without apparent reported discomfort because:

> *People adapt to the thermal conditions they normally occupy, and if they are uncomfortable, they change themselves, or their environment, to restore their own comfort where possible.*

Timely adaptation requires people to anticipate, to the best of their ability, what thermal conditions will be like in their buildings in the near or medium term. Extremely hot or cold killer spaces and / or killer buildings must be eliminated at the design stage or enabled to be made safe during extreme weather over the lifetime of the building. The extent to which a society acts to protect the most exposed and vulnerable of their populations from growing incidences of extreme heat is a measure of the value they place on equality. Because hot people become angry people it may also prove to be a measure, in the long term, of the stability of the society itself.

It is important to recognised what constitute vulnerability. The increasingly extreme weather events have demonstrated that the failure of traditional energy systems pose an increasing risk to populations, not least when the buildings they occupy are totally reliant on machines to remain habitable. In August 2015 the grid in Ankara failed for ten hours leaving widespread chaos in its wake am some people trapped for that time in building lifts[12]. A key indicator of the resilience of a building or city is the extent to which it can function during an extreme weather event during power outages.

Multi-Modal Buildings

Multi-modal or Hybrid buildings that can be both naturally ventilated and and/or air-conditioned enable occupants to be in control of the opportunities needed to adapt both their surroundings and themselves to become or stay comfortable, and also to feel incontrol of doing

11 Roaf, S., F. Nicol and M. Humphreys (2026). Adaptive Thermal Comfort at the Extremes, Routledge, London.

12 Saribulut, L.; G. Ok, And A. Ameen(2023). A Case Study on National Electricity Blackout of Turkey. Energies Vol. 16, 4419. DOI: 10.3390/en16114419

so.[13] People are more comfortable when they are in control of their own environments and there can be enormous energy, cost, and emissions advantages from them being so[14]. To enable people to adaption to changing conditions requires both 'Adaptation Hardware' and also the behavioural 'Software' opportunities to hand. The Hybrid hardware of comfort systems that enable occupants to activate adaptive chances in their environments can range from full mechanical systems to local heaters, coolers or fans as indicated in Table 1.

HVAC BUILDINGS	MIXED MODE
MECHANICALLY COOLED	FULL MECHANICAL COOLING PERSONAL COMFORT SYSTEMS PASSIVE ADAPTIVE ACTIONS SHUTTERS, SHADES, AWNINGS NATURAL VENTILATION
MECHANICALLY HEATED	NATURAL VENTILATION PASSIVE ADAPTIVE ACTIONS CURTAINS, BLINDS, CLOTHING PERSONAL COMFORT SYSTEMS HEATERS, HEATED FURNITURE FULL MECHANICAL HEATING

Key: High Energy → Medium Energy
→ Low Energy No Energy

Table 5.1. How people adapt in buildings depends on the available usable hardware to hand that enables them to either operate spaces in a fully HVAC mode or flexibly in a variety of different comfort modes using both passive and active systems.

But adaptable buildings only work with adapting occupants, who will act according to the available hardware and their own personal temperature preferences and locations. Workers in summer in a south-facing office may prefer to use the external shading with the windows opened and fans on while in the north-facing office open windows may be sufficient for comfort[15]. Multi-Modal buildings can benefit from both fitted and portable equipment to

13 Heschong, L. & Day, J., 2022. 'Why occupants need a role in building operation: A framework for resilient design', in The Routledge Handbook of Resilient Thermal Comfort, Edited by F. Nicol, H. Bahadur Rijal and S. Roaf, London: Routledge.

14 Day J., 2022. 'Tools and rules for behavioural agency in buildings: Minimising energy use while maintaining comfort', in The Routledge Handbook of Resilient Thermal Comfort, Edited by F. Nicol, H. Bahadur Rijal and S. Roaf, London: Routledge.

15 Parkinson, T., de Dear, R. & Brager, G., 2020. 'Nudging the adaptive thermal comfort model', Energy and Buildings, 206, p. 109559, doi: 10.1016/j.enbuild.2019.109559.

modify local conditions because it is almost impossible to predict what certain people will require in terms of comfort in particular weather, day or season. What one can do is set general background to avoid thermal discomfort for the majority in a space, but even that is often best left to local operative to determine as influenced by many different factors, and within safe limits. Clever design will mean that this is achieved without wasting energy, but rather radically reduce its use for keeping occupant thermally comfortable.

Temperature·from	Temperature·to	HYBRID·STRATEGY·
VERY·COLD·	24^{0}C··(75^{0}F)	FULL·BUILDING·HEATING·
VERY·COLD·	24^{0}C··(75^{0}F)	HEATING·IN·OCCUPIED·ROOM·ONLY
VERY·COLD·	24^{0}C··(75^{0}F)	LOCAL·HEATING·OF·PERSON·WITH·PCS
10^{0}C··(35^{0}F)	35^{0}C··(95^{0}F)	NATURAL·VENTILATION·
24^{0}C··(75^{0}F)	35^{0}C··(95^{0}F)	NATURAL·VENTILATION·+·PERSONAL·FAN·
24^{0}C··(75^{0}F)	35^{0}C··(95^{0}F)	NATURAL·VENTILATION·+·ROOM·FAN·
24^{0}C··(75^{0}F)	35^{0}C··(95^{0}F)c	ROOM·FAN·ONLY·
26^{0}C··(80^{0}F)	50^{0}C+··(122^{0}F+)	PERSONAL·/·LOCAL·OR·ROOM·FAN·+·AC
26^{0}C··(80^{0}F)	50^{0}C+··(122^{0}F+)	LOCAL·AC·IN·OCCUPIED·ROOM·ONLY·
26^{0}C··(80^{0}F)	50^{0}C+··(122^{0}F+)	FULL·BUILDING·AIR-CONDITIONING·

Key:· ···High·Energy·→ ···Medium·Energy·¶

→ Low·Energy····· ···No·Energy·¶

Table 5.2. Multi-modal buildings can enable occupants to tailor local temperatures to their own comfort requirements if the adaptive comfort hardware is available to them. The actual temperatures that might trigger such model shifts can only be guessed at as is done here based on global comfort studies.

Premise of this Paper

We have been producing papers in this subject for many years and there is a miss match between the academic discourse and what happens in practice. In order to make the theories around climate-safe design more relevant to this audience their basic assumptions will be applied to flat in Ankara and to a recently published single case study block of flats in Ankara. In doing so conclusions will be drawn that may help to concentrate thinking about how to both design new builds and refurbish blocks to be more climate resilient.

Case study of over-heating in Ankara Flats

In 2022 Nouri et al. published a study of modelled and measured extreme heat thresholds and the need for air-conditioning in a small, naturally ventilated residential dwellings during the 2020 summer in Ankara. Situated in a block of flats within the Bilkent University campus in Ankara, it was constructed during the 1980s and represents the previously recurrent Turkish

residential constructions methods using reinforced concrete structural system of hollow clay brick external/internal walls finished with cement plaster and the load-bearing skeleton, composed of reinforced concrete floors without any outer shell insulation. This method is still commonly used in Turkey today[16]:

Figure 4. Massive development of residential blocks has occurred over the last decade in and around Ankara with many poorly designed for thermal performance and ill-adapted to high temperatures.

Their study excellently lists the scale of the challenge in keeping indoor temperatures at safe levels especially during hotter summers and particularly during extreme heat events. They identify the architectural challenges including the need to enforce up-to-date building constructions codes. They suggest urban thermal planning and management, such as the mapping of such vulnerable structures, and the constitution of urban heat warning systems based upon local extreme heat definitions. In fact, what will improve occupant health and resilience is proving adaptive opportunities in the building and educating residents on adaptive actions to resort to during extreme heat events.

16 A. Santos Nouri, O. Çalışkan, I. Charalampopoulos, S. Cheval and A. Matzarakis (2022). Defining local extreme heat thresholds and Indoor Cooling Degree Necessity for vulnerable residential dwellings during the 2020 summer in Ankara – Part I: Air temperature, Solar Energy, Vol. 242, pp. 435-453, DOI: 10.1016/j.solener.2021.10.059.

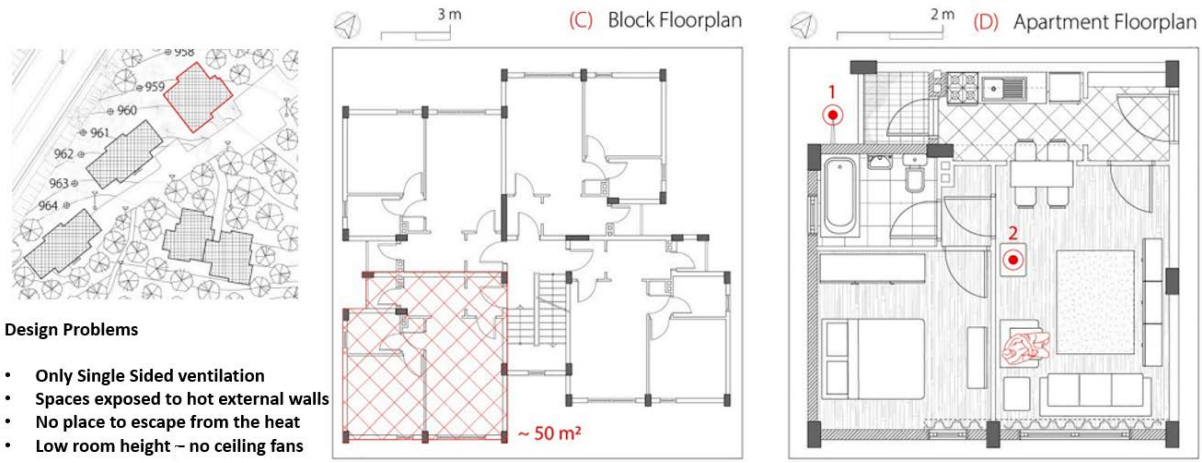


Figure 5. Plans of the flat in the Santos Nouri et al study in Ankara. This flat has a S.E and S.W aspect with external walls exposed to the maximum summer heat.

Looking at apartment in their study are there lessons that can be learnt to ensure that healthy temperatures difference between inside and out in such flats can be maintained. Building performance codes typically deal with construction methods or HVAC ventilation performance. In fact, for thermally well-performing structures a range of changes in the physical form and arrangements of the flats could make a huge difference in the comfort experienced not only during heatwaves but also across the year.

Suggested improvements to enhance the Adaptive Hardware and Behavioural opportunities in the flats to give occupants access better comfort could include:

1. Raising floor to ceiling heights to enable the use of ceiling fans
2. Raising room heights to enable triple element windows to be used with a top hopper central open window section and a lower hopper so even in rooms without cross ventilation effective single sided ventilations – with fans boost – can be achieved.
3. External balcony blind
4. Shade over the access stairs + increase window size to cool stairwell and provide higher air movement for adjacent flats
5. Heavy security fly screen door added outside the front door to enable flat to be cross ventilated during certain times of day in extreme heat events
6. Opening hopper window above front door to enable cross ventilation
7. Operable external awning to be added to the living room windows
8. External louvered slide shutter to pull across the bedroom window
9. Inform occupants that in extremes people should move from the hot flats to the cooler flats of neighbours

10. Provide a cool ventilated basement space with sitting areas so people can use them as a climate refuge in extremes.

For future blocks such simple additional adaptive opportunities must be designed in from the start of a project and more effort made to plan blocks where apartments have cross ventilation and also access to cooler spaces in the flat so south and north facing aspects so occupants can retreat from the heat and move towards the sun when free solar heat is useful in winter. Ultimately it is the Thermal Design of the space indoors that will provide protection from the extremes in climate that will increasingly be felt globally.

The Political Imperative for Climate Safe Design

The first step to instilling citizen confidence in the desire or ability of systems around them to keep them safe in the face of the growing climate challenges is to understand the problems at hand. In our increasingly unequal world, the importance of understanding the simple idea that enabling people to find both mental and physical comfort and peace of mind in the buildings and lives they occupy is a keystone to maintaining political stability and system resilience across continents, climates and cultures. That drive to survive in the evolving extremes of climate ahead requires clear, credible and trustworthy policies and investment aimed at managing the anxieties, fears and emotions of populations about the changing world around them.

Climate Safe design can involve simple and low cost rethinking of the way we design buildings to enhance air movement, manage solar gain, use orientation to optimise the opportunities to take advantage of the free energies around buildings while not being thermally threatened by them

Climate-safe design requires both the physical adaptive opportunities that can be employed to modify climates indoors, access to them and the understanding and education of occupants to use them effectively. Ultimately it is not machines or the low carbon grid with will keep people thermally safe during extreme weather events, it is the building they live and work in.

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BIM 2 BEM: FROM BUILDING INFORMATION MODEL TO BUILDING ENERGY MODEL

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BIM 2 BEM: from Building Information Model to Building Energy Model

Keywords: building information model, building energy model, interoperability, data transfer

Introduction

The Architecture, Engineering and Construction industry is increasingly pushing towards and beyond the limits of ICT technology. One area of work that is of particular interest is the interface between Building Information Models (BIM) and Building Energy Models (BEM). Efforts in this area have a long history, going back to the emergence of the original "building product models" and initial "energy calculation methods" and the building performance simulation tools in which these are embedded. The recent uptake of machine learning algorithms and other associated artificial intelligence technology raises expectations that some of the long-persisting challenges can finally be addressed. However, to do so we will need a carefully directed effort that takes into account some of the underlying pittfalls. This paper, which underpins a keynote address at the Beyond All Limits conference in Ankara in 2025, provides a brief overview of some of the issues that make data exchange between BIM and BEM challenging. To do so, the paper explores a number of areas that are core to deeper understanding:

Background to BIM

Building information modelling has a long background that starts with the initial work that put building data in computers. Generally the application to design, and particularly CAD-systems (computer aided design) is traced back to the work of Sutherland (1963) and his "Sketchpad" system. As capability of desktop computers improved, building design work that traditionally was done on paper and by hand – and hence intrinsically was 2D – was digitalized and moved into the virtual domain. However, in the background other developments were taking place: computers are also good at managing other data, such as the properties of building components (weight, cost, strength) and at connecting those data (relational databases). Two main streams of work could be discerned in the emerging field of building ICT: "product models" and "process models". The category of building product models was mainly concerned with building as systems, and managing system attributes. Building process models typically tended to gear towards construction management, optimizing site operations and the associated

challenges. A seminal work reporting on the state of the art at the end of the last century is the book by Eastman (1999), which also describes this evolution in further detail.

Once building design was moved into the digital world, some important technological innovations tool place. First of all, the traditional process of designing in 2D ("lines on a plane") was transformed into designing in 3D ("forms in space"). This means a fundamentally different way of working. Additionally, the concept of objects was brought in through "object-oriented modelling", where something like a column is no longer an abstract set of lines on a projection, but becomes an element with geometric information as well as other attributes such as strength and weight. Further innovation has been added through parametric modelling, changing in one parameter (e.g. floor height) is propagated through the whole building model. This has opened up completely new ways of design and makes the underlying tools indispensable to modern building design. Architectural design today is fully reliant on design authoring tools like Revit.

At the same time, the building product concept evolved. In the 1990s, significant efforts where invested into the concept of interoperability: the creation of system where a central, shared data repository (sometimes called in Integrated Data Model, IDM) is connected to a suite of tools (the design authoring tool as well as analytical tools such as a costing tool, thermal analysis tool, lighting analysis tools and others).

The term Building Information Model and the associated activities of Building Information Modelling (both BIM) became mainstream umbrella terms to cover these concepts and activities only in the early years of the 21st century (Eastman *et al*., 2011).

Background to BEM

Building energy modelling is a field of building physics (named building science in most of the Anglo Saxon countries) which develops computational models that represent the energy balance of buildings. The main aim making such models is to run computer simulations to assess building performance in terms of energy efficiency and thermal comfort (de Wilde and Augenbroe, 2019). Building energy modelling is a non-trivial activity, which requires the abstraction of complex and large systems into their essence through idealization and simplification. Only then can we apply rules from physics, engineering and computing to replicate building behaviour in the computer.

Building energy models and the building performance simulation tools in which they are embedded emerged in the 1960. They have seen several decades of development, leading to a suite of tools such as EnergyPlus, TRNSYS, IDA-ICE, DEST and others now available to

the industry; a good overview is provided by the Building Energy Software Tool Directory, initially created by the UD Department of Energy and now maintained by IBPSA USA (BEST, 2025). Most building simulation models are complex, since buildings typically have a multitude of rooms, systems and components. Typically these models require thousands of input parameters to define all of this, including the building geometry, and then run for many timesteps – often the number of steps is equal to the number of hours in a year, being 8760. When thinking about building energy models, it is useful to consider them as a "virtual experiment": a test done in the computer, where the building model is subjected to some sort of force (for instance the local weather conditions) and then observed to see how that building behaves under those testing conditions.

Recent developments in machine learning have led to advanced efforts to analyze thermal behaviour. Amongst these are uncertainty and sensitivity analysis. Here a range of experiments is conducted with the model, to find the relation between input and output parameters. This requires even more computations. Given the complexity, an area that is emerging is the use of meta- or surrogate models. Here a 'black box algorithm' is trained to represent the correlation between input and output of a simulation model, so that analysis about trends in this input and output data can be carried out without actually having to rely on a large set of simulation runs. This speeds up and simplifies the analysis efforts. Beyond use in uncertainty and sensitivity analysis, this approach may also be used to support fast responses to design queries.

Fundamental BIM to BEM data exchange approaches and their challenges

Within the concept of interoperability between various building design and analysis tool, the link between architectural design tools and building energy modelling tools has always been prominent. Seminal work from the 1990s is for instance the EU COMBINE Project (Augenbroe 1994, Augenbroe, 1995). From an academic concept, the idea of the Integrated (and Shared) Data Model developped further. Here two main streams can be identified:

1. openBIM: here the main concept is to provide a publicly available, open access central data model that different actors and different tools can access. The dominant model in this category is that of the IFC, Industry Foundation Classes. For a deep overview of IFC see Borrmann *et al* (2018).

2. Closed BIM: here the central model is kept proprietary and is only intended to share data within a limited set of tools. Typically this allows for a much simpler data structure, and makes it easier to ensure effective data exchange. However, this comes at the cost of being closed to the wider world. To make life more complex, it is however often possible to export data into an IFC file for sharing.

Further complexities arise for a range of other approaches and variants. One of these is gbXML, an intermediate format introduced by a group of BIM and tool vendors in 2000 as an open data standard that sits explicitly in between BIM and building energy modelling tools. gbXML represents a 'common shopping list' of data than is useful to send from BIM to BEM. Another is the Rhino-Grasshopper ecosystem, which also connects BIM authoring (Rhino) with a range of analysis tools, through a range of plug-ins or connectors that are typically named after animals. This ecosystem accepts various formats, including IFC and gbXML, but then translates this into the native data model. Yet another approach is the recent Speckle environment; Speckle bypasses the concept of a central data base by enabling a point-to-point data transfer on the principle of semantic data exchange – which in essence means a free flow of data, but at the cost of having to add a label that contains the meaning of each piece of data. A final point to observe it that of "encapsulating analysis" in the architectural authoring tool, for instance in the Insight 360 tool that is available inside Revit. See Figure 1.

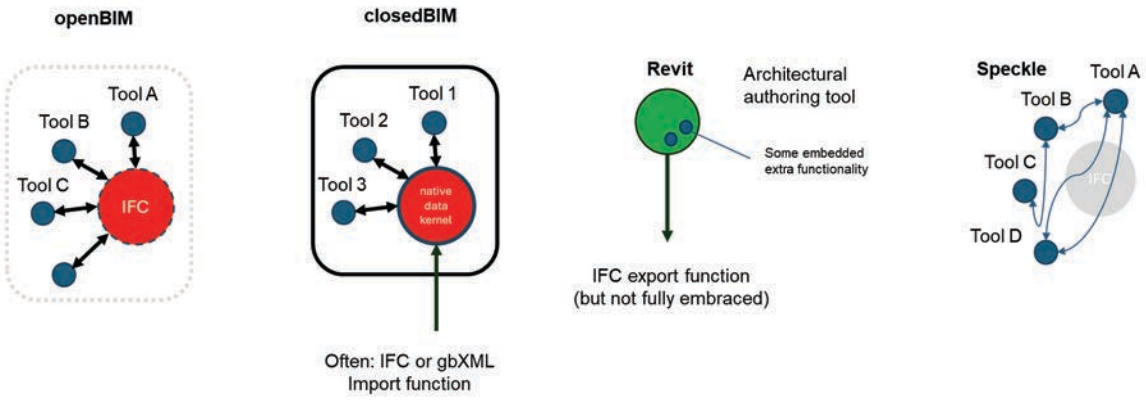

Figure 1: typical BIM to BEM data exchange principles

Whilst a lot of effort has and is being invested in ensuring smooth data transfer between BIM and BEM and the forementioned approaches, industry sees limited uptake of this technology. The export from architectural authoring tools like Revit to IFC or gbXML format, and subsequent import into analysis tools, often comes with a range of errors. Often engineering

companies employ dedicated "BIM Managers" to clean up the files they receive from other firms, before they use them as a basis for their analysis work. Informal comments suggest that, even after cleaning, only 90% of the data is right. Typical issues concern mis-aligned boundaries, missing material property data, challenges with small spaces such as voids and cavities. Many energy consultants still prefer to build up energy models directly within the analysis tool, rather than to rely on import from a BIM model. This gives rise to a need for continuing research, such as the IEA Annex 91 on openBIM for energy efficient buildings. (IEA Annex 91, 2005)

Concluding remarks

The above sections describe some of the fundamental approaches to data transfer from BIM to BEM. A couple of observations need to be made on the current state of the art:

(1) Existing work seems to emphasize the transfer of geometrical information. However, geometry only plans a limited role in building energy models. It is important to remember that the building energy modelling process typically will simplify a number of rooms into zones, and that rooms and walls typically are first simplified into a nodal network and then further into equations that are ultimately solved by matrix calculations. There may be some of effect of view factors and self shading, but typically concerns about full mapping are not taking into account the realities of computational models.

(2) Most efforts thus far are concerned with BIM to BEM. However, to be useful, data transfer should be bidirectional. Only very few recent efforts take this into account. It is worth to reflect on older efforts such as the work by Mahdavi (1997) and explore the thoughts developed on this matter.

(3) In general, efforts in the BIM to BEM data transfer claim often claim to support building design, and the engineering of high performance buildings. Often there is a claim that this work helps towards attaining a more energy efficient, sustainable built environment. The author hold that this claim is "beyond all limits". Firstly, design support using building simulation is a thorny and difficult subject. See for instance the perspective paper by de Wilde and Bleil de Souza (2024). Secondly, data transfer from BIM to BEM are only one part of a complex puzzle. To truly make better buildings and create a better

world, we need a much deeper reflection on the principles of building engineering and design. This will require bringing together the old avenues of building product modelling and building process modelling, reflecting on best practice workflows. Thirdly, there are some very difficult challenges in mapping an architectural design into an energy model which require deep domain knowledge and human intervention, limiting the prospect of automation and standardization.

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HOLISTIC DESIGN DECISION MAKING AT THE NEXUS OF SUSTAINABILITY AND FIRE SAFETY ENGINEERING: A PRELIMINARY REVIEW OF CURRENT LIMITS AND CHALLENGES

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Holistic Design Decision Making at the Nexus of Sustainability and Fire Safety Engineering: A Preliminary Review of Current Limits and Challenges

Abstract: This paper reviews some of the challenges and limitations of integrating sustainability and fire safety in building design, which is the challenge at the heart of a new PhD study starting at Lund University. As regulatory frameworks push for energy efficiency and carbon reduction, and design optimization, unintended risks can arise with the use of more biobased materials for example. Of particular concern in this work are unintended fire hazards and risks. The review begins to explore how current design decision-making often lacks holistic thinking and tools to balance these competing objectives. Fire tragedies like the Grenfell Tower emphasizes the need for a framework that account for both fire-resilience and sustainability. The Sustainable and Fire Resilient Built Environment (SAFR-BE) project is presented as a step toward a structured, expert-based decision-making initiative. The paper concludes with an overview of future works and anticipated challenges.

Keywords: sustainability, fire safety, design, decision-making

Introduction

Since the oil crisis of the 1970s, reducing energy use in buildings has been central to the EU's climate strategy, with energy efficiency emerging as a key policy response to improve oil security (Economidou et al. 2020; Papadopoulos 2016). Since the 1992 Rio Conference, countries have prioritized climate action through key agreements like the UNFCCC, the Kyoto Protocol (1997), and the 2015 Paris Agreement (Tobin et al. 2018). In 2002, the EU introduced the Energy Performance of Buildings Directive (EPBD), setting minimum energy standards and mandatory energy performance certificates for buildings. In 2009, the EPBD was strengthened to align standards across EU countries and promote nearly zero-energy buildings (NZEBs) (Economidou et al. 2020). To achieve NZEBs, cost-effective and energy saving design principles need to be applied (D'Agostino and Mazzarella 2019).

However, buildings have many other objectives that must be met. Fundamentally, a building needs to fulfil its initial purpose, which is a safe shelter (e.g., structurally stable, hazard-resistant, and fire-safe). Objectives for safety are found in national building regulations, as well as EU regulations. For example, to ensure comparability of construction products across the EU the Construction Products Regulations (CPR) sets requirements for construction works and buildings like safety, accessibility, and stability (Construction Products Regulation (CPR) - European Commission 2025). Buildings also have several client objectives, from aesthetics to operational performance. In the end, all objectives need to be appropriately accounted for.

To comply with requirements of the United Nations Sustainable Development Goals, the EPBD and CPD in Europe, a wide range of performance criteria need to be met

simultaneously in any building. These include being energy- and water-efficient, using low-carbon and bio-based materials. To ensure healthy lives and promote the well-being goal of the UN agenda (Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs 2025), a building should provide a good indoor air quality, thermal comfort with adequate daylight, and comfortable ventilation. To achieve the net zero building goals, it should have a low-carbon footprint and integrate renewable energy sources. It should also harmonize with its social and cultural context. To illustrate that, a graphic representation is shown in Figure 1.

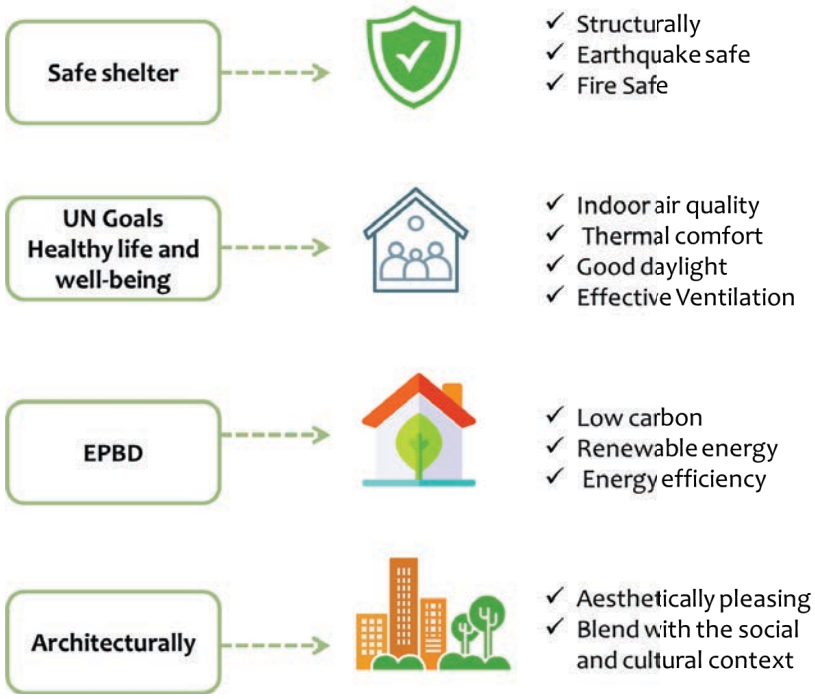

Figure 1- Different aspects a building needs to achieve

Given the multiple, and sometimes competing, building goals and objectives, decision-making by different building stakeholders can be quite complicated especially with future uncertainty. Decisions in building design begin in the early-design stages, such as site selection, building orientation and geometry. There is sometimes a difference between the decision itself and the outcomes of that decision as decisions are based on predictions (de Wilde 2018). These choices influence later decisions like systems choices, façade design, and glazing types etc... Sometimes, a decision that benefits one aspect may negatively impact another. For example, maximizing daylight on the north façade often means more glazing, which can increase heat loss and require additional insulation, raising material use and embodied energy (Dixit et al. 2010). In such case the question is: which should be prioritized adequate daylight or carbon reduction and who gets to decide?

As buildings aim for higher energy efficiency and lower environmental impact, new materials and construction methods, such as bio-based materials, external insulation systems and composite cladding, are often introduced. However, some of these materials may compromise fire safety if not properly assessed. The Grenfell Tower fire in 2017 tragically exemplifies this conflict. In that case, the façade system, selected for thermal performance and visual appeal, used combustible cladding and insulation materials that significantly contributed to the rapid-fire spread resulting in 72 deaths (Independent Review of Building Regulations and Fire Safety: final report 2018; McKenna et al. 2019). Such incidence raises the need for integrated decision-making frameworks that address both sustainability and fire safety, ensuring that improvements in one area do not unintentionally increase risk in another.

The SAFR-BE concept was developed to highlight the potential for competition between sustainability and fire resilience objectives and to outline a pathway forward for more holistic decision-making to balancing these objectives in the built environment (McNamee and Meacham 2025; Meacham et al. 2023; Meacham and McNamee 2023) Initial steps were taken with support from the SFPE foundation (Meacham et al. 2023) with a focus on sustainable and fire resilient buildings (SAFR-B) through the development of a framework for assessing and aligning design choices made to attain both sustainability and fire resiliency design objectives. The Venn Diagram below represents the intersection of decision-making, sustainability, and fire safety. The current effort builds from this initial work with a focus on creating risk and decision support mechanisms that can be used by designers, regulators, and others to more readily identify and address potentially competing sustainability and fire resilience objectives at various stages of the building design process.

Figure 2- Venn Diagram

Sustainability

Sustainability concerns started growing in the 1960's and 1970's as a result of industrial and economic development impact on the environment and their potential risk on the future generation (Brundtland 1987). Dating back to the 1972, a significant amount of research has been conducted to define sustainability. The publication of Blueprint for Survival played a key role in defining the concept of sustainable development. The Brundtland Commission in 1987, introduced the most widely recognized definition of sustainable development describing it as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Basiago 1995). Following this definition, sustainability came to be understood through the three interconnected pillars: social, economic, and environmental sustainability (Mann 2011).

The UN Sustainable Development Goals (SDGs), based on the Brundtland Commission's definition, aim for a sustainable and equitable world by 2030, focusing on key areas like climate action, responsible consumption, clean energy, sustainable cities, life on land, and clean water.(Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs 2025).

Actual application of these principles may be quite challenging due to complexity of integration of different aspects of sustainability (Mann 2011). Because of this complexity, sustainability can be described as a 'suitcase concept', including many different elements that must be understood and unpacked both individually and in relation to one another. Figure 3 (right) inspired by Isaksson and Steimle, shows how different important problems are connected and how changes in one area can affect others (Mann 2011).

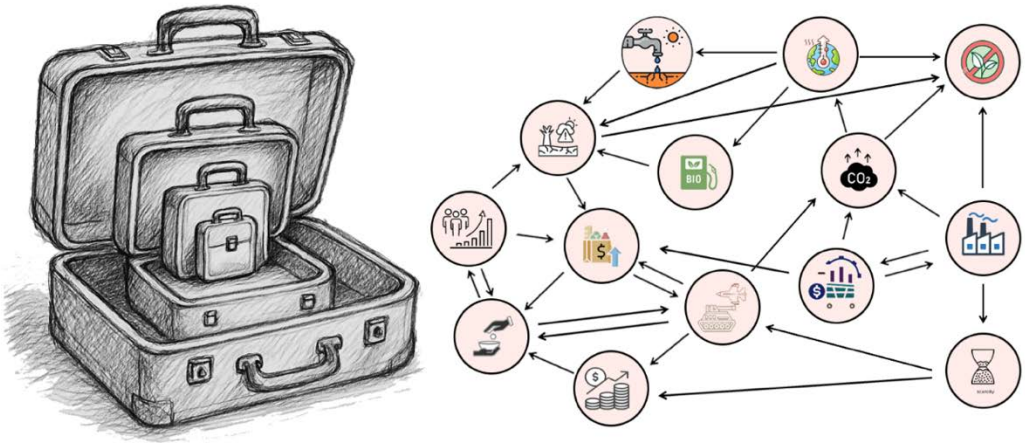

Figure 3- Left Suitcase concept illustration AI generated (ChatGPT), Right, inspired from (Sustainable Lens page 50, 2011).

Similarly, in the context of buildings many decisions are connected. Understanding how one choice affects another is key to making buildings more energy-efficient and sustainable. When optimizing energy use, it's necessary to think of operational energy and embodied energy during a building's life cycle. For example, strategies like more thermal insulation often contributes to lower operational energy but increases the embodied energy due to use of more materials (Mirabella et al. 2018; Rauf 2022). Focusing only on embodied carbon and energy-related impact might lead to an increase in other environmental loads, for example, toxicity and/or ecosystem depletion (Mirabella et al. 2018).

Fire Safety

Fire is a hazard due to its inherently destructive impact on both the built environment and occupants. Fire risk is increasing due to climate-driven natural hazards and also as a technological hazard, where some sustainability measures, like energy systems or added insulation, can unintentionally elevate fire risk (Frantzich et al. 2025).

Resilience can be defined as the ability to prepare for, absorb, recover from, and adapt to adverse events (Frantzich et al. 2025). Building fire resilience involves a combination of protective measures to prevent fires ignition, control fire spread and impact and enable quick suppression of fire. These strategies should protect occupants and minimize damage, making recovery easier. Fire safety is an important component of fire resilience. The main objectives of fire safety are protection of life, property, business and the environment (*ibid)*. Fire safety can be achieved by prevention of fire ignition or managing the fire impact. Managing the fire impact is done by managing the fire or the exposed. The exposed means anything that is being protected like the occupant life safety and environmental impact (Meacham and McNamee 2023, chapter 10). This illustrates a similar concept to the suitcase concept discussed in the sustainability chapter earlier.

In many incidents, "green" elements may have been a fire cause, like cladding systems, energy storage and photovoltaic (PV) systems or timber structures (McNamee and Meacham 2025). A fire's impact on sustainability is multidimensional from pollutants' release (in air, water and soil) to embodied and operational energy that will be used to rebuild/renovate the damaged structures (Martin, Tomida, and Meacham 2016; McNamee, Marlair, and Truchot 2020). Another aspects are the economic cost of fire which results from property damages and the social impact which results from deaths and injuries (McNamee et al. 2020). Quantification of the fire's impact is difficult, especially in identifying and appropriately sampling the

pollutants' impact following a fire event. Particularly when considering both the short and long-term impacts of fire (Martin et al. 2016).

The literature suggests that there are no easy solutions for developing building regulatory systems and design approaches that are holistic for balancing multiple objectives, such as sustainability and resiliency. Problems are easy to recognise but solutions are difficult to be agreed upon and implemented (Meacham 2016; Meacham et al. 2005). Which is why a systematic approach is needed.

Design Decision-Making

Most decisions that people make in their daily lives have a limited impact on society. But decisions engineers make can greatly impact the society (Hazelrigg 2012). For example, a decision was made to refurbish the cladding materials in the Grenfell Tower. When a fire incidence happened, this materials made fire spread faster and easier, which lead to the tragic loss of 72 lives (McKenna et al. 2019). On the other hand, engineers have been taking decisions to lower building energy consumption and therefore contribute to better environmental sustainability.

Normative decision-making theories provide a foundation for ideal decision processes, offering prescriptive models based on logic and rules to guide individuals toward optimal outcomes. These theories establish idealized "gold standards" ; focusing on how decisions should be made, rather than how they are typically made in practice (Meacham 2004; Meacham et al. 2023; de Wilde 2018). However, in practice, people's decision-making deviate from the normative models (Galotti 2005). Descriptive studies of decision making explain how people make decisions in the face of certain and uncertain events (Bell, Raiffa, and Tversky 1989; Hickson and Khemka 2014). There are different approaches for normative decision-making methods like: Analytic hierarchy process (AHP), cost benefit analysis, linear additive models, multi-criteria decisions analysis (MCDA), outranking methods, the payback period and the utility theory (Garmston 2017). In comparison to normative decision theory, naturalistic decision-making is based on descriptive studies of how people take decisions in real life. It studies how the environment impacts the expert's decision-making process. Design and engineering are among the areas where naturalistic decision-making is commonly used (de Wilde 2018). Naturalistic decision making is seen as something that evolves over time, rather than one static decision event (Meso, Troutt, and Rudnicka 2002). Key naturalistic decision-making strategies include (de Wilde 2018):

- Recognition-Primed Decision, where experts rely on past experience.
- Image Theory, based on goals, beliefs, and values.
- Decision Ladders, which guide choices through step-by-step stages.

In the building industry, decisions are made constantly by a range of stakeholders and at various stages of a project life. From the building owner to the architect, contractor, and ultimately the occupants, each decision influences the others. But what shapes the final architecture of a building? Is it the regulatory framework, the environmental context, owner's objective, insurance policies, the various stakeholders or the consultant's expertise and vision?

It is essential to identify where the most critical decisions occur along the building life cycle, how they are made, and where improvements can be introduced to strengthen the decision-making process. Often, decisions in this industry are driven by experience, common-practice, and resources' availability.

To enhance the decision-making process, the first version of the SAFR-BE project presented a conceptual framework and tested its applicability on a small multi-story residential building in Sweden. The project decision-making approach was based on the Analytical Hierarchy Process (AHP). The AHP was structured in different levels: the goal criteria and sub-criteria and alternatives decision options. It compared elements at each level relative to the one above, assigning priorities and weights to evaluate and rank the alternatives. The SAFR-BE assessment tree had two main objectives: sustainability and fire resilience. These were supported by seven strategies. At the base of the tree are nine key attributes, each linked to one and evaluated through specific survey items. The framework used expert evaluations to assess the importance and performance of building attributes related to sustainability and fire resilience (Frantzich et al. 2025). In practice, the industry faces high workload and limited time and funding to do such analysis (de Wilde and Prickett 2009) therefore a decision-making tool that is practical and efficient would help the industry. The SAFR-B framework represents an initial effort towards meeting this need.

Discussion and Future Works

Addressing sustainability requires balancing its environmental, economic, and social aspects while managing competing goals like energy efficiency, cost, and indoor quality. At the same time, fire safety must be integrated through proactive risk analysis and impact management.

In practice many contradicting objectives exists, for example a structure made with bio-based insulation and timber may score well on sustainability metrics but pose fire risks if not addressed appropriately (Meacham and McNamee 2020). Conversely, a high strength concrete structure may require less material, but to ensure fire safety and prevent spalling a higher column dimension may be necessary resulting in higher embodied carbon (Almasailam, Purnell, and Black 2025).

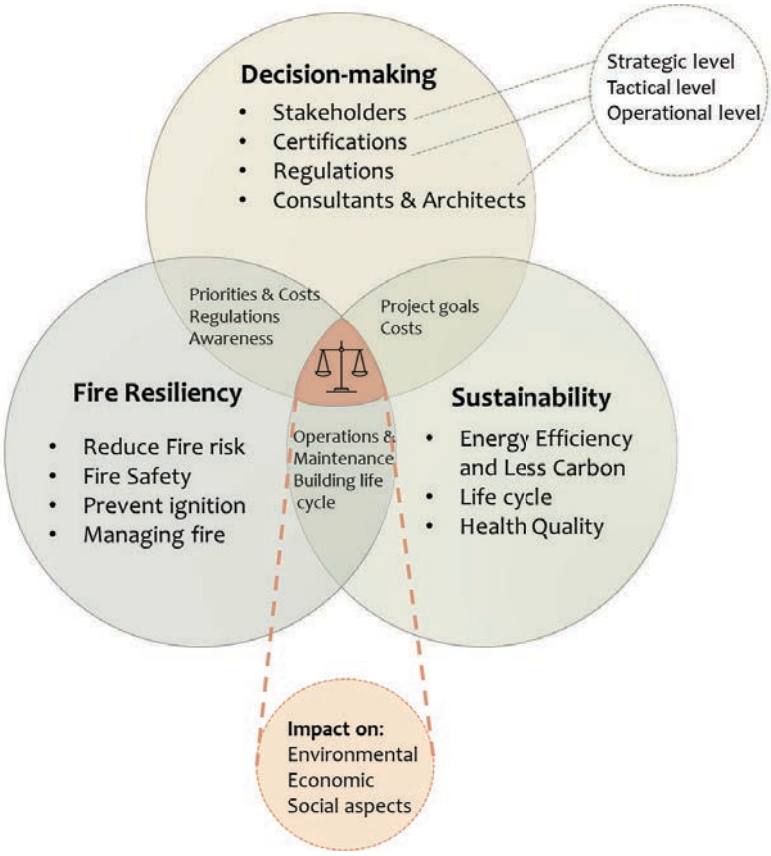

Figure 4- Venn Diagram

Figure 4 illustrates how sustainability, fire safety, and decision-making intersect. Design decisions are made continuously, starting at a strategic level and shaping all subsequent choices. Understanding how each stage, and stakeholder, influences outcomes is key to satisfy and balance sustainability and fire safety objectives. Equally important is selecting the right decision-making approach to achieve that.

When balancing sustainability and fire safety, several key questions must be contemplated to develop an effective decision-making framework:

1. When are decisions made in a building life cycle?
2. How can naturalistic decision-making be integrated with normative strategies? Combining practice with theory?

3. What influence do early design and later construction decisions cause?
4. What fire risks do new bio-based materials pose, and how effective are current fire-resistant technologies?
5. How do operations and maintenance affect sustainability and fire safety goals?
6. How can fire risk be quantitatively included throughout the building life cycle?

These questions are at the heart of a new doctoral research starting at Lund University in Sweden. Answering these questions will guide the development of a framework to help stakeholders balance sustainability and fire safety. A first attempt at a general methodology is proposed and illustrated in Figure 5.

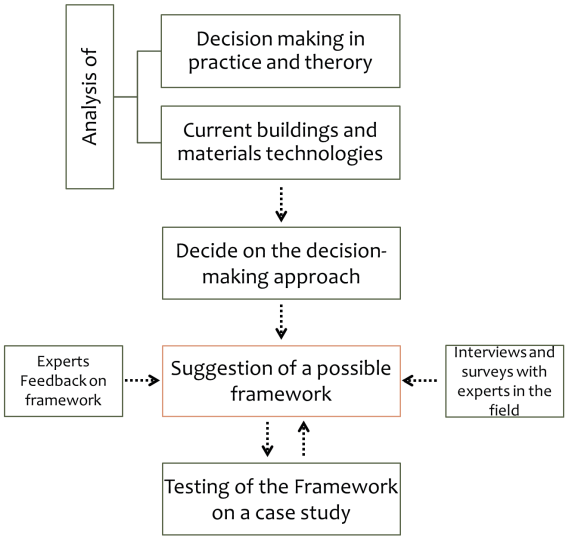

Figure 5- Proposed methodology for future works

Some characteristics of the target framework ought to be:

- Applicable in practice
- Easy to use and not time consuming
- Integrated with industry practices
- Well-defined goals and targets
- Flexible to accommodate different concepts

Expected Challenges and Knowledge Gaps

Some of the main challenges that are expected include the complexity of unpacking the concept of sustainability to a level that is sufficiently detailed for analysis without becoming overly complicated. Furthermore, it will require significant effort to establish clear methods to measure and evaluate sustainability and fire safety, and the potential crosstalk that metrics may have on one another. Setting an appropriate system boundary for both sustainability and fire

safety will also require significant work. And finally, selecting an appropriate decision-making method to capture both quantitative and qualitative factors, while integrating theoretical decision-making models with practical industry needs, will be challenging. At current, the following knowledge gaps are already emerging from the first review of literature: a clear definition of sustainability, the behaviour of new environmentally friendly technologies and materials within the context of fire safety.

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SUSTAINABLE HERITAGE DOCUMENTATION OF THE *FRIGIDARIUM* MOSAICS IN THE GREAT BATH COMPLEX AT SYEDRA

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Sustainable Heritage Documentation of the *Frigidarium* Mosaics in the Great Bath Complex at Syedra

Abstract: This study examines the Great Bath Complex of Syedra Ancient City (Alanya, Türkiye), focusing on the frigidarium mosaics that depict the Twelve Labors of Heracles. Dated to the early 3rd century CE and covering 164.2 m², the mosaic is one of the largest and best-preserved in the region. Beyond its artistic value, it provides a case study for sustainable and non-harmful conservation. Rather than the traditional Munsell system, the Natural Color System (NCS) was applied for mosaic color analysis, enabling accurate, repeatable, and non-invasive documentation. Complementary orthophotos and aerial drone surveys produced high-resolution records that minimize contact with the surface and support long-term monitoring. The integration of architectural study, advanced imaging technologies, and sustainable color analysis in the context of interior environments offer a methodological framework for climate-resilient heritage conservation, contributing to wider debates on safeguarding fragile archaeological remains through innovative, low-impact practices aligned with contemporary conservation ethics.

Keywords: sustainable conservation; cultural heritage documentation; Syedra; Natural Color System; interior environment

Introduction

The conservation of archaeological remains in the Mediterranean has increasingly shifted toward sustainable and non-invasive methods**.** Rising temperatures, humidity fluctuations, extreme rainfall, and the pressures of mass tourism threaten fragile remains such as mosaics, wall paintings, and mudbrick constructions (Matero, 2004; Cassar, 2009). These risks are compounded by the fact that traditional conservation often relied on chemical treatments or invasive pigment sampling, which may accelerate deterioration in the long term. As a result, emphasis has been placed on preventive and digital conservation**,** including high-resolution documentation, color monitoring, and non-contact imaging techniques (Mastandrea et al., 2020).

Ancient city of Syedra, located in modern Alanya (Antalya province, Türkiye), presents a proper case study for this shift. Excavations carried out since 2019 have revealed one of the most impressive bath complexes in southern Anatolia, with a *frigidarium* floor mosaic depicting the Twelve Labors of Heracles**.** This mosaic, measuring 164.2 m², stands as one of the largest and best-preserved in the region (Ergürer, 2023). The present study explores both the architectural features of the bath complex and the non-invasive methods used to document the mosaic, focusing especially on sustainable approaches: the application of the Natural Color System (NCS) for non-invasive color analysis, and the use of orthophotos and aerial drone imaging for long-term documentation.

Historical and Urban Context of Syedra

Syedra is situated on the summit of Asar Tepe, approximately 20 km east of Alanya, overlooking the Mediterranean coast between Pamphylia and Cilicia. At 400 m above sea level, the city controlled a wide coastal zone, and ancient authors often placed it ambiguously between the two regions (Ruge, 1937; Mitchell, 1993). Archaeological evidence suggests occupation as early as the 9th century BCE, with Cilician and Cypriot ceramics found on site (Şahin, 2020; Ergürer 2024).

Figure 1. Location of Syedra (Ergürer & Ergürer, 2024)

During the late Hellenistic period, Syedra, like many coastal towns, suffered from pirate activity. An inscription indicates that the citizens sought guidance from the oracle of Apollo at Claros to address this threat (De Souza, 1997). Pompey's 67 BCE campaign brought peace to the region, establishing stable Roman rule.

The reign of Emperor Tiberius marked a turning point, as Syedra began issuing its own coinage -the earliest sign of civic autonomy and economic vitality. By the 2nd and 3rd centuries CE, the *Pax Romana* facilitated urban growth across southern Anatolia. Cities such as Perge, Side, and Syedra invested in colonnaded streets, baths, and *gymnasia* (Yegül, 1992). Syedra flourished as a regional center, hosting athletic games and aligning itself with Septimius Severus during his civil war against Pescennius Niger, thereby securing imperial favor (Levick, 1967).

Syedra also played a role in early Christianity. It was represented by Bishop Gaius at the Council of Chalcedon (451 CE), placing it among the episcopal sees of Pamphylia and Cilicia (Dagron, 1974). The 4th-6th centuries witnessed prosperity with church building, yet

the Arab raids of the 7th century disrupted stability. Syedra appears in episcopal lists until the 12th century, after which it declined into obscurity, though traces of Seljuk pottery attest to its continued strategic function (Foss, 1994).

The Great Bath Complex: Architecture and Function

The Great Bath Complex lies to the south of Syedra's well-preserved colonnaded street, connected by a monumental staircase. The preserved walls, rising over 16 m, indicate the building's imposing presence (Şahin, 2020). Planned in conjunction with an adjacent gymnasium, the bath complex follows the Roman model of integrated bathing and athletic culture (Fagan, 1999).

Its north-south orientation and phased construction suggest adaptation to topography and evolving needs. Rooms 1-2, possibly earlier in date, were later modified: one became a *caldarium* after insertion of a hypocaust. Subsequent additions include service corridors, cisterns, and smaller chambers. To the east lies the *palestra* (9), an open courtyard for exercise.

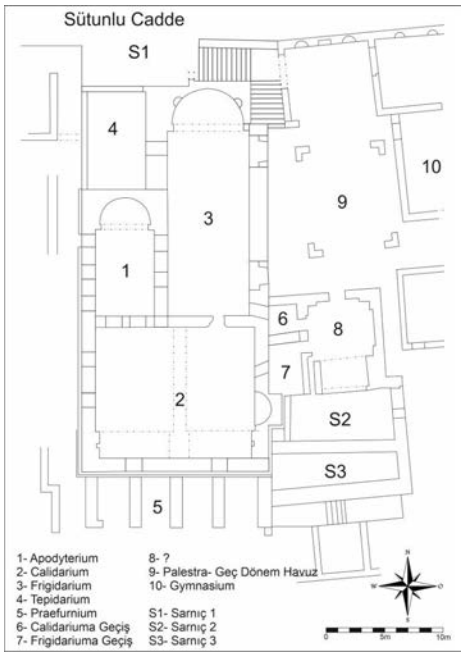

Figure 2. The Great Bath Complex, plan (Hüber, 1993)

The *frigidarium* (Room 3), or cold room, is the best-preserved part of the complex. It contains remains of painted marble imitation on the southwest walls and, most notably, the extensive floor mosaic discovered during 2019-2020 excavations. Measuring 7.9 × 21.91 m, the mosaic pavement is similar in size of those of at Antioch, Zeugma, and Perge in scale and craftsmanship (Levi, 1947; Dunbabin, 1999).

The mosaic demonstrates the vitality of bath culture in Syedra. Cold baths were not merely functional but also symbolic, emphasizing the luxury and cultural prestige of civic

amenities. The presence of mythological iconography in the frigidarium underscores how Roman elites fused leisure, ritual, and education in public space.

The Frigidarium Mosaics: Iconography and Technique

The main panel (2.51 × 15.14 m) depicts the Twelve Labors of Heracles, bordered by geometric patterns in *opus tessellatum*. This theme, while prominent in sculpture and wall painting, is relatively rare in floor mosaics, making the Syedra example particularly significant. Each labor -ranging from the Nemean Lion to the Apples of the Hesperides- is rendered in sequential vignettes.

Comparable mosaics from Antioch (Daphne), Lydda (Israel), and Hispania attest to the popularity of Heraclean cycles in the Roman world (Levi, 1947; Ling, 1998). Yet the Syedra mosaic is exceptional for its completeness and scale. Its inclusion in a bath underscores Heracles' symbolic associations with endurance, strength, and purification -qualities resonant with the bathing experience (Yegül, 1992).

Figure 3. The *frigidarium* section of the Great Bath of Syedra (Syedra Excavation Archive)

Figure 4. The floor mosaic depicting "The Twelve Labors of Heracles" (Syedra Excavation Archive)

Executed in *opus tessellatum*, the mosaic employs tesserae ranging from 0.5 to 13 mm. Larger *tesserae* were used for borders, while finer *tesserae* produced figural detail. The palette includes black, white, red, brown, yellow, and gray-blue, combined to create intermediate tones and light-shadow effects (Ergürer, 2023). Such *chiaroscuro* effects, along with perspective rendering, produce a striking three-dimensionality (Dunbabin, 1999). The mosaic demonstrates the mastery of Cilician workshops, which were influenced by Antiochene styles but adapted them for local contexts. The emphasis on realism, polychromy, and dynamic composition reflects broader artistic trends of the Severan period (Ergürer, 2023).

Sustainable Documentation and Non-Harmful Conservation Methods

Mosaics are highly vulnerable to environmental stressors such as fluctuations in humidity, temperature, and exposure to water infiltration. In baths, where the original function involved thermal contrasts, pavements are often weakened by salts and moisture even in their archaeological afterlife (Roby & Demas, 2012). Traditional conservation strategies sometimes involved lifting pavements or applying chemical consolidants. While such methods once dominated practice, they are now seen as potentially harmful due to their irreversible interventions (Cassar, 2009).

In response, contemporary practice emphasizes preventive conservation**,** digital documentation**,** and minimal intervention**,** ensuring that the material remains accessible for future generations (Matero, 2004). The work at Syedra follows this approach, prioritizing non-invasive recording methods to avoid further deterioration.

A central feature of the project was the application of the Natural Color System (NCS) for documenting *tesserae* colors. The NCS is a perceptual model developed to reflect how humans categorize color in terms of hue, chromaticness, and blackness. Unlike the Munsell system, which requires subjective visual matching to printed charts, the NCS can be applied with a digital handheld scanner, producing objective and replicable results.

At Syedra, the NCS Color Scan 2.0 was used to measure tesserae colors from figural elements such as Heracles' face (see Table 1). This provided quantitative data in the form of NCS notations, which could be re-measured in the future to detect fading, discoloration, or biological alteration.

The advantages of NCS in heritage work are significant, as it is non-invasive, requiring no material sampling or alteration, and objective, reducing observer bias compared with

traditional methods. It is also repeatable, enabling the monitoring of changes over decades, and transferable, allowing meaningful comparison across different mosaic sites.

Comparable applications, such as the study of the Circus Mosaic in Barcino (Barcelona), have demonstrated the value of NCS in mosaic conservation, producing datasets more robust than Munsell-based documentation (Schiatti et al., 2021).

In addition to color analysis, the Syedra mosaics were documented through orthophotography and UAV (drone) imaging**.** High-resolution aerial photography was used to generate scaled, georeferenced orthophotos of the frigidarium floor. These images allow precise mapping of tesserae, geometric patterns, and areas of damage.

Complementing this color-based approach, advances in aerial documentation have further strengthened sustainable conservation practices. Practical applications of drone-based orthophotos in heritage preservation have shown that UAVs can produce accurate documentation of archaeological sites while minimizing direct contact with fragile remains (PA SHPO, 2019). Orthophotos are now a standard component of archaeological recording, providing scaled digital images that preserve detailed information for both research and conservation (UAV Coach, 2024). In the Syedra project, this approach enabled the creation of a comprehensive digital archive of the mosaic in its fully uncovered state, an essential step given that the pavement was subsequently reburied for protection after 2020.

Both NCS and drone-based orthophotos serve long-term climate-resilient strategies. With increasing rainfall and humidity fluctuations in the eastern Mediterranean (Cassar, 2009), fragile pavements are at risk even when reburied. Digital archives ensure that high-quality records exist for both scholarly and management purposes, reducing the need for repeated physical uncovering.

Furthermore, these methods contribute to community-centric conservation: digital outputs can be displayed in museums, online exhibitions, or local cultural centers, making heritage accessible while reducing physical strain on the site.

Table 1. NCS notations of the tesserae of Herakles' face.

Mosaic Part	NCS Notation	Color
	S 1020-Y20R	
	S 2005-Y30R	
	S 2010-Y30R	
	S 3020-Y40R	
	S 4010-Y30R	
	S 4020-Y60R	
	S 5010-Y30R	
	S 5010-Y50R	
	S 6005-Y80R	

Discussion

The Syedra project highlights how sustainable documentation methods are redefining conservation practice. Instead of applying consolidants only after visible damage has occurred, digital methods allow continuous preventive monitoring (Roby & Demas, 2012). Similarly, the use of the Natural Color System (NCS) replaces subjective visual estimation with quantitative, replicable data (Schiatti et al., 2021). Orthophotos and UAV surveys further extend the scope of documentation by creating datasets that can be compared across sites, thereby promoting regional studies of mosaic condition and style (Remondino, 2019). At the same time, digital archives enhance accessibility, allowing wider use by scholars and the public and fostering education and sustainable tourism (Mastandrea et al., 2020). When compared with older practices such as pigment sampling or manual drawings, the sustainable approach adopted at Syedra demonstrates an ethical commitment to minimizing harm while maximizing knowledge

production. It positions conservation within broader debates on sustainability, where environmental, cultural, and social dimensions converge.

Conclusion

The frigidarium mosaics of the Great Bath at Syedra Ancient City stand as one of the finest examples of mythological mosaic art in Asia Minor. Their scale, completeness, and iconographic richness render them invaluable to our understanding of Roman art and bath culture. Yet their fragility necessitates careful strategies for conservation.

By applying the Natural Color System (NCS) for non-invasive color analysis and employing orthophotos and UAV surveys for digital recording, this study has developed a framework for sustainable, non-harmful, and climate-resilient heritage preservation and interior environments. These approaches minimize risk, generate replicable datasets, and enable long-term monitoring while contributing to both scholarship and community engagement.

As Mediterranean heritage sites face increasing climatic pressures, these methods provide a model that could be adapted to other mosaics, wall paintings, and archaeological remains. Syedra thus serves not only as a case study but also as a benchmark for integrating sustainability into conservation theory and practice.

Acknowledgments

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BIOMIMETIC TRANSFORMATION IN PAVILION TYPOLOGY: COMPARATIVE ANALYSIS OF NATURE-INSPIRED MATERIALS FOR SUSTAINABLE DESIGN

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Biomimetic Transformation in Pavilion Typology: Comparative Analysis of Nature-Inspired Materials for Sustainable Design

Abstract: In the field of architecture today, not only aesthetic and structural solutions but also design approaches that are environmentally compatible, flexible, and transformable have gained significance. In this context, biomimetic materials drawing inspiration from the structure, function, and environmental responsiveness of organisms in nature offer new possibilities to architectural practice in terms of sustainability and innovation. Especially when evaluated at the scale of temporary structures, material types that can transform their shape, self-heal, or react to environmental stimuli provide significant contributions in terms of spatial adaptation, user experience, and resource efficiency. This study investigates the multifaceted contributions of biomimetic materials to architectural design, particularly through the lens of pavilion architecture. The analyses carried out in line with criteria such as material circularity, structural flexibility, and environmental sensitivity demonstrate that nature-inspired solutions can be integrated into architectural production processes and tested through pavilion structures.

Keywords: Biomimetic Architecture, Biomimetic Materials, Pavilion Design, Sustainability, Experimental Architecture

Introduction

Today, architecture extends beyond aesthetic concerns to actively address environmental challenges and promote sustainable living. Issues such as climate change, resource scarcity, urban density, and growing energy demand have necessitated a comprehensive reevaluation of all components in the design and construction process. As a result, sustainability-driven strategies increasingly influence architectural decisions, from material selection and construction techniques to spatial design and conceptual frameworks. Among the leading approaches shaping this transformation is biomimicry, which draws on the structural, functional, and ecological strategies developed by nature over millions of years. Rather than imitating natural forms superficially, biomimetic design focuses on analyzing how living systems function and integrating these principles into the built environment. In this context, biomimetic materials adaptive, responsive to environmental stimuli, and capable of high performance with minimal energy have emerged as valuable tools in the pursuit of sustainable architecture.

Pavilion structures offer a distinctive platform for experimental design and material exploration in architecture. Their rapid prototyping potential, material flexibility, and adaptability to different environmental contexts allow for structural and technological experimentation. As such, pavilions provide valuable opportunities to test biomimetic materials and observe how they can be integrated into architectural production.

This study examines the use of biomimetic materials in pavilion architecture and their relationship with sustainable design. Through examples such as HygroSkin, Hy-Fi, Bloom, ICD/ITKE, and MycoTree, it evaluates the architectural contributions of materials like hygroscopic wood, thermo-bimetal, mycelium, and bio-fiber composites.

For instance, HygroSkin provides passive ventilation with wooden modules that open and close in response to humidity, while Bloom creates temperature-sensitive shading through thermo-bimetal panels. Hy-Fi offers a biodegradable structure made of mycelium bricks, and ICD/ITKE explores spider silk-inspired systems through robotic fabrication. MycoTree tests the load-bearing capacity of mycelium in an experimental branching form. These examples demonstrate the potential of biomimetic materials in terms of environmental responsiveness, integration with fabrication techniques, and user experience.

Biomimetic Approach and the Concept of Material

The concept of biomimetics is an interdisciplinary approach that aims to integrate nature's evolutionary knowledge accumulated over millions of years into human-made systems and design practices. Derived from the Greek words bios (life) and mimesis (imitation), this term refers to the development of innovative solutions by drawing inspiration from the structures, functions, and systems of living organisms.

The term "biomimetics" was first introduced into scientific terminology in the 1950s by American biophysicist Otto Schmitt. In his doctoral research, Schmitt focused on designing a device that mimicked the biological functioning of nerves, which laid the foundation for the concept of biomimetics (Karakoç, 2022). This concept has since been defined as a design principle that seeks sustainable solutions to human challenges by referencing the structures and principles that nature has tested and refined over centuries.

However, during this period, the concept of biomimetics remained largely within the scope of engineering and materials science and did not reach a broader audience. The more comprehensive interpretation of biomimetic principles in relation to architecture, product design, and sustainable lifestyles became possible through the contributions of Janine Benyus. In her 1997 book Biomimicry: Innovation Inspired by Nature, Benyus introduced the concept of biomimicry and described nature not merely as a source of inspiration but also as a "model, measure, and mentor":

- Nature as a model: Drawing inspiration from nature's designs and processes to solve human problems.

- Nature as a measure: Using nature as an ecological standard or benchmark to evaluate the validity of innovations.
- Nature as a mentor: Understanding that it is not only what we can see in nature but what we can learn from it offering a new way of observing and interpreting the natural world (Türk, 2018).

Through this perspective, Benyus highlighted the value of nature's evolutionary intelligence as a foundation for innovation. Her approach expanded biomimetics beyond engineering, framing it as a comprehensive design philosophy applicable to sustainability, ecology, and everyday life. In this way, biomimetic thinking evolved from a specialized concept into a widely accessible approach that fostered greater public engagement and awareness.

Until the early 20th century, the interaction between nature and architecture remained at a superficial level, often limited to imitating the form of living organisms. However, with subsequent advancements, the analysis of the characteristics, behaviors, and ecosystems of organisms in nature has contributed significantly to the development of sustainable design approaches. Today, the process of examining and transferring nature into architectural design has accelerated in parallel with the advancement of analytical methods for studying natural systems (Karakoç, 2022).

These developments have facilitated the integration of nature-derived strategies into sustainable architectural practice, fostering the design of environmentally responsive and energy-efficient buildings. Contemporary design approaches increasingly engage with not only the formal characteristics of natural systems but also their underlying biological processes, aiming to translate these dynamics into the built environment. Within this context, biomimetic thinking promotes a shift from conventional energy-focused sustainability toward a more holistic paradigm grounded in ecosystem-based, adaptive, and integrative design principles.

In recent years, the rapid advancement of digital technologies has significantly enhanced the effectiveness of biomimetic design processes. With the incorporation of generative techniques and parametric forms into design, computer technology has become a vital design tool, adding a new dimension to the relationship between nature and architectural design. Through computer-based modeling and simulation technologies, both living and nonliving forms found in nature can now be analyzed more effectively, and their formal developments can be examined in greater detail. This evolution has led to the emergence of new approaches in architecture (Korkmaz, 2022, p. 94). These methods not only increase structural efficiency

but also improve durability and offer innovative solutions. Biomimetic strategies have become particularly prominent in building envelope design.

In this context, Biomimetic materials offer architects new opportunities to create energy-responsive structures that achieve maximum impact with minimal resources. Examples include hygroscopic wood, thermo-bimetals, mycelium-based biocomposites, and photochromic surfaces. With properties such as shape transformation, biological origin, and self-healing capabilities, these materials contribute to sustainability and innovation in architecture. However, testing their applicability in permanent, full-scale buildings remains limited due to technical and economic constraints. In this regard, pavilion structures provide ideal experimental platforms where such materials can interact with environmental conditions and be observed through user experience offering a unique framework for exploring the architectural potential of biomimetic approaches.

Pavilion Architecture as an Experimental Medium: Historical Legacy and Digital Future

Pavilions are a distinct architectural typology where experimental design and innovative material applications come to the forefront. As small-scale, rapidly built, and temporary structures, they offer designers greater creative freedom. Beyond exhibition purposes, they function as experimental laboratories for research, prototyping, and interdisciplinary exploration. These characteristics provide architects with a freer and more creative design environment. Pavilions are not only examples of exhibition or representational architecture but also serve as laboratories for research, prototyping, technological testing, and interdisciplinary collaboration. These temporary structures differ in several ways from conventional architectural practices. They are transitory, as their duration of existence is predetermined; they can be constructed and dismantled quite rapidly. Moreover, the architects themselves are often directly involved in their construction. Additionally, they tend to be inexpensive, relatively smaller in scale, and lighter in structure compared to permanent architectural works of a similar kind. In essence, they are highly suitable for investigating the boundaries of architecture on a reduced scale (Tuncbilek, 2020, p. 398).

Historically, pavilions began as small garden structures for rest or viewing, often emphasizing aesthetics and blending with nature. By the 19th century, international exhibitions redefined them as temporary yet impactful architectural forms, serving as experimental platforms for national representation.

One of the earliest and most notable examples of this transformation is the Crystal Palace, designed by Joseph Paxton for the Great Exhibition held in London in 1851. Utilizing industrial materials such as glass and cast iron within a modular system, the structure went beyond being a temporary exhibition hall and became a pioneering prototype that embodied key concepts of modern architecture, such as technology and mass production. It holds a significant place in pavilion history as an early demonstration of how temporary architecture can serve as a platform for innovation.

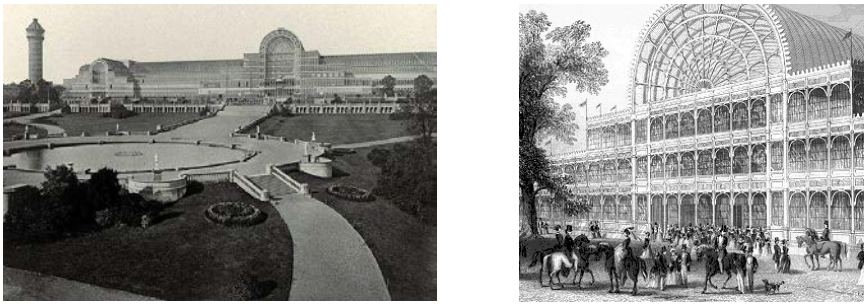

Figure 1. Crystal Palace designed by Joseph Paxton for the Great Exhibition in 1851. (Source: Arkitektuel, n.d., https://www.arkitektuel.com/kristal-saray/)

Since the second half of the 21st century, pavilions have evolved beyond exhibition spaces into architectural laboratories where material, form, structure, and spatial experiments can be conducted. This transformation has accelerated with the advancement of digital fabrication technologies, enabling the integration of contemporary methods such as parametric design, robotic manufacturing, and simulation-based analysis into architectural processes. A prominent example of this is the *HygroSkin – Meteorosensitive Pavilion*, which demonstrated the potential of adaptive architecture using biomimetic wooden modules responsive to humidity changes without relying on any electronic systems.

Figure 2. HygroSkin – Meteorosensitive Pavilion by Achim Menges, Oliver David Krieg andSteffen Reichert. (Source: ArchDaily, 2013,

https://www.archdaily.com/424911/hygroskinmeteorosensitive-pavilion-achim-menges-architect-in-collaboration-with-oliver-david-kriegand-steffen-reichert)

Experimenting with the new materials and new methods enriches architectural practice and discourse. In this respect, this paper suggests that pavilion design can be interpreted as a laboratory for experimentation in architecture. This indicated that the critical position of pavilion design could be considered in terms of bothmaterials and methods as the conceptual base from which experimentation inarchitecture can be launched. An architect‟s choices of materials and techniques can be a key to creating possibilities and re-setting the architectural limitations. (Tuncbilek, 2020, p. 399).

In this context, pavilions offer a unique platform for testing biomimetic materials and integrating them into architectural practice through experimental design processes. Unlike conventional building typologies, the small scale and temporary nature of pavilions encourage the exploration of innovative materials and construction techniques.

Biomimetic Materials and Pavilion Architecture: Towards an Experimental Paradigm

Biomimetic materials, inspired by the structural, functional, and environmental characteristics of living organisms, contribute sustainable solutions to architecture through features such as shape transformation, responsiveness to environmental changes, self-healing capacity, and biologically derived content. However, the application of these advanced systems in large-scale and permanent buildings is often limited by technical and economic constraints. Pavilions, with their short lifespan and low-cost production processes, provide ideal settings for the implementation of such experimental materials.

In this context, it is important to clarify the conceptual scope of terms such as "biobased," "biomorphic," and "biomimetic" to avoid ambiguity. While bio-based materials are derived from biological sources, and biomorphic design refers to aesthetically nature-inspired forms, biomimetic approaches focus on transferring functional principles observed in nature into architectural design. Making these distinctions helps clarify the study’s focus and highlights the specific strategies contributing to sustainability.

Moreover, the flexible assembly systems and adaptability to parametric design inherent in pavilions facilitate the integration of biomimetic thinking with digital tools such as parametric modeling, robotic fabrication, and environmental simulation. In this regard, biomimetic approaches systematically transfer the operational principles of nature into architecture, while pavilions serve as creative prototypes that embody these principles in physical form.

Ultimately, the relationship between pavilion architecture and biomimetic material use goes beyond a temporary design solution; it represents an emerging architectural language shaped at the intersection of design, material, and environmental interaction. This production model introduces a new paradigm that reimagines architecture through the principles of sustainability, adaptability, and innovation inviting architects to think with nature, rather than simply drawing inspiration from it.

Material Design Relationship Through Case Studies

The integration of biomimetic principles into architectural design offers innovative potential not only at the conceptual level but also within physical production processes. This approach becomes particularly evident in temporary and experimental pavilion structures, where nature-inspired material systems can be observed as they transform into architectural form through concrete examples.

Due to their short lifespan and limited programmatic requirements, pavilions provide a suitable ground for testing the relationship between material and design. Through these structures, both the environmental responsiveness of biomimetic materials and their interaction with architectural systems can be analyzed in depth.

The examples presented in this section offer an opportunity to evaluate design approaches based on the form, behavior, and adaptive mechanisms of natural organisms, in conjunction with the technical performance and environmental sensitivity of the materials used. In doing so, biomimetic thinking is revealed not only as a source of design inspiration but also as a functional and experimental tool in contemporary architectural practice.

Table 1. Pavilion Examples with Project Aim and Contextual Information

Pavilion Name		Pavilion Year	Place	Project Aim	Project Context
(ArchDaily, 2013, https://www.archdaily.com/424911/hygroskin-meteorosensitive-pavilionachim-menges-architect-incollaboration-with-oliver-david-kriegand-steffen-reichert)	HygroSkin – Meteorosensitive Pavilion	2013	Stuttgart, Germany	Research pavilion exploring material responsiveness without mechanical systems.	The pavilion utilized hygroscopic wooden modules responsive to humidity, serving as an early example of integrating biomimetic materials with computational design.
(Source: Dezeen. (2014, https://www.dezeen.com/2014/07/0 1/tower-of-grown-bio-bricks-by-theliving-opens-at-moma-ps1-gallery/)	Hy-Fi Pavilion	2014	MoMA PS1 Courtyard, New York, USA	To create a biodegradable prototype within the MoMA PS1 Young Architects Program using mycelium-based bricks.	Constructed in New York within the MoMA PS1 Young Architects Program, Hy-Fi was a biodegradable prototype built entirely from mycelium-based biobricks.
(Source: eVolo.us, 2013, https://www.evolo.us/bloom-bydosu-is-environmentally-responsiveinstallation/)	Bloom Pavilion	2012	Los Angeles, USA	Exploring environmental responsiveness through thermobimetals.	Designed by DO|SU Studio Architecture, Bloom employed heatsensitive thermobimetals, testing environmental responsiveness through an experimental installation.
(Source: ArchDaily, 2014, https://www.archdaily.com/522408/ icd-itke-research-pavilion-2015-icditke-university-of-stuttgart/)	ICD/ITKE Research Pavilion 2013-14	2013-2014	Stuttgart, Germany	Investigating digital fabrication techniques informed by biological processes.	Built at the University of Stuttgart, the pavilion translated the silk-spinning behavior of spiders into robotic fabrication, exploring lightweight and efficient structural systems.
(Source: Serpentine Galleries,2015 https://www.serpentinegalleries.org /whats-on/serpentine-pavilion-2015designed-selgascano/)	SelgasCano's Serpentine Pavilion 2015	2015	London, UK	To design the 2015 edition of the Serpentine Pavilion series, emphasizing temporary and experimental architecture.	Designed for the Serpentine Galleries in London, the pavilion employed colorful and semitransparent plastic panels to create an experimental play of light and space.

Table 2. Comparative Analysis of Biomimetic Materials in Pavilion Architecture

Pavilion Name		Nature-Inspired System	System Aimed to Be Resolved	Applied Biomimetic Material	Biological Equivalent
(Source: ArchDaily, 2013, https://www.archdaily.com/424911/hygroskin-meteorosensitive-pavilion-achim-menges-architect-in-collaboration-with-oliver-david-krieg-and-steffen-reichert)	HygroSkin – Meteorosensitive Pavilion	The Hygroscopic Opening Closing Mechanism of the Spruce Cone	Environmental adaptation achieved without the use of an active mechanical system	Hygroscopic layered wood panels	The reorientation of plant tissues in response to humidity.
(Source: Dezeen. (2014, https://www.dezeen.com/2014/07/01/tower-of-grown-bio-bricks-by-the-living-opens-at-moma-ps1-gallery/)	Hy-Fi Pavilion	Construction principles of microorganisms	Low-carbon construction with renewable material	Bio-bricks (mycelium-based + PLA)	The mycelial network formed by fungi beneath the soil a self renewing and environmentally regenerative system that naturally purifies its surroundings.
(Source: eVolo.us, 2013, https://www.evolo.us/bloom-by-dosu-is-environmentally-responsive-installation/)	Bloom Pavilion	Plants' responsiveness to environmental stimuli	Providing shading by responding to heat without using active energy	Thermo-bimetal	Shape transformation of plant leaves in response to heat (e.g., mimosa, pine cone)
(Source: ArchDaily, 2014, https://www.archdaily.com/522408/icd-itke-research-pavilion-2015-icd-itke-university-of-stuttgart/)	ICD/ITKE Research Pavilion 2013-14	Inspired by the silk-spinning strategies of insects in nature, the structural and directed fiber arrangements of silkworm larvae have been analyzed.	Structural Potential of Fiber-Based Biological Systems	Glass and carbon fiber-reinforced composite material	The silkworm cocoon directional weaving of fibers forming an organic, load-bearing shell
(Source: Serpentine Galleries,2015 https://www.serpentinegalleries.org/whats-on/serpentine-pavilion-2015-designed-selgascano/)	SelgasCano's Serpentine Pavilion 2015	Inspired by the semi-permeable and lightweight biological surface properties of insect membranous wings and leaf epidermis.	The design aims to allow natural daylight penetration during the day while creating a colorful spatial experience.	ETFE (Ethylene Tetrafluoroethylene) membrane	The interaction of light with thin membranous structures—such as butterfly wings or leaf epidermis—has been mimicked.

Table 3. Design Strategies Based on Biomimetic Material Responses in Selected Pavilions

Pavilion Name		Design Production Method	Design and Fabrication Method	Environmental Response	Architectural Contribution from a Biomimetic Perspective
(Source: ArchDaily, 2013 https://www.archdaily.com/424911/ hygroskin-meteorosensitive-pavilionachim-menges-architect-incollaboration-with-oliver-david-kriegand-steffen-reichert)	HygroSkin Meteorosensitive Pavilion	Parametric design + robotic fabrication	The moisture induced deformation of wood defines the form of the envelope.	The panels adapt to environmental conditions by opening and closing in response to humidity levels.	Solar control, natural ventilation, and light permeability are achieved entirely through the material's intrinsic responsiveness, without the need for an external energy source, thereby minimizing the carbon footprint.
(Source: Dezeen. (2014 https://www.dezeen.com/2014/07/01/tower-of-grown-bio-bricks-by-theliving-opens-at-moma-ps1-gallery/)	Hy-Fi Pavilion	3D printing + modular system	The organic form was constructed through the arrangement of bricks. The permeability and lightness of the bricks defined both the aesthetic and structural form.	The bricks are breathable in structure, enabling natural ventilation within the interior space and thereby eliminating the need for energy consumption.	Hy-Fi, by integrating mycelium-based bricks, transfers the regenerative capacity and environmentally adaptive transformation abilities of natural organisms into architectural production. In this respect, it functions not only as a structural system but also as an ecological manifestoserving as a physical embodiment of the symbiotic relationship that biomimetic architecture establishes with nature.
(Source: eVolo.us, 2013 https://www.evolo.us/bloom-bydosu-is-environmentally-responsiveinstallation/)	Bloom Pavilion	CNC cutting, parametric modeling based on thermal behavior	Movable facade surfaces that open and close in response to heat have been achieved.	Thermo-bimetals deform with temperature changes to create openings, enabling passive ventilation in the interior.	By proposing a passive system that responds to the environment without energy consumption, it establishes a sustainable material system in building envelope design.
(Source: ArchDaily, 2014 https://www.archdaily.com/522408/ icd-itke-research-pavilion-2015-icditke-university-of-stuttgart/)	ICD/ITKE Research Pavilion 2013-14	Robotic fabrication	The orientation of composite fibers determines the loadbearing form of the structure. The material behavior shapes the form.	It creates an extremely lightweight, durable, and flexible surface.	Through the digital reinterpretation of the woven systems of living organisms in nature, it stands as an innovative example in both the production process and architectural form.
(Source: Serpentine Galleries,2015 https://www.serpentinegalleries.org /whats-on/serpentine-pavilion-2015designed-selgascano/)	SelgasCano's Serpentine Pavilion 2015	Parametric design combined with a modular system	The flexibility and lightness of the material have enabled the creation of interlocking forms.	The structure filters daylight, producing colorful shadows inside and enabling natural ventilation.	Nature-inspired performances of materials like ETFE have been tested in temporary structures such as pavilions. The material's relationship with nature, user interaction, and environmental responsiveness exemplify the translation of biomimetic thinking into spatial design.

Table 4. Material Behavior and User Interaction in Biomimetic Pavilion Architecture

Pavilion Name		Construction Method and Performance Feedback
(Source: ArchDaily, 2013, https://www.archdaily.com/424911/hygroskin-meteorosensitive-pavilionachim-menges-architect-incollaboration-with-oliver-david-kriegand-steffen-reichert)	HygroSkin Meteorosensitive Pavilion	The pavilion was constructed using multilayered wooden panels fabricated through robotic cutting and assembly processes. These panels respond passively to changes in humidity without requiring mechanical or electronic systems, utilizing the hygroscopic properties of wood. This behavior allows the structure to adapt to its environment without energy consumption. The project has been recognized as a pioneering example in experimental architecture and passive ventilation strategies, frequently cited in academic discourse for its innovative integration of material behavior and digital fabrication.
(Source: Dezeen. (2014, https://www.dezeen.com/2014/07/01/tower-of-grown-bio-bricks-by-theliving-opens-at-moma-ps1-gallery/)	Hy-Fi Pavilion	Developed by The Living, this pavilion was built using biodegradable bricks composed of mycelium and corn stalks. The bricks were grown in molds and cured using sunlight, minimizing carbon emissions and enabling localized, low-energy production. After the exhibition, the entire structure was disassembled, and the materials were composted, making it a prototype for circular design in architecture. The project received praise for merging ecological material innovation with architectural form, while users appreciated its natural texture and lightweight atmosphere.
(Source: eVolo.us, 2013, https://www.evolo.us/bloom-bydosu-is-environmentally-responsiveinstallation/)	Bloom Pavilion	The structure was formed using thermo-bimetal panels cut with CNC technology. These panels curl in response to temperature changes, creating a constantly shifting façade that provides passive shading without relying on external energy sources. The dynamic visual experience was highlighted by users as both engaging and unexpected. Bloom stands out for transforming thermal responsiveness into an expressive architectural form, merging environmental adaptation with sensory interaction.
(Source: ArchDaily, 2014, https://www.archdaily.com/522408/icd-itke-research-pavilion-2015-icditke-university-of-stuttgart/)	ICD/ITKE Research Pavilion 2013-14	Inspired by the silk-weaving behavior of spiders, this pavilion employed robotic fiber placement techniques to form a lightweight structure from carbon and glass fibers. Digital simulations guided the placement of the fibers to optimize structural strength with minimal material. The integration of natural construction logic with advanced fabrication technologies has made this project a benchmark in biomimetic structural design. Detailed performance analyses of the pavilion have validated its effectiveness and architectural potential.
(Source: Serpentine Galleries,2015 https://www.serpentinegalleries.org/whats-on/serpentine-pavilion-2015designed-selgascano/)	SelgasCano's Serpentine Pavilion 2015	Built using lightweight, semi-transparent ETFE membranes stretched over a steel frame, the pavilion created a colorful spatial environment filled with filtered natural light and shadow play. Inspired by biomorphic forms, its plan offered a series of interconnected, tunnel-like spaces. The design emphasized experiential qualities, guiding users through vibrant pathways that reacted dynamically to sunlight. Visitors described the pavilion as joyful, immersive, and sensorially rich, reflecting the fusion of parametric design, membrane architecture, and playful spatial composition.

The table offers a structured analysis of how biomimetic materials are integrated into pavilion architecture. Each case draws from a biological system, aiming not only for aesthetic expression but also for environmentally responsive and experimental spatial models.

These pavilions demonstrate shared principles, particularly in the interplay between material and form. Materials reflect nature's regenerative, adaptive, and resource-efficient strategies. Here, material becomes an active design agent, enabling interaction with the environment.

HygroSkin uses the hygroscopic behavior of wood to create humidity-responsive surfaces; Bloom applies thermo-bimetals for thermal reactivity. Hy-Fi introduces biodegradable mycelium bricks, while ICD/ITKE reinterprets spider silk behavior through robotic fabrication.

These structures show a reciprocal relationship between material and form, where environmental responsiveness is digitally controlled via parametric tools. This supports sustainability goals such as climate adaptation and circular resource use. Pavilion temporariness allows experimental testing and user feedback, enabling materials that face cost or technical barriers in permanent architecture to be prototyped.

In conclusion, the selected examples function as prototypes illustrating the architectural potential of biomimetic materials. They provide not only formal innovation but also insight into fabrication, environmental integration, and sustainability, informing future architectural practice.

While these pavilions highlight experimental potential, transitioning biomimetic materials into permanent construction is still challenged by durability, regulation, and cost. For example, although mycelium bricks are eco-friendly, they lack long-term structural reliability; adaptive materials like thermo-bimetals require precise control and are cost-intensive.

Nonetheless, these experiments significantly shape sustainable design thinking by revealing new possibilities in material behavior and low-energy adaptation. In this regard, biomimetic materials are not merely conceptual, but active agents in redefining architecture's relationship with nature.

Conclusion

The integration of biomimetic principles into architecture redefines the relationship between the built environment and nature, both formally and conceptually. This is not only a technical innovation but also a holistic design perspective that links material, space, and

environmental interaction. Pavilion structures, as temporary and experimental typologies, provide flexible platforms for testing and advancing this transformation.

In this study, examples such as HygroSkin, Hy-Fi, Bloom, ICD/ITKE, and MycoTree demonstrate how nature-inspired materials like hygroscopic wood, thermo-bimetal, mycelium, and bio-fiber composites shape architectural form, enhance adaptability, and influence user experience. These materials act not only as structural or visual elements, but as responsive components engaging with environmental data.

Pavilions allow these innovative materials to be applied at low cost and small scale, overcoming constraints of permanent construction. Moreover, when combined with digital design and fabrication methods, biomimetic strategies support goals such as circularity, energy efficiency, and ecological responsiveness.

In conclusion, biomimetic materials in pavilion design not only draw inspiration from nature but actively promote design in collaboration with it. This approach offers a forwardlooking and sustainable foundation for future architectural production.

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TOWARDS THE DEFINITION OF CIRCULAR BIO-HYBRID BUILDING MATERIALS. AN EXPERIMENTAL GLOSSARY LINKING RESEARCH AND DESIGN

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Towards the definition of Circular Bio-hybrid Building Materials. An experimental glossary linking research and design

Abstract: In a joint effort to increase the level of circularity in the construction sector, research is advancing with a new approach that looks at hybridisation between organic and inorganic materials, combining circular design principles with bio-inspired multi-species and multi-material innovations. This perspective is a fundamental step in the process of defining Circular Bio-hybrid Building Materials, the subject of the research. The methodology combined an extensive literature review with the construction of an experimental glossary of 55 key terms, later applied to 12 emblematic case studies ranging from architectural projects to experimental prototypes. The conclusions reveal multiple trajectories of research and design, highlighting the opportunities and challenges of bio-hybrid approaches, particularly regarding End-of-Life disassemblability, and leading to an initial definition of Circular Bio-hybrid Building Systems.

Keywords: circular materials; bio-based materials; bio-hybrid materials; built environment; disassemblability

Introduction: towards a circular bioeconomy in the construction sector

The construction sector is responsible for almost 50% of EU-wide material consumption by weight, impacting on both natural resources depletion and GHG emissions, and contributes to almost 40% of the EU's total waste generation (EC, 2020). The EU aims to double recycled material use between 2020 and 2030, to reduce the extraction of primary raw materials and related environmental impacts, as improving material efficiency could reduce GHG emissions of 80% (EC, 2020). However, in 2023 recycled material accounted just for 11.8% of material used in the EU, while the global economy's circularity rate decreased from 7.2% in 2015 to 6.9% in 2021 (Circle Economy, 2025).

While strengthening circularity policies, the EU is currently developing the third version of its Bioeconomy Strategy, acknowledging how bioeconomy possesses the potential to advance the EU's environmental objectives through the development of a circular economy that does not compromise natural systems (EC, 2025). Building a sustainable, circular bioeconomy in the construction sector is therefore mandatory to tackle the global challenges of climate change and resources depletion, as emphasised by the Dutch government, which aims to achieve this by 2050 by developing buildings and infrastructure "in such a way that all materials and raw materials are reusable or biobased" (De Bouwagenda, 2018). In this combination, emphasis is placed "on achieving (higher) quality reuse (including dismantlable construction) and the implementation of biobased materials in all submarkets of the construction industry" (De Bouwagenda, 2018).

However, currently bio-based materials represent only 3% in mass of the building materials used in Europe and 10% in volume (Cardellini & Mijnendonckx, 2022), showing a

significant potential for expanding the use of such materials, particularly those derived from waste streams, in line with circular bioeconomy goals. In fact, previous research has shown how bio-based materials can produced with locally sourced waste materials, allowing building materials to be produced within cities, and even at the neighbourhood scale (Tucci et al., 2025), to drastically reduce climate-altering emissions.

While over the last 20 years research and design experimentations have focused on the substitution of traditional building materials with organic and even living materials, a new approach is looking at hybridisation between organic and inorganic materials, as one promising direction to drastically reduce the impacts of the construction sector (Trubiano, et al. 2024). This approach, based on designing systems that provide for multi-species and multi-material collaboration, can represent one of the ways to combine circular design principles with bio-inspired material innovations (Dade-Robertson, et al., 2024).

Literature Review

Experimentation in architecture in recent years has focused on bio-based materials, according to different approaches concerning origin, production processes and construction methods. Organic materials reduce the need for extracted materials by replacing components, offering performance levels equal to and, in some cases, superior to traditional materials (Linh Le et al., 2023). One research line exploits organic waste materials from forestry, agriculture and biomass residues as building materials, representing key local solutions (UNEP, 2023). An interesting case is RiceHouse (IT), which designs and manufactures innovative materials using rice waste, creating a direct link between agriculture and construction chains.

More recently, research has focused on delegating production processes directly to other species, by directing biological processes of organisms (such as bees and silkworms) and microorganisms (such as bacteria and fungal mycelia) to obtain production processes of materials, components and buildings. Within such experiences, one relevant case is the Mediated Matter Group research team of Neri Oxman (Massachusetts Institute of Technology), which has worked for years on experimentation about collaboration between organic and inorganic worlds, developing technologies capable of enabling co-design, co-manufacturing and co-habitation across species and searching for sustainable methods of manufacturing and construction. Another significant experience is work carried out by the Hub for Biotechnology and the Built Environment (HBBE) by Research England with Northumbria University (NU) and Newcastle University (NCL), which aims at integrating living organisms into architectural

processes, developing biotechnologies to create "Living Buildings", responsible and responsive to their natural environment.

Furthermore, one emerging concept is bio-hybridisation. Biohybrid materials, a definition originating in regenerative medicine, refer to the "synergistic combination of living cells with nonactive materials […] which has become a new paradigm for smart materials" (Wang et al., 2022). This category is explored in different fields, including robotics (Soft Robotics Lab at ETH Zurich) and the built environment. Transferred to construction, this approach aims at developing bio-hybrid architectural systems coupling living and technical complexes, interpreting living materials as smart materials that can interact with the environment and react, turning buildings into sensing and computing structures. In Denmark, Prof. Phil Ayres has established the Chair in Biohybrid Architecture, which involves "the symbiotic coupling of living biological complexes with artificial elements to create dynamic systems for achieving architectural objectives" (Ayres, 2021). This emergent research field, pursued in EU funded projects Flora Robotica and Fungateria, focuses on incorporating characteristics and dynamism of living complexes – such as growth, self-repair, decision-making, and resource balancing – to create opportunities to invent spatial and tectonic vocabularies and architectural technologies. HBBE is also working in this direction, experimenting biohybrids between mycelium and textile fibres (Sherry et al., 2023).

These promising experiences show huge potential for environmental sustainability, but - if considered from a circularity standpoint - reveal aspects requiring attention. Among the most critical aspects are undoubtedly material durability and the impossibility of completely replacing functions currently performed by inorganic materials. This awareness leads to reflect on the relationship these materials have with other inorganic components, both in assembly and behaviour during use, and in End-of-Life (EOL), particularly regarding the possibility of disassembling parts for biological and technological cycles theorised by Braungart and McDonough (2002). A renewable and regenerative material such as mycelium might be combined with synthetic binders that may affect its EOL biodegradability.

Research aims

In this context, the research aims to understand how feasible it is to replace/hybridise technical materials with bio-matrix materials in layered architectural components, and how these components can be integrated into the design of circular buildings. Therefore, the research

objective, through an integrated and interdisciplinary approach, is to develop an innovative environmental design framework, aimed at the orienting technical and technological solutions towards the use of Circular Bio-hybrid Building Materials (CBBM). In fact, at the heart of the framework elaboration, the research aims at proposing a new definition of CBBM – partially organic, partially inorganic, and fully consistent with the principles of circularity in both the production and EOL phases – exploiting waste streams (organic and inorganic) for their production. The framework will also integrate design criteria supporting material selection and indicators to accurately measure the benefits in terms of the reduction of climate-altering emissions and resource consumption.

Within the larger scopes of the research, this contribution specifically aims to structure an experimental glossary correlated to a selection of case studies, linking design and research experiences and interpreting them systematically. This research product supports the formulation of the preliminary experimental definition of CBBM.

Research methododology

The research methodology was characterized by an iterative process (Figure 1) starting with literature review, allowing initial keywords identification, with relative definitions from multiple sources. Then, terms were used to explore architectural project databases, to identify relevant case studies using circular and bio-based materials, as well as to search for more experimentations in literature and research project databases. The collected case studies (around 60) refer to different scales/levels of complexity, from proper buildings – less diffuse today – to small installations such as exhibition pavilions and prototypes. This led to increased selected keywords, followed by another phase of definitions collection in literature.

The successive step was of the comparison of the multiple collected definitions to build a glossary of 55 terms (Table 1), relating to bio-based and circular materials from the design and production standpoint (considering also sources, resources and processes typical of the different materials). The glossary was therefore articulated into five sections: *approaches*, *material families*, *material typologies*, *resources* and *processes*.

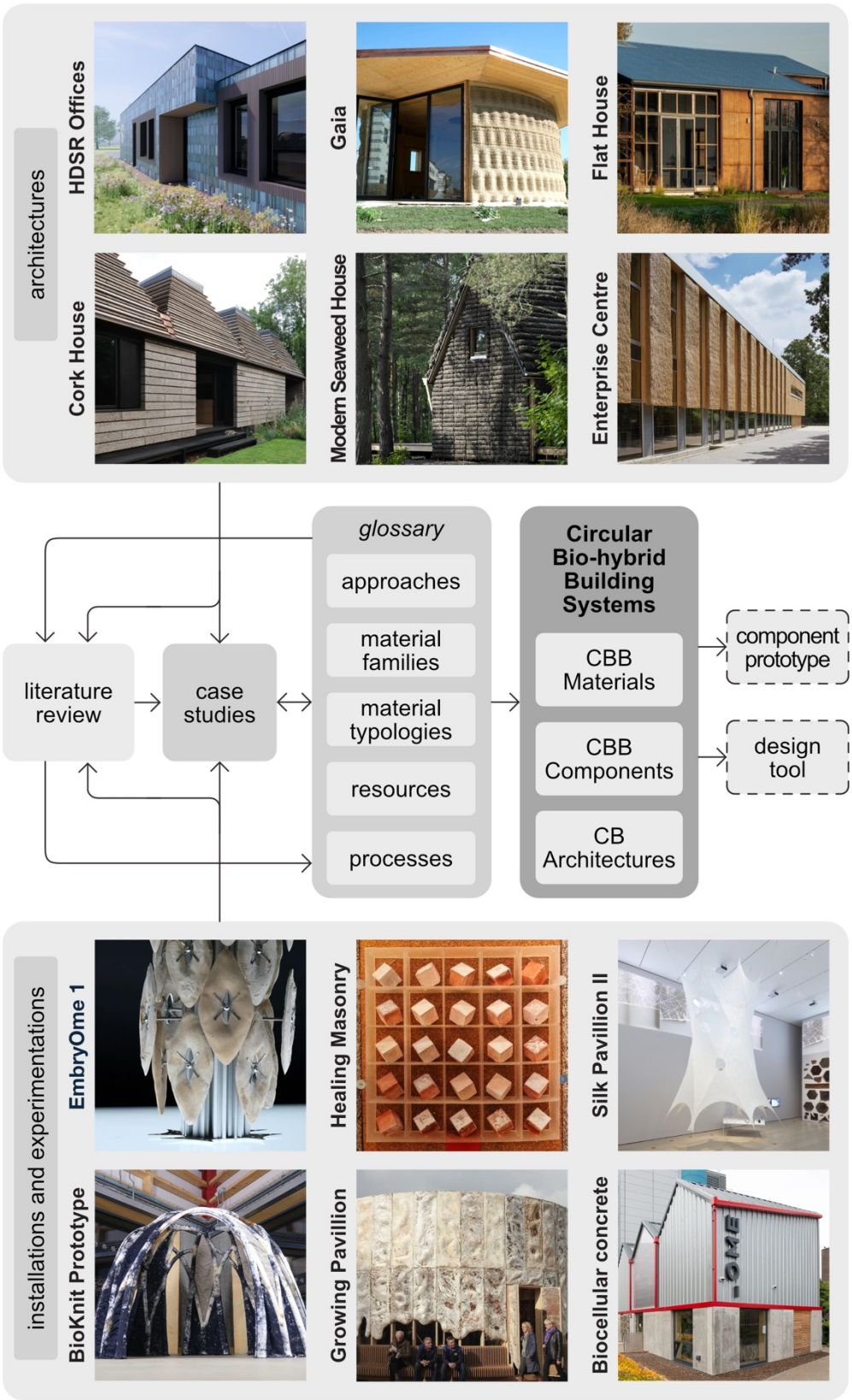

Figure 1. Research methodology flowchart, illustrating the two main groups of case studies (architectures, i.e. proper buildings, and installations and experimentations) explored in the terminological glossary development. The dotted boxes highlight the research next steps.

Table 1. Structure and contents of the glossary, with the indication of the references.

Glossary category	Glossary terms	Literature review references
approaches	*biodesign, biomimetics, biomimicry, biomorphism, bioregional design, bio-tech, knitted architecture, living construction, regenerative design, re-upcycling*	Agkathidis, 2017. Ayres, 2021. Gibbs, 2025. Hebel&Heisel, 2017. Morrow et al., 2023. Pellizzari&Genovesi, 2021. Subirós, 2025.
material families	*biobased materials, biocomposite, biogenic, biohybrid, bio-waste materials, biopolymers, circular bio-based building materials, circular neomaterials, cultivated materials, ex-novo materials, harvested materials, living materials, neo-classics materials*	Hebel&Heisel, 2017. Kapsali, 2016. Linh Le et al., 2023. Morrow et al., 2023. Pellizzari&Genovesi, 2021. Ramsgaard& Tamke, 2022. Vilaboa Díaz et al., 2022.
material typologies	*biocement, biogenic ceramics, biolaminate, bioplastic, bioresin, carbon dioxide polymer, engineered living materials (ELMs), green biocomposite, hardwood composite materials, materials from the Sludge of Water Treatment Plant (SWTP)*	Ayres, 2021. Dade-Robertson et al., 2024. Gibbs, 2025. Hebel&Heisel, 2017. Morrow et al., 2023. Pellizzari&Genovesi, 2021. Vilaboa Díaz et al., 2022.
resources	*adhesive matrix, bacterial cellulose, biomatrix, feedstock, hygromorphs, protomaterial, regenerated fibres, starch adhesives, substrate*	Hebel&Heisel, 2017. Kapsali, 2016. Lee, 2025. Morrow et al., 2023. Pellizzari&Genovesi, 2021. Peters, 2014.
processes	*Additive Manufacturing (AM), biocompatibility, biocycling, biofabrication, biofouling, biomineralisation, bioprecipitation, bioprinting, bioreceptivity, bioremediation, bio-welding, Microbially Induced Calcium Carbonate Precipitation (MICCP), standardization*	Antonelli&Tannir, 2019. Ayres, 2021. Hebel&Heisel, 2017. Morrow et al., 2023. Vilaboa Díaz et al., 2022.

The next step entailed using the glossary terms to systematically assess 12 emblematic case studies (six *architectures*, three *installations* and three *experimentations*), selected in order to represent the different trajectories of research, design and experimentation - in the combination of different approaches and material typologies, using different resources and developed with various processes, at all scales of the built environment (Table 2).

The last step, currently in progress, is the formulation of the definition of CBBM, as a synthesis and progression from the findings gathered within the framework established by the experimental glossary linking design and research.

Findings and discussion

The analysis results of the 12 case studies through glossary term attribution are reported in Table 2 and visualized in Figure 2, showing multiple connections between each case and different glossary term sets. Below, the critical reading of case studies through keywords is summarised, aiming to illustrate the identified research lines.

The study conducted by the HBBE about the behaviour of bacteria such as Sporosarcina pasteurii, which has natural *biomineralisation* capabilities, led to the use of *Microbiologically Induced Calcium Carbonate Precipitation (MICP)* to create sustainable and architecturally

applicable forms: the EmbryOme 1 project[1], inoculating these bacteria into bioreactors called "Water Kilns", mimicing traditional kilning processes using a biotic liquid medium to solidify sand aggregates, leads to the formation of calcium carbonate crystals entirely underwater, naturally cementing the sand particles into solid elements, prototypes of architectural panels.

The behaviour of the same bacterium was exploited in the Healing Masonry project (Morrow et al., 2023), involving the *biomineralisation* process to develop biotechnological systems expressing natural weathering and self-healing, according to a *living construction* approach where living cells are used to construct and transform materials at multiple scales. Cubic clay samples, treated with different pigments and textures to replicate defects and fissures typical of masonry facades, visually reflect the healing process.

The role that living matter can play in relation to inorganic matter is the subject of the HBBE Biocellular concrete experiment (Morrow et al., 2023), which prototyped vertical façade panels in recycled concrete consisting of 90% by-products (eggshells, lycra, fly ashes) with high porosity, favouring water retention and biological life development. In line with the principle of *bioreceptivity*, which expresses a material's ability to be colonised by living organisms without undergoing biodeterioration, the prototype proves to be optimal for plant growth on its surface. The result is a *biohybrid material* capable of sequestering carbon dioxide in both its inorganic (through carbonation processes in production) and its organic component (through photosynthesis processes in use).

In the Bioknit Prototype (Morrow et al., 2023) the HBBE explored opportunities for upscaling mycelium construction through *knitted architecture*, testing how 3D knitted fabric (wool and linen) can be programmed and applied structurally at human scale using fungi and bacteria. The monolithic free-standing *biohybrid* structure was created using biotechnology, digital fabrication and computation. A 1.8 m high, 2 m diameter framework guided mycelium growth to form a bespoke composite hosting separately cultivated layers of *bacterial cellulose*. In parallel, the Growing Pavilion, by the New Heroes and Krown.bio[2], is not monolithic but consists of several modules: a 10-tonne CO_2-negative and 95% circular structure made up of raw materials (wood, mycelium, residual hemp, bulrush, cotton) combined to obtain different components - from vertical mycelium panels to the bio-laminate flooring, made by combining cattail fibres with a biopolymer – proving how bio fabrication processes can valorise different biobased materials in innovative forms and uses.

[1] See: http://bbe.ac.uk/water-kiln/.
[2] See: https://thegrowingpavilion.com

In parallel to the focus on microorganisms, another research line studies the potential role of organisms in the construction of *bio-hybrid* architectures. Oxman's Silk Pavilion II[3], 6 m high and 5 m wide, was created by 17,532 silkworms placed on a soluble mesh scaffold inserted into a rotating metal structure, designed to facilitate the upward spinning of the worms, which produced 11,650 km of silk threads based on the substructure in a *biofabrication* process involving living materials and biological processes to produce new materials.

Two case studies deal with innovative use of traditional natural materials. The Enterprise Centre project[4] by Architype adopts the *bioregional design* approach, involving local resources and skills and a low-tech approach, with a simple assembly of prefabricated components facilitating disassembly. Thatch not only forms the façade cladding inside wooden cassettes but also serves as raw material for various non-structural indoor uses. The Flat House[5] by Practice Architecture also focuses on *harvested materials*, grown and processed locally. However, the resources are not used directly but processed using innovative systems to create the façade cladding: corrugated bioplastic panels, made from a bio-composite of hemp fibres, sugar and a bio-resin.

Although natural resources are easy to cultivate and dispose of, a higher level of circularity can be achieved by relying on biological waste from various supply chains, such as agriculture and forestry, through a process of *re-upcycling,* climbing the value spiral through its reintroduction into industrial production cycles. The Cork House by MPH Architects[6] was built by juxtaposing blocks of by-product cork from the forestry industry without mortar, which would compromise the level of disassemblability: organic waste from industrial processes is recovered and reused in an attempt to return to industry through a process of *standardisation*. On a similar line but pushing exploiting innovative technologies, the RiceHouse architectural prototype Gaia[7] was created using a Crane WASP 3D printer and a mixture based on clay, silt and sand, chopped rice straw and husks, by *re-upcycling* rice industry waste resources. Built in just a few weeks, with walls 45 cm thick, Gaia opens new economic scenarios in which the bio-waste from 1 hectare of cultivated rice paddies is sufficient for 100 sqm of built surface area. A further case, the Modern Seaweed House[8], by Vandkunsten Architects, uses biomass from a

[3] See: https://oxman.com/projects/silk-pavilion-ii
[4] See: https://www.ribaj.com/buildings/adapt-low-carbon-enterprise-centre-uea-architype
[5] See: https://www.architectsjournal.co.uk/buildings/from-farm-to-form-flat-house-by-practice-architecture-2
[6] https://www.matthewbarnetthowland.com/cork-house
[7] See: https://www.ricehouse.it/storie/gaia/
[8] See: https://vandkunsten.com/en/projects/seaweedhouse

different origin: drawing on the historical tradition of seaweed roofing from a regenerative design perspective, it revisits it in a modern key. In an attempt at *standardisation*, the organic resource is grouped into knitted nets and then juxtaposed on the façade inside prefabricated wooden cassettes, providing thermal-acoustic insulation and the more innovative role of façade cladding. In this case, the resource is converted in a *circular biobased building material*, wholly derived from renewable biological sources, not from industrial production waste but rather from natural, uncultivated biomass, abundant on the coast near the building.

A more recent research line works on *ex-novo materials*, resources considered non-recoverable that, thanks to new processes, become part of new production cycles. Experimentation by Hoogheemraadschap De Stichtse Rijnlanden and NPSP Delft on waste from the *Sludge of Water Treatment Plant (SWTP)* to produce architectural components will allow to produce of panels covering the façade of the HDSR office building[9], designed by Schoots Architecten. The panels - resistant to UV radiation with expected lifespan of min. 50 years - are composed of cellulose fibres from 180,000 tonnes of toilet paper that ends up in Netherlands sewer system yearly and *biopolymer* Kaumera, extracted from the residual product of purification process, waste sludge. The 200 m² façade will require material from 2,000 toilet paper rolls, saving 10 tonnes (or 75%) of CO_2 emissions compared to brick façade.

For each of the 12 case studies, the level of disassemblability of the organic and inorganic components at the EOL was assessed in a scale from 0 to 2 (Table 2), as one of the crucial requirements for circular bio-hybrid systems. In some cases, such as the Biocellular concrete prototype or the Silk Pavilion II, the separation between the organic and inorganic part can be easily achieved, and the EOL processes can follow separate biological and technological cycles (level 2). In other cases, such as the Gaia building or the BioKnit, this separation is not possible, but this is not a limit as the structure can be crushed and used as inert material for new 3D printing mixtures or dispersed in agricultural soil as it is completely biodegradable and rich in nutrients (level 0). In cases reaching level 1, finally, disassembly is not facilitated by design choices ensuring easy separability between layers/components, but there is no complete material/component fusion that would make it impossible.

Table 2. Comparative analysis of the case studies, which highlights the combination of some of the keywords from the glossary in each of them and assess the disassemblability level of the different solutions.

[9] See: https://schootsarchitecten.nl/nieuws/klimaatneutraal-en-circulair-bouwen-met-gevelpanelen-uit-reststoffen-rioolwaterzuivering

Case study	Pr. cat.	Designer/ Researcher	Year	Type of approach	Type of component	Material family/typology	Type of resources	Type of processes	Dis. level
Biocellular concrete	E	HBBE (NU + NCL)	2021	*living construction*	vertical panels	*bio-hybrid*	recycled concrete, by-products (egg shells, lycra, fly ash)	*biomineralisation, carbonation, bioreceptivity*	1
BioKnit Prototype	I	HBBE (NU + NCL)	2021	*bio-tech, knitted architecture*	freestanding structure	*bio-hybrid, biocomposite, cultivated mat.*	wool, mycelium, *bacterial cellulose*, sawdust, water	*biofabrication, bio-welding, biocompatibility*	0
Cork House	A	MPH Architects	2019	*re-upcycling*, design for disassembly	blocks	*bio-waste*	by-product cork from the forestry industry	*standardization*	2
Embry-Ome 1	E	HBBE (NU + NCL)	2021	*biodesign, living construction*	vertical panels	*biohybrid, biogenic*	fabric casts, *biomatrix* (calcium ions, urea), bacteria	*biofabrication, bioprecipitation (MICP)*	1
Enterprise Centre	A	Architype	2015	*bioregional des.,* low-tech	façade cladding	*harvested m.*	thatch cassettes	prefabrication	2
Flat House	A	Practice Architecture	2019	*regenerative design*, low-tech	façade cladding	*harvested m., bioplastic, biocomposite*	hemp fibres, sugar *bioresin*	prefabrication, molding	2
Gaia	A	RiceHouse	2018	*re-upcycling, regenerative design*	structural envelope	*biohybrid, bio-waste*	clay, silt and sand, chopped rice straw and rice husks	*additive manufacturing*	0
Growing Pavillion	I	Biobased Creations	2019	*biodesign, living construction*	panels and laminate	*bio-waste, bio-laminate, cultivated mat.*	bacteria, mycelium, hemp, cattail, rice straw, wood	*biofabrication,* molding	1
Healing Masonry	E	HBBE (NU + NCL)	2021	*biomimicry, living construction*	blocks	*biohybrid, biogenic*	lime mortar, bacteria, calcium ions, urea	*biomineralisation, bioprecipitation (MICP)*	1
HDSR Offices	A	HDSR, NPSP Delft	t.b.b.	*re-upcycling, regenerative design*	façade cladding	*bio-waste, material from SWTP*	cellulose fibers from recycled toilet paper, biopolymer	molding	1
Modern Seaweed House	A	Vandkunsten Architects	2013	*regenerative design*, design for disassembly	insulation and façade cladding	*circular bio-based build. material*	seaweed (eelgrass), knitted nets and wooden cassettes	*standardization,* prefabrication	2
Silk Pavillion II	I	OXMAN	2020	*biomimicry, living construction, knitted arch.*	soft envelope	*biogenic, bio-hybrid*	silkworm-spun silk, PVA knit text, aluminum, stainless steel cables	*biofabrication*, kinetic manufacturing	2

Notes. For project category (Pr. cat.), A = architecture, E = experimentations, I = installations; for year, t.b.b. = to be built; the terms indicated in italics correspond to glossary entries; the level of disassemblability is assessed on a scale from 0 (not disassemblable) to 2 (fully disassemblable).

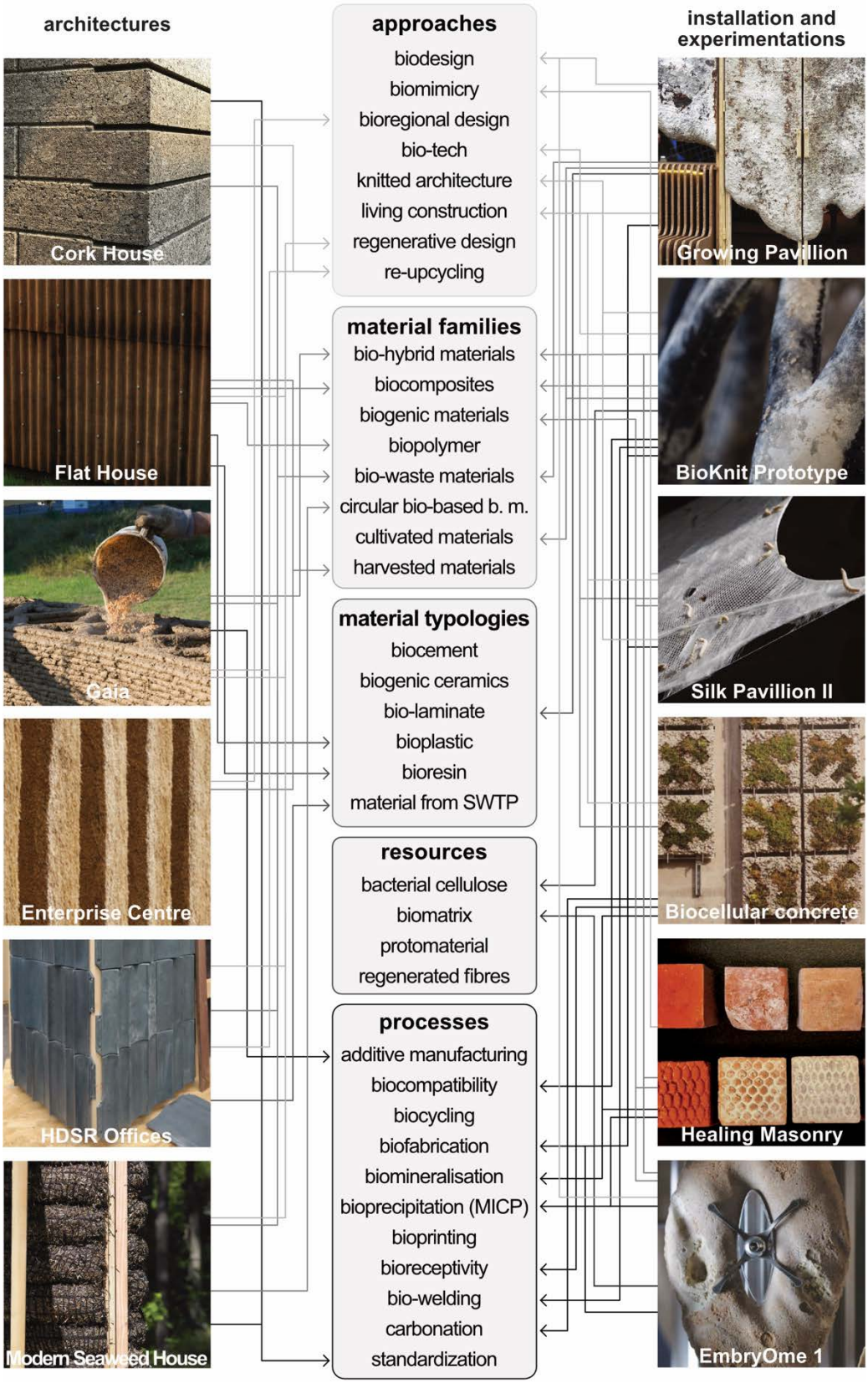

Figure 2. Mapping of 37 terms from the 5 sections of the glossary in the 12 case studies selected for the research activity. On the left, the 6 *architectures*; on the right, the 6 *installations and experimentations.*

Conclusion: towards the definition of Circular Biohybrid Building Materials

From the literature review and case study analysis that led to the compilation of the glossary, a complex picture of research and design approaches emerges, attempting to hybridise organic resources and processes with inorganic elements in the realisation of materials, components and architectures of the future. The biohybrid direction appears to be one promising road to pursue to reduce the impact of the construction sector. However, it seems necessary to consider biohybrids systems' potential, limitations and necessary precautions, particularly regarding EOL. In the broad and sometimes overlapping landscape of projects and experimentation, establishing definitions allows interpreting and directing research towards new design and technical solutions, reducing misunderstandings and misinterpretations linked to different nuances of meaning that terms acquire depending on context and disciplinary field.

In an attempt to define the characteristics of the circular-biohybrid approach in architecture, applying it to the different scales of material, component and building, the research proposes an initial definition of Circular Biohybrid Building Systems (CBBS), intended as the overall set of strategic technical-design solutions aimed at achieving the objectives of this approach. CBBS are therefore defined as materials, components and structures related to the built environment that feature a combination of a *bio-based* organic component, originating from *biowaste* or *cultivated materials*, and a second-life inorganic component, originating from recycled or reused materials. The *biohybrid* system thus intended must be effectively structured in terms of *biocompatibility* of the parts and the possible *bioreceptivity* of the inorganic elements towards living matter. Both biological and geological or artificial parts should be produced locally with resources recovered from the shortest distance from the intervention site, including through bioprocesses. Particular attention must be paid to the study of the stratification and assembly of the parts to achieve a sustainable life-cycle for the system, making it easy to disassemble the parts into techno- and bio-cycles or making them recyclable or biodegradable without separation.

In the next research steps, the definition of CBBS will be declined to the different scales of material, component and architecture. Once consolidated, these definitions will serve as the foundation for future research developments in two directions: the elaboration of a design support tool for materials selection, in which the glossary will be included, and the design and prototyping of a Circular Bio-hybrid Building Component. In fact, the ultimate research objective is to validate the CBBS definition through an applied experimentation.

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SUSTAINABILITY IN MODELLING, ASSESSMENT, AND DESIGN TOOLS

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SUSTAINABLE MODELLING OF HISTORIC MASONRY: LEARNING FROM THE PAST

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Sustainable Modelling of Historic Masonry: Learning from the Past

Abstract: Masonry structures constitute the majority of Italy's architectural heritage and display a distinctive mechanical behaviour due to their inability to resist tensile stresses. These characteristic challenges conventional elastic approaches, calling for assessment methods grounded in geometry and equilibrium. Building on historical construction principles and modern limit analysis, this study examines selected arches, vaults, and domes to illustrate how non-elastic frameworks can effectively capture their stability conditions. The cases include single-span arches with localised damage, as well as complex double-shell domes, where construction choices and historical modifications directly influenced thrust distribution. Across these examples, structural safety emerges as a function of the thrust line's containment within the masonry thickness, independent of material deformation capacity. The findings emphasise that sustainable heritage conservation lies not only in the inherent eco-compatibility of masonry but also in the adoption of non-invasive, methodologically coherent assessment strategies that respect the original design logic of historical structures.

Keywords: rigid no-tension material; equilibrium analysis; masonry domes; masonry arches; architectural heritage

Introduction

The conservation of architectural heritage in Italy inevitably intersects with the problem of masonry structures, which constitute the overwhelming majority of historical buildings across the territory. Masonry is not a single material, but rather a collective denomination that encompasses a vast variety of constructive practices, ranging from refined isodomic arrangements to coarse rubble masonry. Despite their typological and mechanical variability, these systems share a fundamental characteristic: their inability to resist tensile stresses.

This simple yet profound limitation radically distinguishes masonry from modern structural materials and calls for a paradigm shift in its analysis and preservation. several scholars since the second half of the twentieth century have argued—most notably Benvenuto, Heyman and Giuffrè (Benvenuto, 1991; Giuffrè, 1993; Heyman, 1966)—masonry ought not to be approached through the lens of elastic theory, but rather through a framework rooted in equilibrium and geometry. In this view, structural safety is not assessed through stresses and strains, but by verifying the existence of admissible compressive stress fields or compatible collapse mechanisms.

This approach aligns not only with the intrinsic mechanical nature of masonry but also with the cultural and environmental dimension of conservation. Traditional masonry structures were built using locally sourced materials—such as the Neapolitan yellow tuff—employing construction rules handed down through generations. These structures embody a form of territorial sustainability, being both materially and culturally integrated with their environment.

To preserve such heritage in a sustainable and respectful manner, structural assessment methods must be coherent with the original logic of construction. This implies both avoiding invasive techniques and employing modelling strategies that are compatible with the assumptions underlying historical design practices. In this sense, sustainability extends beyond the eco-compatibility of the material itself and also encompasses the methodological coherence of the structural analysis.

In this paper, calculation models consistent with the mechanical nature of masonry are presented and discussed, with particular attention to methods based on limit analysis and geometric compatibility rather than on elastic theory. Through the examination of selected historical arches and domes, the discussion explores how these approaches can be applied to diverse structural configurations, offering assessments that are both respectful of the original construction logic and aligned with the principles of sustainable heritage conservation.

Assessment of arches, vaults and domes

In antiquity, the design of buildings was governed by empirical knowledge, scale modelling, and traditional craftsmanship, with proportions defined through geometric and arithmetic rules rather than a formal structural theory (Cennamo et al., 2018; Huerta Fernández, 2004). A conceptual shift occurred in the seventeenth century, when a theoretical framework for the analysis of masonry structures began to emerge (Angelillo, 2019; Cennamo & Cusano, 2018; Frunzio & Di Gennaro, 2021). Research has shown that masonry behaviour is governed not solely by material strength, but also by block geometry, bond patterns, and frictional resistance between units (Angelillo, 1993; Beatini et al., 2018; Como, 1992; Heyman, 1995; Huerta, 2008). These principles, rooted in long-standing construction traditions, underpin the structural logic of arches, vaults, and domes—elements that today represent a significant part of architectural heritage (Cennamo & Cusano, 2018; Di Gennaro, 2025; Marmo et al., 2019; Olivieri et al., 2025; Oppenheim et al., 1989; Rocchetta et al., 2019).

A decisive theoretical contribution was made by Heyman (1995), who departed from elastic theory and adopted the static and kinematic theorems of limit analysis. In his model for curved masonry, stability is defined as a problem of geometry and equilibrium, under the assumption of infinite compressive strength. Collapse, therefore, is not attributed to material failure, but to the appearance of a sufficient number of hinges that convert the structure into a mechanism. In arches, such mechanisms—already discussed by eighteenth-century authors (Mascheroni, 1785; Rondelet, 1834; Serlio, 1600) —arise when the thrust line approaches the

edge of a voussoir, creating tensile stresses beyond the capacity of the joint and initiating cracks. This cracking is characteristic of the structural response to small displacements of supports, which alter the geometry of the pressure line and the resulting horizontal thrust (Angelillo, 2019; Como, 2013).

Historic masonry buildings frequently combine distinct structural elements and materials, such as stone, timber, and, in later additions, steel or reinforced concrete (Cennamo et al., 2025a; Di Gennaro et al., 2025). Considerable attention has been given to the mechanical behaviour of non-tensile masonry and to the beneficial effects of integrating timber members into such systems (Cennamo et al., 2025b; Frunzio et al., 2019, 2022; Massaro et al., 2024).

Equilibrium-based interpretations in heritage masonry: some examples

The evaluation of masonry structures can often be addressed without recourse to elastic theory, relying instead on the principles of geometry and equilibrium. This emerges clearly when examining both elementary and complex examples of historical construction.

In the case of masonry arches, the response to horizontal actions is largely governed by the position of the thrust line within the section. A parametric investigation into arches with localised intradosal damage has shown that even minor geometric reductions, when located in critical regions, can alter hinge formation patterns and substantially lower the collapse multiplier (Di Gennaro, 2025). Such behaviour can be fully interpreted through kinematic mechanisms, with failure occurring as soon as the thrust line approaches the intrados or extrados, independent of material elasticity.

This same logic is evident in large vaulted systems. The double-shell dome of the San Gennaro Chapel in Naples (Figure 1) provides a striking example: following the earthquake of 1688, the replacement of the original masonry lantern with a lightweight timber structure, connected through an intricate truss system between the shells, ensured that the pressure curve remained well within the masonry thickness (Cennamo et al., 2025a, 2025b). The resulting configuration exhibits stability even under seismic excitation, not through increased material resistance but by maintaining a geometry that prevents mechanism activation.

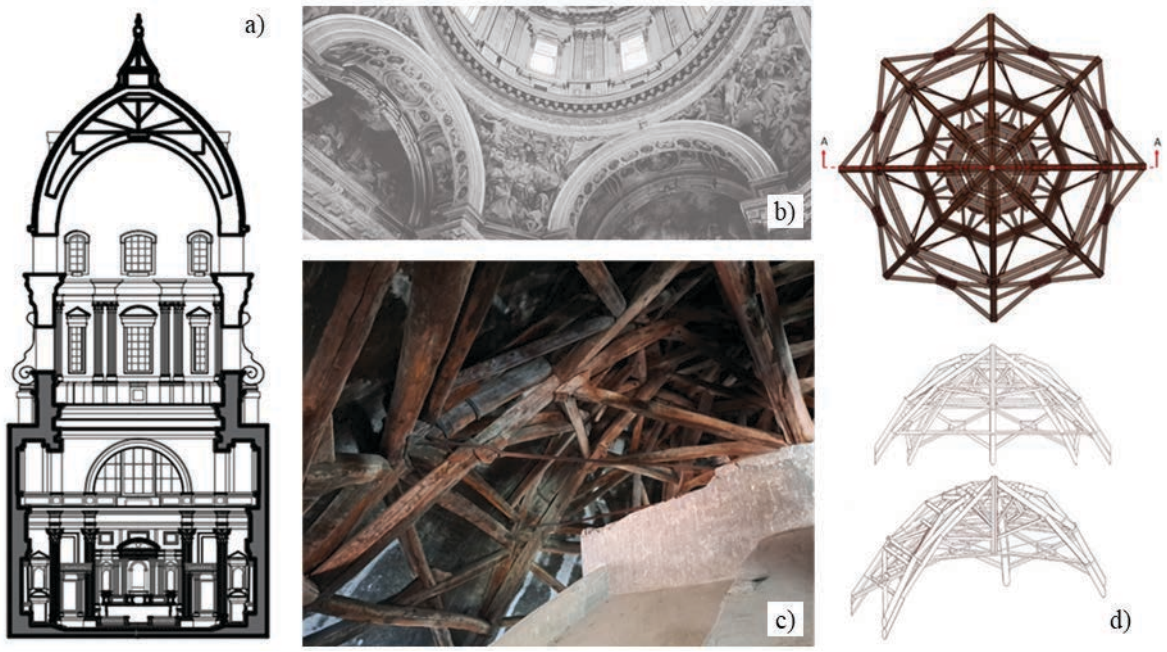

Figure 1. The dome of San Gennaro Chapel a) Vertical section of the Chapel; b) Internal view of the dome; c) The wooden truss; d) Graphical representation of the wooden truss

Similarly, the double-shell dome of Santa Maria alla Sanità (Figure 2) reveals how constructional choices affect stability. Historical documentation and geometric surveys identified four distinct building phases, each leaving a structural imprint. Limit analysis applied to the reconstructed stages demonstrated that variations in curvature, shell thickness, and internal connections modified the thrust distribution, in some cases bringing it dangerously close to the boundaries of the masonry (Cusano, Montanino, Cennamo, et al., 2021). The assessment, rooted entirely in geometric compatibility, clarified the role of these alterations without invoking material deformation.

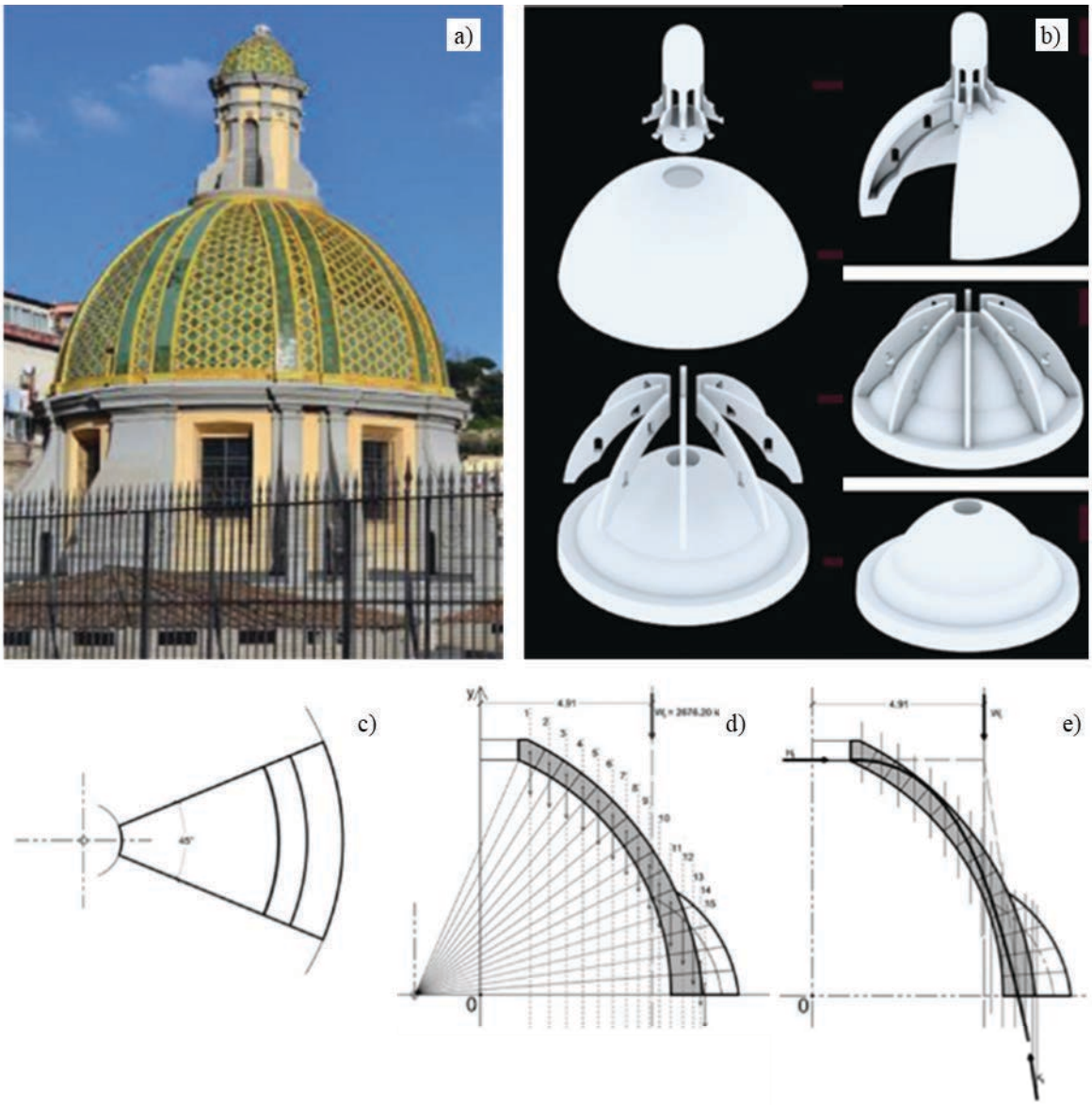

Figure 2. The dome of Santa Maria alla Sanità. a) External picture; b) Three-dimensional visualization of the structure of the dome; c) Plan view of Lune; d) Thrust-line analysis: computation of the total weight of the inner shell.; e) Thrust-line analysis: equilibrium analysis of the inner shell;

A further illustration comes from the neoclassical dome of San Francesco di Paola (Figure 3), where three distinct assessment techniques—Thrust Line Analysis, Modified Thrust Line Method, and Minimum Energy Approach—were compared (Cusano, Montanino, Olivieri, et al., 2021). While differing in formulation, all operate within the same non-elastic framework, and all identified the interplay between dome geometry and support conditions as the determining factor for stability.

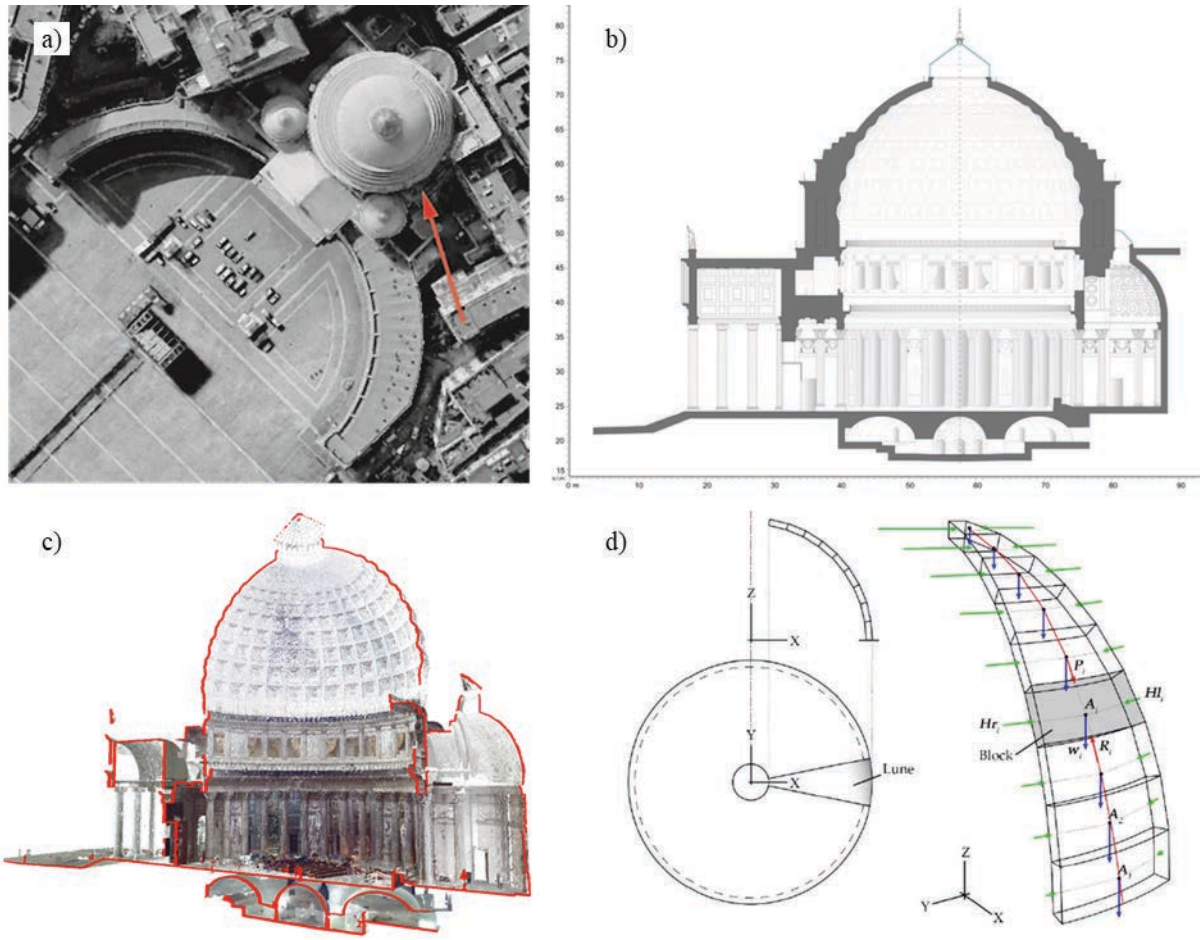

Figure 3. The dome of San Francesco di Paola. a) Aerial view; b) Section of the dome; c) Cloud of points of the inner space; d) elevation view of a lune divided into blocks.

Across these examples, from single-span arches to monumental domes, the decisive factors in structural safety emerge from the balance of form and load, demonstrating the enduring validity of approaches that view masonry as a material with no tensile capacity and infinite compressive strength.

Findings and Discussion

The comparative examination of the selected case studies highlights consistent patterns in the structural behaviour of masonry arches, vaults, and domes when analysed through methods that disregard elastic deformation and focus instead on geometry and equilibrium. Across different scales and typologies, the decisive parameter for safety was found to be the position of the thrust line relative to the masonry thickness, with instability triggered by its migration towards section boundaries.

In the case of arches, parametric analyses revealed that localised intradosal damage can significantly reduce the collapse multiplier, even when material integrity is otherwise preserved. This sensitivity underscores the geometric nature of stability loss, in which failure is associated with the formation of a sufficient number of hinges to create a mechanism, rather than the exhaustion of material strength.

For domes, both the San Gennaro Chapel and Santa Maria alla Sanità demonstrated how historical construction choices—including modifications to the lantern, the introduction of lightweight timber frameworks, or alterations in shell profile and thickness—directly influence thrust distribution. These effects were successfully captured by equilibrium-based assessments, which identified configurations in which the pressure curve remained fully contained, as well as situations where it approached critical boundaries. Notably, the timber framework in the San Gennaro dome exemplifies how historical interventions, conceived without recourse to modern theory, can achieve long-term stability by acting on geometry rather than material resistance.

The analysis of the San Francesco di Paola dome further confirmed that while different non-elastic assessment methods—Thrust Line Analysis (TLA), Modified Thrust Line Method (MTLM), and Minimum Energy Approach (MEA)—vary in their computational formulation, they converge in identifying geometry–support interaction as the dominant stability factor. This agreement reinforces the reliability of the equilibrium approach across multiple modelling strategies.

Overall, the findings suggest that for non-tensile masonry, the most effective path to accurate safety evaluation lies in approaches that reconcile historical construction logic with geometric compatibility. Such methods not only align with the intrinsic behaviour of the material but also offer a sustainable framework for heritage preservation, minimising the need for intrusive testing and allowing for assessments that respect the original fabric of the structure.

Conclusion

The analyses conducted on masonry arches, vaults, and domes confirm that structural safety in non-tensile masonry can be reliably assessed through approaches rooted in geometry and equilibrium, without recourse to elastic theory. The general principle emerging from the results is that stability is governed by the position of the thrust line within the masonry thickness and by the capacity of the structure to prevent its migration towards critical boundaries. This holds true across a range of typologies and scales, from single-span arches to monumental domes.

Some variations were observed in the predicted safety margins when different non-elastic analytical methods were applied—such as the Thrust Line Analysis (TLA), Modified Thrust Line Method (MTLM), and Minimum Energy Approach (MEA)—but these differences did not alter the fundamental conclusion that geometry–support interaction is the dominant factor in stability assessment.

The practical implication of these findings is that reliable evaluations of historical masonry structures can be achieved through non-invasive modelling techniques that respect the mechanical nature of the material and the original construction logic. This is particularly relevant in the conservation of heritage buildings, where intrusive investigations can compromise the integrity of the fabric and the authenticity of the work.

Sustainability, in this context, extends beyond the inherent eco-compatibility of masonry as a natural and locally sourced material. It also resides in a structural assessment approach that is non-invasive and respectful of the original design principles by which these constructions were erected centuries ago. When appropriately revisited and adapted, these historical construction rules can provide a sound basis for expanding conservation strategies for Italy's architectural heritage.

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DIGITAL MODELS AS A TOOL FOR SUSTAINABILITY IN MUSEUM SPACES

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Digital Models as a Tool for Sustainability in Museum Spaces

Abstract: The paper illustrates the results achieved on the theme of accessibility, inaccessibility and hyper-accessibility, aimed at promoting critical awareness of places and greater use of structures. The aim of the research is to enable visits to spaces that are currently closed, while ensuring the building's sustainability and accessibility for different categories of visitors. The case study is the National Palace of Mafra in Portugal, where research has produced a series of graphic visualisations for the enjoyment of inaccessible places through the creation of virtual images that illustrate the beauty of the palace. The issue of inaccessibility, due to the artistic value of some rooms and the military restrictions on part of the building, contrasts with the flow of tourists who crowd the paths dedicated to them throughout the year, becoming incompatible both for the sustainability of the building and for the impossibility of visiting the interstitial spaces between the various parts of the palace. This contribution aimed to outline the path of knowledge through the use of 3D technologies for the understanding, documentation and enjoyment of inaccessible spaces.

Keywords: 3D model, museum, Portugal, fruition on site, accessibility

Introduction

The work, part of a broader study on European museum structures, illustrates the results achieved on the theme of accessibility, inaccessibility and hyper-accessibility, aimed at promoting critical awareness of places and greater use of structures.

Issues related to inaccessible or unusable spaces are addressed in numerous writings by international authors, who define inaccessibility and fruition in parallel terms, where the first represents the impossibility of walking on a space, while the second refers to the failure to carry out certain activities in spaces built and intended to perform specific functions. The case study is the National Palace of Mafra in Portugal, where research has produced a series of graphic visualisations for the enjoyment of inaccessible places through the creation of virtual images that illustrate the beauty of the palace.

The issue of inaccessibility, due to the artistic value of some rooms and the military restrictions on part of the building, contrasts with the flow of tourists who crowd the paths dedicated to them throughout the year, becoming incompatible both for the sustainability of the building and for the impossibility of visiting the interstitial spaces between the various parts of the palace. In this context, two-dimensional and three-dimensional surveying and graphic documentation activities were carried out on the Mafra site, preceded by a preliminary bibliographic and iconographic survey of the site.

As is well known, King João V (Da Gama, 1985), without an heir after three years of marriage, made a solemn vow to build a monastery in the town of Mafra if his wife, Maria Anna of Austria, gave him descendants. At the end of that same year, Maria Anna of Austria gave birth to Maria Barba, the future sovereign, and six years later, on 17 November 1717, in the

presence of the Patriarch of Lisbon and the Royal Court, the first stone was solemnly laid. (De Oliveira, 2015)

The origin of the monument is linked to a vow made by King João V “the Magnificent” in 1711, after a meeting with Friar António de S. José, a member of the Franciscan Order of Santa Maria de Arrábida. On 22 October 1730, at the king’s request and on his 41st birthday, the Basilica and Convent were consecrated, although the dome and sacristy were still incomplete. The Monastery was officially considered complete in 1750, the year of the King's death, although work on individual elements continued under his successors. (Da Gama, 1985)

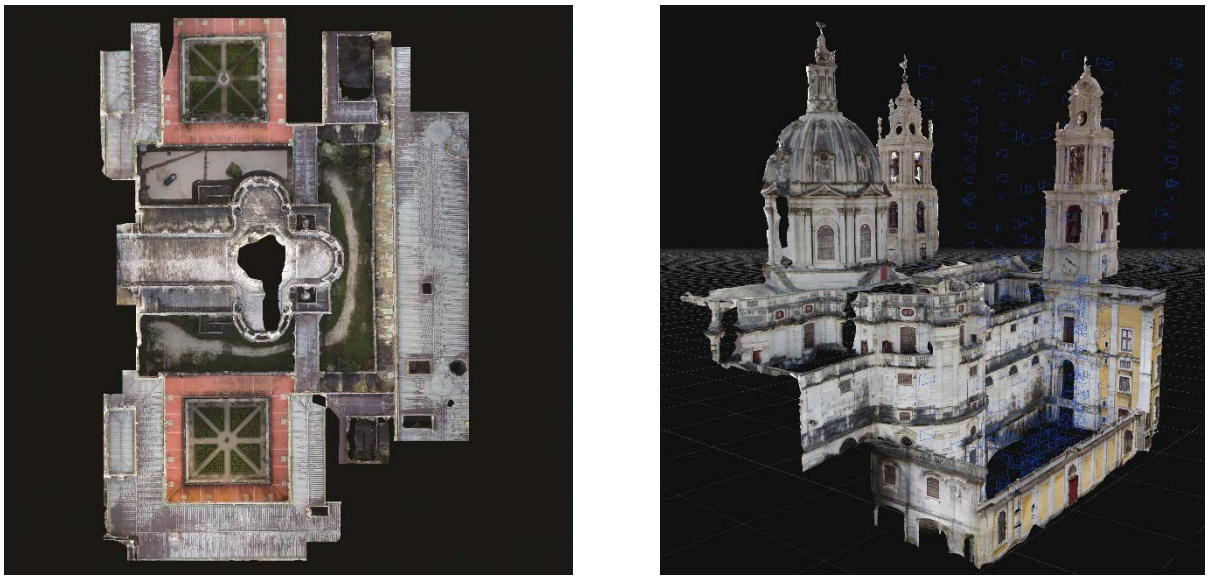

Figure 1. Point cloud of the National Palace of Mafra in Portugal. Detail of the courtyards and the Basilica.

Literature Review

The theme of sustainability in places has been addressed on numerous occasions, particularly in the field of architectural drawing, especially in relation to the use and management of museum spaces. (Càndito, Meloni, 2022)

As part of the ongoing study, the contribution addresses the inaccessibility of spaces in the National Palace of Mafra in Portugal, with a focus on open spaces, a series of courtyards and gardens that are located between the various parts of the Palace and can only be viewed by tourists and curious visitors from the windows of the building. (Corniello, 2021)

The relationship with technologies that can partially or totally solve the problem is addressed in interdisciplinary writings illustrating methods and tools for the preservation of architecture and landscape. This is where the architectural model comes in, and in particular

the survey model understood as three-dimensional geometric data applied to existing architecture.

The theme of the built heritage model, in fact, allows for the initiation of 3D investigation and experimentation processes on which to analyse the current state of affairs and propose interventions for the use of the site in person and remotely. (Salerno, 2017) The survey model constitutes a valuable database to be divided into categories that can be analysed individually but, at the same time, the unity of the building is represented in extreme detail. The process of creating the survey model is closely linked to previous fieldwork carried out using the tools of the discipline of Drawing, with in-depth investigations and documentation of the architecture and natural contexts.

Graphic reconstruction and methodologies

Analysis of the building survey and bibliographic and iconographic sources shows that the original project was a monastery for thirteen friars, which was later extended, first to forty, then to eighty and finally to three hundred friars, including the Royal Palace and the Basilica. The project was further expanded and re-proposed following the historical-critical architectural lines of the time.

The sources consulted indicate a direct correspondence with Rome and the project idea guided by the Marquis of Fontes, in collaboration with architects Carlo Gimac, Carlo Fontana, Tommaso Mattei, Filippo Juvarra and Antonio Canevari. The drafting of the final design and supervision of the works was entrusted to Johann Friedrich Ludwig, a goldsmith and architect of German origin who worked in Rome for a few years and, having been noticed by the Jesuits, was invited to Lisbon as official goldsmith, then chosen by the King for the work on the Monastery. (De Oliveira, 2015)

The construction diaries reveal a rich collaboration between Italian and Spanish architects involved in the massive construction, as well as several important historical figures of the time: Carlo Batista Garvo from Milan and his son Antonio, who were responsible for the masonry work; Tadeu Luís from Italy, who was in charge of the carpentry work; Dr Leandro de Melo, the chief prosecutor of Torres Vedras, who supervised the workers; and António Soares de Farias, who was the treasurer.

The palace, with its imposing and spacious appearance, was a royal residence; it was a destination during the summer months for members of the royal family who enjoyed hunting in the nearby Tapada Nacional de Mafra reserve. (De Oliveira, 2015)

Inside the palace, the king established several schools: the country's first school of fine arts and the second school of design, as he wanted to have experts in architecture in his kingdom. As is well known, in 1753, the school of sculpture was founded, directed by Alessandro Giusti, to address the lack of teaching of this art form in Portugal. (De Oliveira, 2015) Currently, the palace serves various religious, museum and representative functions, and some rooms are managed by the military, meaning that they are not accessible or usable. The structure has therefore always been a theatrical machine, in addition to its representative function at the service of the royal family and the entire city of Mafra.

The building consists of two large contiguous rectangular structures of different sizes, one located to the east, which includes most of the convent and the ancient palace of the infants, and one to the west, which includes the Royal Palace and the Basilica of Our Lady and Saint Anthony. The imposing façade, developed on three levels, is 232 metres long and faces west, towards the city of Mafra. At the ends of the palace stand massive square towers, developed on three main orders, surmounted by two others and a large bulbous dome, a geometric shape typical of Central Europe.

The Basilica is located in the centre and forms the axis of symmetry of the project. It is flanked by the King's Palace to the north and the Queen's Palace to the south. It is developed on two orders, marked respectively by Ionic columns for the first level and composite columns for the second, between which three openings and two niches alternate, each containing a marble statue. The central balcony for blessings is inspired by the structure in St. Peter's Basilica in Rome, although it was conceived as a manifestation of the sovereign's power and not for religious purposes. The façade is surmounted by a triangular tympanum, in the centre of which stands a huge medallion by the sculptor Carlo Monaldi, depicting in bas-relief the patron saints of the monastery: the Madonna and Child and St. Anthony in adoration. The two bell towers adjacent to the Basilica are reminiscent of those of the Church of Sant'Agnese in Agone in Rome, drawn by Borromini.

The Royal Palace, as the sovereign's minor residence, comprised the west façade of the complex, the two towers and the third floor of the north, south and east façades. The royal apartments are located in the two side towers: the north tower was generally used by the King, while the south tower was used by the Queen. The other floors were used for numerous rooms for servants, services and spaces for culture and the bourgeois population. The palace was closely linked to the city centre and was a meeting place and cultural hub for the local population. Four phases were identified in the planning of the survey: photographic, drone and

photogrammetric surveys with the creation of point clouds and data processing using Agisoft Metashape software. (Apollonio, Remondino, 2010)

This project took into account the actual dimensions of the building and the possible impediments arising from the use of drones or digital cameras. Triangulation in relation to the spaces required greater attention, as it was necessary to ensure that the images overlapped and were correctly aligned during the survey phase. Initial photographic images were taken, on which vertical and horizontal paths were traced to plan the drone's flight and avoid shadow areas in the representation.

The characterisation of the footage allowed for the definition of certain image filtering procedures in order to determine the greatest noise reduction (Apollonio, Remondino, 2010) and maintain the geometric configuration, given the large size of the space to be surveyed.

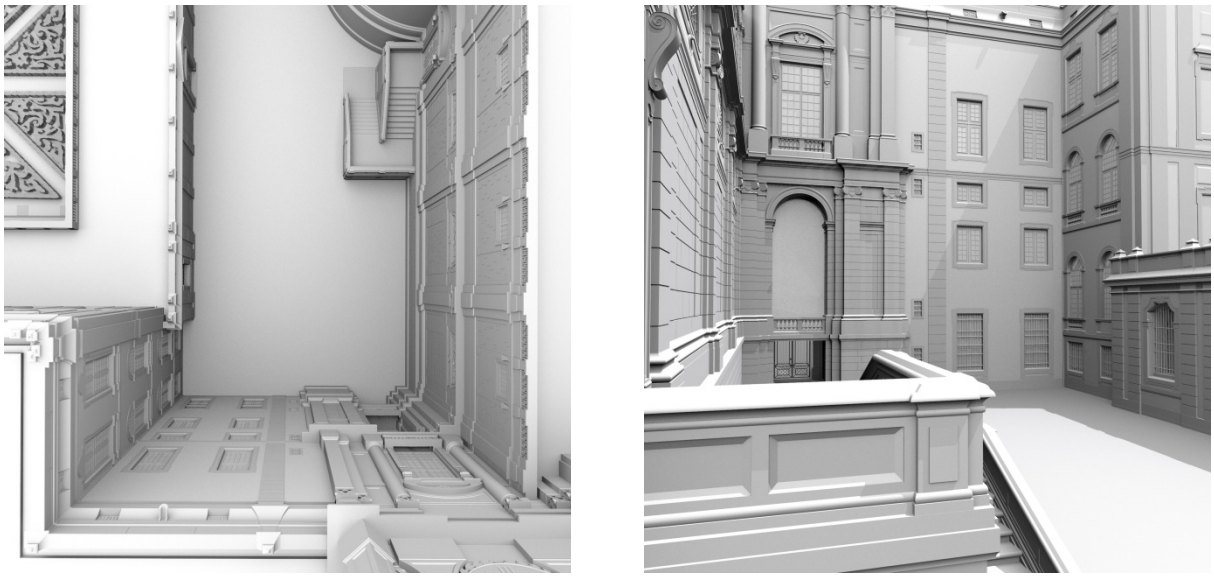

Figure 2. 3D model of the National Palace of Mafra. Detail of the Basilica courtyard.

The images collected by both the drone and the digital camera were merged into a single image with polygonal characteristics (Apollonio, Remondino, 2010). This activity led to the creation of a merged image of the point cloud.

The merge was used to obtain two-dimensional surveys and a 3D model for the digital visualisation of the interior of the palace. (Gioioso, Corniello, 2024)

The survey also constituted the preliminary phase for the study of the monumental structure of the National Palace of Mafra, outlining differences and similarities with contemporary European examples, both in terms of size and shape and in terms of purpose and construction period, such as the Escorial building in Madrid. (Chías, 2020)

The survey activities mainly concerned the Pátio do Rei, the Claustro da Basilíca, the Pátio da Raínha and the Claustro do Exército. Several photographic surveys were carried out and subsequently, using a DJI four-wheel drone, images were taken for the Agisoft Metashape photogrammetric software.Flight plans were prepared for individual internal facades and planimetric views, following an 80% overlap of the images. Flight plans were prepared for individual internal facades and planimetric views, following an 80% image overlap. In addition to the traditional plans and sections produced on a scale of 1:100 and 1:500, the results produced included the creation of a 3D survey model.

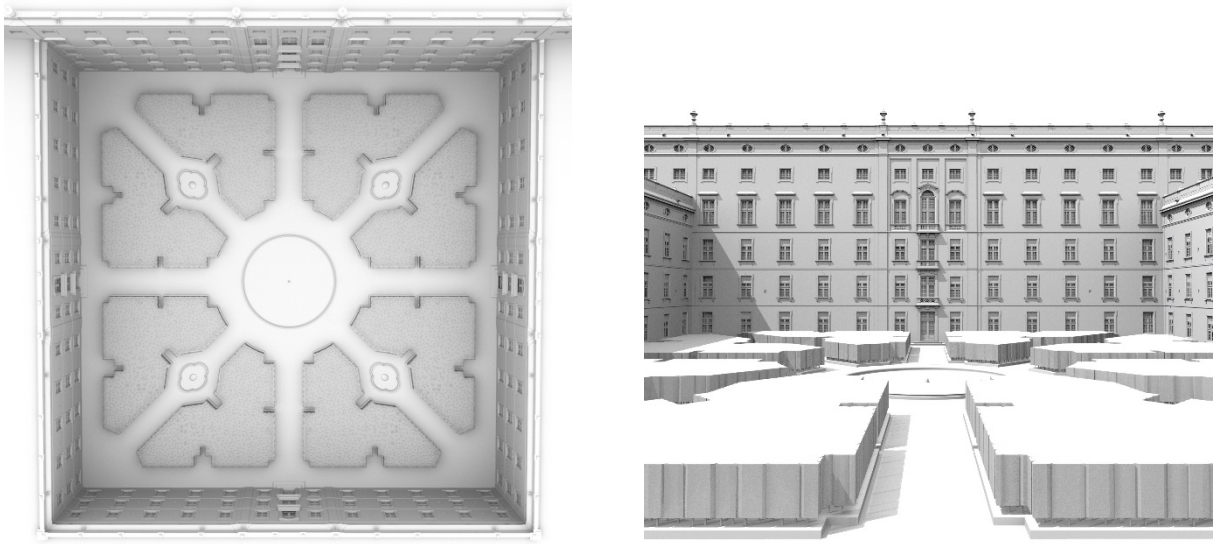

Figure 3. 3D model of the National Palace of Mafra. Detail of the military courtyard.

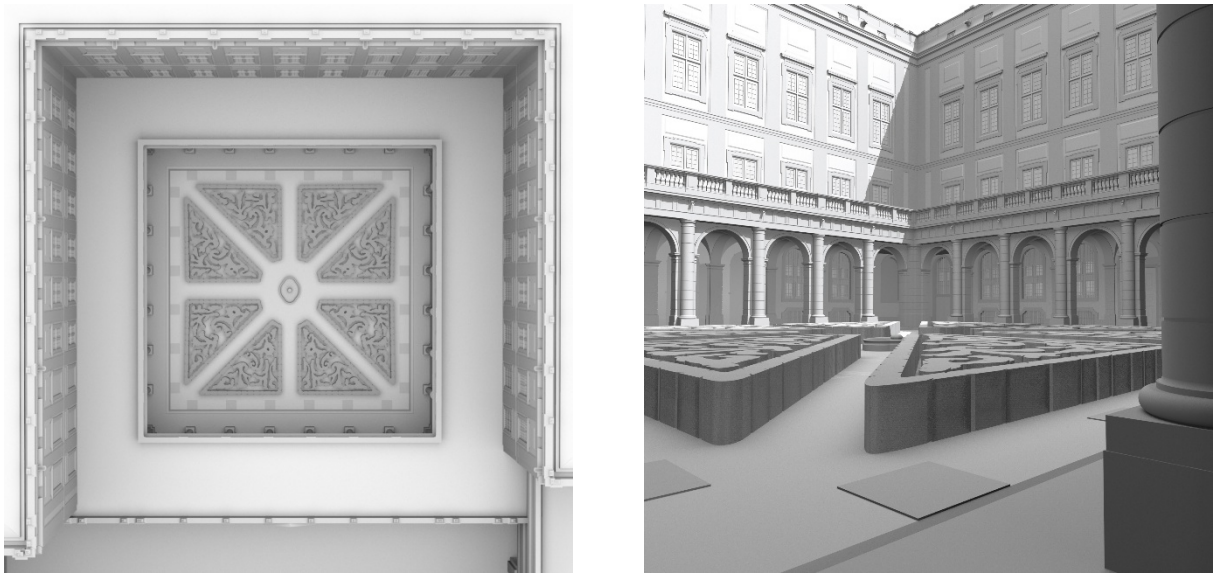

Figure 4. 3D model of the National Palace of Mafra. Detail of the nord courtyard.

3D modelling for sustainable spaces

The 3D survey model of the National Palace of Mafra was created with a dual purpose: to monitor the built space and to enable digital access to inaccessible areas. As is well known, the model represents a three-dimensional construction that reproduces a building (AA.VV., 2011) or a natural or built landscape. This graphic activity has often been associated with new constructions, an act of representing something that does not exist, in order to provide a guide to illustrate the future, and little with the possibility of documenting the current state of affairs, which is relegated to traditional plans, sections and elevations.

The digital model does not entirely replace a visit to the monument, but it allows fragile or disabled individuals to experience spaces that are inaccessible or unreachable for various reasons. From the steep stairs leading to the roof terraces to the paths in the attics, from the library to the archive, these are places dedicated to the preservation of a unique tangible and intangible heritage, which for centuries has represented a cultural treasure to be protected and safeguarded and is now illustrated through a series of three-dimensional images that define the architecture as a connecting element between the city and its suburbs.

The 3D model tool allows direct control of space that is not always recognisable in projective operations; it implies highly complex theoretical skills that are not limited to the use of software but above all to the spatial representation of the building. (Corniello, 2020)

It constitutes an illusory representation of the building, but through the knowledge of surveying, it preserves the numerical indications of measurement, shape and geometry. This image, often lacking in material consistency, blurs the boundary between the evocation of reality and authentic reality, merging the concepts of drawing, vision, reality and figuration. (De Rubertis, 1994)

The relationship between survey drawing and survey model intersects in a direct relationship between the simulation of the visual condition and restores movement to the building, giving a space-time dimension to the reality represented. (AA.VV., 2011)

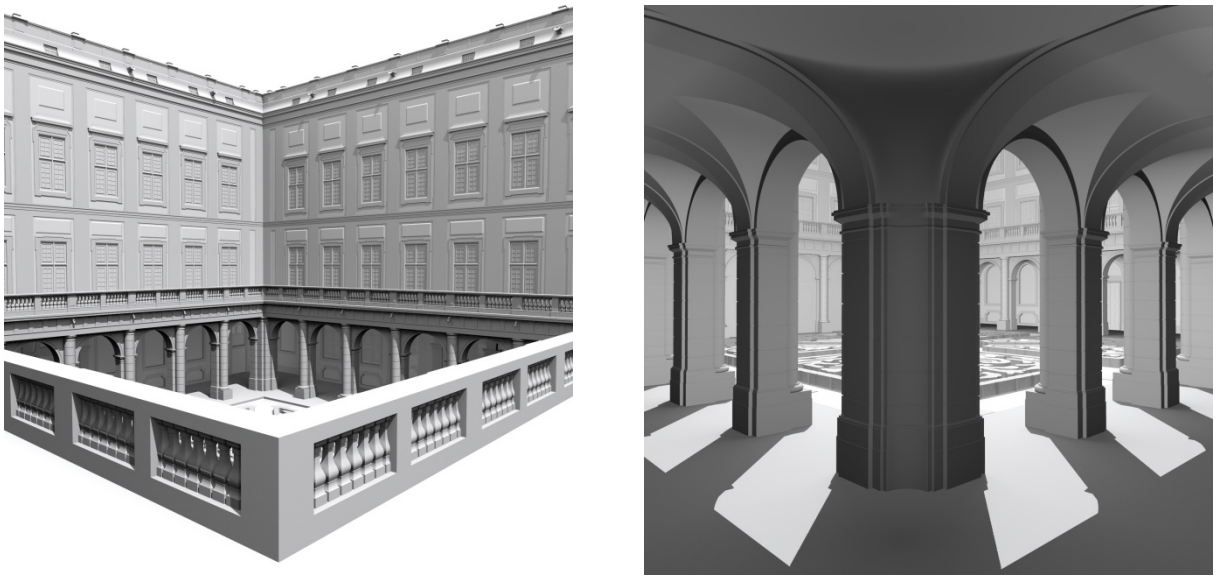

Figure 5. 3D model of the National Palace of Mafra. Detail of the sud courtyard.

This theoretical assumption forms the basis for the graphic production of the relief model of the National Palace of Mafra, where the digital spatial creations reveal the clarity of the spaces, their symmetry, the rhythm of the round arches and the geometry of the shrubs and hedges.
The 3D process required theoretical reasoning during the export of the survey data, the point cloud, to the Rhinoceros 3D software, (Gioioso, Corniello, 2024) to the quantity of points surveyed and the considerable level of detail. We proceeded with a reduction of the numerical data relating to the detailed information and the simplification of the shapes into “family groups” belonging to the same construction type and with similar shapes and geometries. This simplification allowed the data to be managed on common hardware without having to divide the complete model into several parts.
The result, reliable in terms of spatial geometry and the configurations of the vaults and arches, fulfils the stated purpose of illustrating the building to a wide audience and transferring information about inaccessible areas of the Palace.

Conclusion

This contribution aimed to outline the path of knowledge through the use of 3D technologies for the understanding, documentation and enjoyment of inaccessible spaces.
The activities carried out aim at the 3D representation of spaces that are currently closed to the public for sustainable use through digital technologies. As is well known, virtual use (Bevilacqua, Williams, 2018) is a tool for reducing the problem of inaccessibility through paths of knowledge of the asset, ensuring the sustainability of the building. In addition to constituting

a knowledge database, 3D models are the invisible and discreet eye of the user of the inaccessible space.

The case study is a powerful example of the stratification of functions, both for the original structure and for the museum function subsequently assigned to the building.

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OPTIMIZING ACOUSTIC PERFORMANCE OF A SEMINAR ROOM IN A CULTURAL HERITAGE BUILDING

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Optimizing Acoustic Performance of a Seminar Room in a Cultural Heritage Building

Abstract: Acoustics in heritage building context have significant influence in preserving the structure as well as perceiving the historic atmosphere. This study examines Ahmet Piriştina City Archive and Museum's seminar room and its acoustic performance. In this research, acoustic simulation is demonstrated and evaluated to validate on-site sound (dB(A)) measurements, with the aim of assessing their accuracy. Therefore, acoustic modelling was performed using Pachyderm Acoustic plug-in, which is integrated within Rhino and Grasshopper. The seminar room geometry was modelled based on architectural drawings, and materials were assigned to match the existing conditions inside. Simulations were conducted using a geodesic sound source and stationary receiver to reveal the sound distribution within the space and calculate the reverberation time (RT60), clarity (C80) and sound pressure level (SPL). This research investigates the value of acoustic simulation tools in a heritage building, providing non-destructive methods to analyse and enhance acoustic environments while respecting its architectural design.

Keywords: acoustic simulation, optimization, heritage buildings

Introduction

Heritage buildings are significant structures for cultural memory of cities, and it is crucial to preserve them. Among multiple aspects of heritage conservation, acoustic surroundings play a large role (Mu et al., 2022). For this reason, the acoustic modelling of heritage buildings has gained importance, as acoustics contribute to maintaining the experience of historic spaces (Millán et al., 2024). However, when focusing on preserving a heritage building, acoustics particularly may be neglected due to providing indoor comfort or design decisions (Carvalho et al., 2013). Acoustic measurements and digital simulations help preserve and recreate the original sound of historic spaces (Katz et al., 2020). Thereby, investigating acoustics in heritage structures involves multiple disciplines, including acoustics, music, history, and archaeology, with initial sound assessments providing a basis for deeper interdisciplinary research. Accordingly, this study aims to evaluate the existing acoustic performance in a heritage building room, which is the seminar room of Ahmet Piriştina City Archive and Museum (APIKAM), through real-world data and acoustic simulations for validation. Furthermore, the study explores strategies of enhancing acoustic performance and determines the influence of material interventions. By analysing reverberation time (RT60), speech clarity (C50), and sound pressure level (SPL), this research aims to demonstrate how simulation tools can evaluate and improve acoustics in heritage buildings while respecting historic identity.

Literature Review

The Role of Acoustic Performance Concepts

Architectural design of space is highly important for good acoustic environments and preventing excessive noise. Particularly in heritage buildings, the acoustics require more attention and, to understand the acoustic performance of heritage spaces, it is essential to first define several key acoustic concepts. These include parameters such as reverberation time (RT60), clarity (C50 and C80), and speech transmission index (STI). These parameters are commonly used for evaluating and determining the sound behaviour within enclosed environments, since they facilitate quantifying how the sound scatters, how it reflects, and decays in space. The most important way to measure the acoustic quality of a space depends on its reverberation time which varies with its materials, shape, and use (Katz et al., 2020). Other important measures are clarity (C50 and C80), how well speech can be understood (STI), and how even the sound distributes throughout space (Mu et al., 2022). Many studies analyse the acoustics of historic buildings through these parameters. For example, Karabiber (1999) examined historic mosques in Istanbul to indicate problems that is related to long reverberation time and insufficient speech clarity, during sermons and prayers inside. Carvalho et al. (2013) studied museums by analysing parameters like reverberation time (RT60), STI or RASTI, HVAC sound levels, and the background noise of visitors to support new guidelines in the context.

Application of Acoustic Simulation in Heritage Contexts

In accordance with the increased use of digital methods in heritage conservation, acoustic simulations facilitate evaluating sound quality without interfering with the original structure. These digital approaches are especially important in historic environments where the preservation of architectural identity is critical, since acoustics highly influence the function of space and its cultural value. There are studies in Europe that use various methods to explore the acoustic heritage of ancient theatres, churches, and historic sites, for understanding the connection of cultural history (Katz et al., 2020). Such as, Berardi et al. (2015) utilized the Odeon software for acoustic simulations, proposing temporary acoustic treatments that reduced the Palatine Chapel's long reverberation time to acceptable levels while preserving its historical value. Another study carried out simulations with Odeon software to compare the acoustics of Hagia Sophia as a church, mosque, and museum, showing how design adjustments affected acoustics over time (Weitze et al., 2002). It is clear that, acoustic quality is necessary for spaces

like churches, temples, and museums, to support their intended function (Mu et al., 2022). For example, Álvarez-Morales et al. (2020) examined York Minster cathedral's Chapter House, acoustic behaviour through calculations and simulations, to discover high reverberant acoustic environments, and its impact in religious meetings or events. In this context, acoustic simulations serve as both a valuable preservation and interpretation tool, allowing architects to experiment with acoustic solutions that enhance quality of the sound, without permanently affecting the structure.

Methods

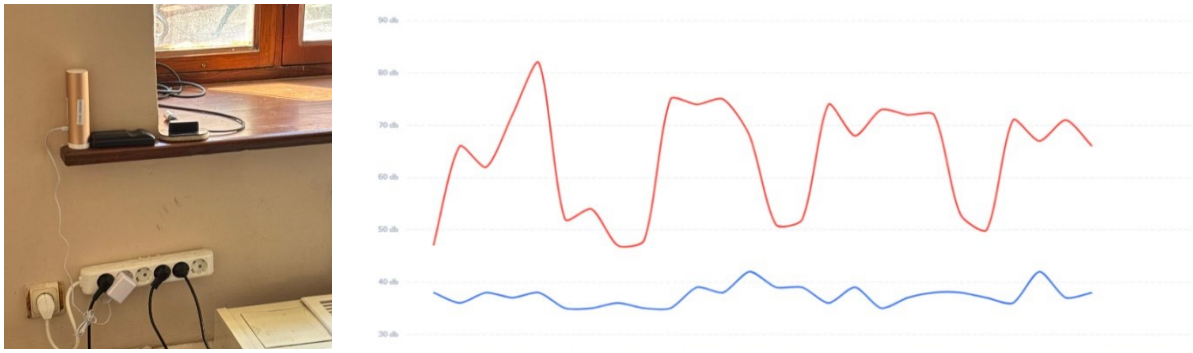
Tool Selection for Acoustic Simulation

There are several acoustic simulation tools available with different strengths and limitations. For instance, Odeon, Ease, and CATT are free standing programs, while Pachyderm and Acoustic Shoot operate as plug-ins for Rhino/Grasshopper, enabling parametric workflows suited to architectural modeling (Hanula, Kornfeld, & Ohtake, n.d.). In this study, Pachyderm (Version 2.6.0.15) was selected as the simulation tool, due to its easy integration within Rhino and Grasshopper, providing an adaptable design environment. Therefore, the combined use of Pachyderm and Grasshopper facilitates the dynamic simulation process and offers advantages in conducting acoustic analyses.

Room Acoustics Measurement Phase

For the purpose of this study, which is to evaluate the acoustic performance of the Ahmet Piriştina City Archive and Museum's seminar room, a two-phase methodology was adopted. The first phase involved room measurements in real-world, by understanding the material properties as well as the room dimensions through site visits and architectural drawings. On-site, room acoustic measurements were obtained using a smart indoor air quality monitor, which is a permanent device in the seminar room, and it continuously records sound pressure levels and other environmental parameters (Fig.1a). The purpose of these measurements was to collect data for validation against the acoustic simulation and gain insights into the room's acoustic conditions. Collected data were accessed from both the website of the smart device and its smartphone application, which provided daily minimum and maximum dB(A) values. The recorded values from the device represent the daily noise levels throughout June 2025. Peak values around 83 dB(A) reflect times during high activity or events, whereas the lower values near 33 dB(A) represent quiet periods or nighttime levels

when the room remains unoccupied (Fig. 1b). This long-term data provides an understanding of seminar room's existing acoustic environment, supporting the implementation of interventions with additional acoustic treatments. Accordingly, these measurements were integrated into the simulation tool, using actual spatial features and sound source properties to allow a reliable comparison of acoustic behavior.



(a) (b)

Fig. 1. (a) Smart indoor air quality monitor device in the seminar room. (b) Daily maximum and minimum noise levels dB(A) recorded by the device during June 2025.

Acoustic Modeling and Simulation Phase

Next, an acoustic simulation phase was performed to assess sound movement, its spatial distribution, and to validate the tool's accuracy against the device-measured data. The acoustic simulation of the Ahmet Piriştina City Archive and Museum's seminar room was conducted using Pachyderm Acoustic and Grasshopper plug-ins within the Rhino software. Firstly, a simplified 3D model of the interior space was modeled in Rhino with the collected data from architectural drawings, and unnecessary details that would not significantly affect sound behavior were avoided. The 3D model included walls, floors, ceiling, doors and windows.

In the acoustic simulation phase in Grasshopper, 3D geometry materials were imported as "Brep'' elements and connected to the Pachyderm "Polygon Scene" component to define the seminar room as a reference for simulation environment. Material property settings were applied to simulate sound interactions with surfaces. A sound source was assigned as "point'' using the "Geodesic Source'' component. The "Visualize Pachyderm Rays" component was then used to simulate ray tracks, demonstrating how sound bounces and travels in space. Results were visualized with a color gradient and vector display, to illustrate sound levels and direction. Initial, high-energy sounds appeared in red, then shifted to blue as the energy

decreased, visually representing the reduction in intensity over distance and time. After simulating the behavior of the points inside the room, in order to conduct calculations on them, another Grasshopper data was formed. Two points were assigned, one for the "Geodesic Source" which is the start of the sound, representing the presenter, and the other one being "Stationary receiver" of the sound, as the listener in the room. Three simulations were assigned to energy time curve for assessing the data of reverberation time (RT60), clarity (C80) and sound pressure level (SPL). Following the findings of existing conditions, to enhance the acoustic performance of the room, acoustic PET felt-based panels (50 x 50 x 6 cm) were installed on the ceiling with a non-invasive, demountable system in three cases. First, few panels were applied, then the numbers gradually increased, and finally panels fully covered the ceiling surface. This application aimed to examine the changes in the simulation outputs while lowering the reverberation time through the effective sound absorption properties of the panels.

Case Study

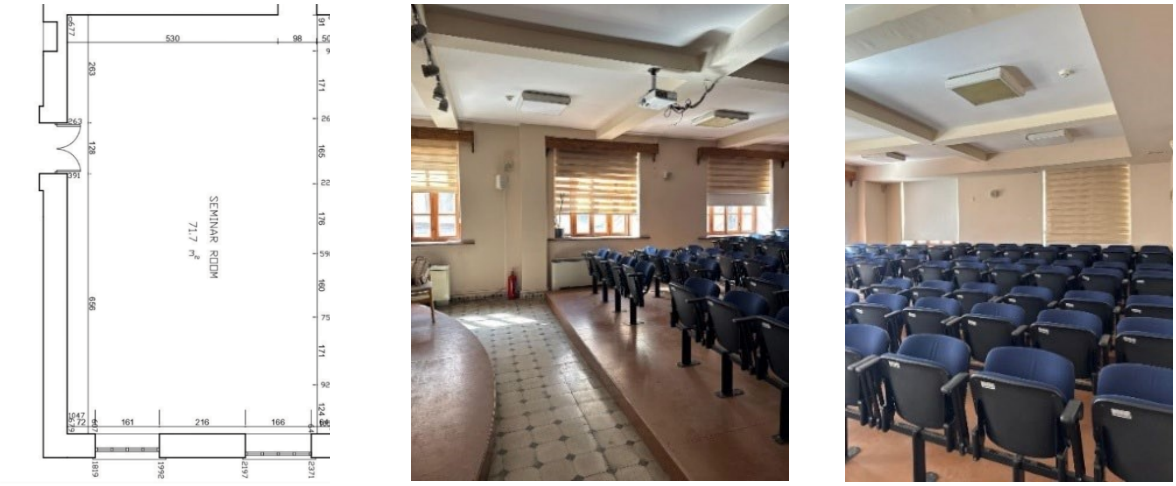
Context and Background of APIKAM

In this research, Ahmet Piriştina City Archive and Museum (APIKAM) was chosen as a case study. It was designed by the architect Mesut Özok, and it is in Izmir, Turkey. Originally built in 1932 as a fire station, it later restored and officially opened in 2004 as Turkey's first city archive and museum (APIKAM, n.d.). The building hosts exhibitions, events, educational programs across its three floors that include offices, exhibition halls, seminar room, archives, library, and a cafe. APIKAM connects past and present by providing digital access to documents of Izmir's history. Thereby, it plays a significant role in the city as a heritage building that preserves and reflects Izmir's cultural identity.

Description of the Seminar Room

The spatial configuration of Ahmet Piriştina City Archive and Museum (APIKAM) includes diverse functions but in this study, the seminar room on the ground floor of the building was selected, due to its regular, well-defined geometry, enclosed volume, and acoustic relevance. The seminar room serves as a space for lectures, discussions, educational presentations, and various events. The room features a 71.7m^2 rectangular layout with dimensions of 10.58 meters in length, 6.78 meters in width and 3.15 meters in height (Fig. 2). The interior materials contain plaster walls, plaster ceiling and natural stone tile flooring with elevated wood platform in the seating and presentation areas. The doors and window frames

are also wood, contributing to the room's sound absorption. Due to the heritage and historical status of the building, invasive testing and retrofit interventions are restricted, making digital acoustic simulation an ideal tool for evaluating the room's acoustic performance in a nondestructive manner. Thus, this research aims to validate and improve the measured field data from APIKAM seminar room through the acoustic simulation environment.



(b)

Fig. 2. (a) Plan of the seminar room, (b) Interior of the seminar room.

Results

Visualization of Simulated Sound Behavior

The acoustic simulation of the seminar room in Ahmet Piriştina City Archive and Museum, conducted using Pachyderm Acoustic plug-in with Grasshopper, produced a set of visual outputs that offered interpretation of the sound intensity and its scattering. As the sound distributed across the surfaces of the room, its energy gradually decreased, resulting in a transition of color through orange, yellow, green, and finally blue. This gradient method demonstrated how the sound naturally behaves over distance and highlighted zones with potential acoustic weaknesses or insufficient coverage. Accordingly, it was analyzed that in back corners or near-window areas in the room, the sound energy dissipated rapidly. Additionally, the directional vector display illustrates the ray paths generating from the sound source in the assigned point, as the presenter. These rays showed how sound bounced and the directions it traveled between the surfaces, allowing observations of the reflection patterns, behaviors and their density. Areas where many sound rays overlapped revealed possible echoes or high reflections. In contrast, zones where the rays were widely spaced indicated greater sound absorption and diffusion. In this sense, the simulation provided the acoustic strengths

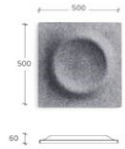
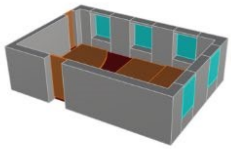
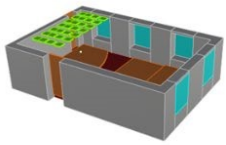
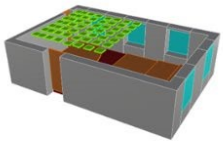
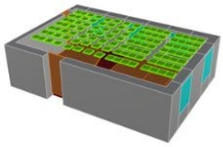
and limitations of the current room design and supported potential adjustments, such as material additions for more efficient sound absorption, repositioning sound sources or modifying the room geometry. Therefore, the visualized sound performance facilitated evaluating acoustic parameters and future design decisions in the seminar room.

Data Validation & Comparison

On-site acoustic measurements using the smart device provided continuous dB(A) values, capturing sound levels in the seminar room in daily, weekly, monthly and yearly periods. These measurements generated graphical data, indicating how acoustic performance was affected by the daily events, visitors and room occupancy. However, due to the features of Pachyderm Acoustic plug-in, which simulates visual and measured performance of the sound, based on the geometry and material properties, it is not relevant to compare hourly or daily sound data from the smart device. Therefore, instead, the measured data serves as a reference for the acoustic environment and noise levels within space, helping to understand the room conditions. This approach validated that the simulation reflects real settings, while recognizing the limitations of time-based field data with simulation results.

The findings for the acoustic parameters (RT60, C80, SPL) are summarized in Table 1. Simulation data from Pachyderm/Grasshopper for the seminar room's existing condition, before any panel installation, revealed reverberation time (RT60) as 0.74 s, clarity (C80) as 8.53 dB and sound pressure level (SPL) as 84.24 dB. In the first case with 28 PET felt-based panel installations ($7m^2$), RT60 did not differ significantly, resulting in around 0.74 s, due to the limited ceiling coverage, while C80 slightly increased to 8.84 dB and SPL reached 84.54 dB. In the second case, increasing the number to 56 panels ($14m^2$), indicated a more effective sound absorption, as RT60 dropped noticeably to 0.73 s, C80 decreased to 8.14 dB, and SPL reduced to 83.74 dB. In the third case with 112 panels ($28m^2$), the parameters changed modestly, RT60 remained around 0.73 s, C80 lowered to 8.03 dB, and SPL decreased to 83.68 dB, demonstrating that additional panels had little influence, since ceiling was already mostly covered. These results revealed that among the three cases, second case showed the most acoustic improvement across all acoustic parameters.

Table 1. Comparison of acoustic parameters for PET felt-based panel application cases. The bottom row shows a PET felt-based panel image and 3D model configuration for each case. Panel image retrieved August 26, 2025, from https://www.feltouch.tr/product/octopus/.

Acoustic Parameters	Existing Conditions	First Case	Second Case	Third Case
Reverberation Time (RT60)	0.74 s	0.74 s	0.73 s	0.73 s
Clarity (C80)	8.53 dB	8.84 dB	8.14 dB	8.03 dB
Sound Pressure Level (SPL)	84.24 dB	84.54 dB	83.74 dB	83.68 dB
 PET felt-based panel	 0 panel	 28 panels (7 m²)	 56 panels (14 m²)	 112 panels (28 m²)

Discussion & Conclusion

In this study, the acoustic performance of seminar room in Ahmet Piriştina City Archive and Museum was examined with a non-invasive, digital simulation method. The use of Pachyderm Acoustic plug-in enabled visualizations of sound behaviors, and calculations of acoustic parameters including reverberation time (RT60), clarity (C80) and sound pressure level (SPL). The visual outcomes highlighted acoustic strengths and weaknesses in the room to guide spatial solutions. The integration of PET felt-based panels, in three cases, contributed to slight reductions in reverberation time, clarity and sound pressure level. Within the 71.7m^2 seminar room, the area covered by panels gradually increased in ratios of x, 2x, and 4x (7m^2, 14m^2, 28m^2). The most effective acoustic performance was achieved in second case, with 56 panels covering a total surface area of 14 m^2, corresponding to approximately 20% of the ceiling. These findings demonstrated that even partial interventions with PET felt-based panels improved acoustic parameters. However, this study relied on simulation data thus, real-world conditions may not be fully explored. This study suggests that adjustable, non-invasive material interventions can change the acoustics of a heritage building room and it offers insights into practical modification methods. Future research should investigate alternative materials and configurations to achieve optimal acoustic performance in similar contexts.

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SYSTEMATIC ANALYSIS OF THE LIFE CYCLE ASSESSMENT METHOD IN RENOVATION WORKS

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Systematic Analysis of the Life Cycle Assessment Method in Renovation Works

Abstract: Currently, decarbonization studies are being carried out in different sectors in order to reduce global climate change and environmental problems caused by carbon emissions and to achieve the 2050 climate targets. One of these sectors is the construction sector, which comes to the fore more than other sectors due to its high resource consumption, energy demand and carbon emissions. In the existing construction sector, it is also an important requirement to carry out renovation works to ensure energy efficiency and reduce carbon emissions by minimizing the damage caused to the environment.
In renovation processes, determining renovation strategies by evaluating the entire life cycle of a building, including production, manufacturing, construction, operation, use, maintenance and end of life, is an important method used to reduce carbon emissions and energy use.
With this study, it is aimed to investigate the applications made using the life cycle evaluation method in the renovation works carried out for the purpose of decarbonization and zero energy in the buildings.

Keywords: life cycle assessment; renovation; decarbonization design

Introduction

Carbon emissions are increasing rapidly due to resource consumption and human activities worldwide. Increasing oscillations cause disruption of the natural balance, environmental problems such as climate change and global warming. In recent years, by combating these problems, different studies have been carried out to reduce carbon emissions and to use energy efficiently. The Paris Climate Agreement, which has formed a guiding framework in studies and has come to the forefront in the fight against environmental problems, has drawn attention to the importance of limiting the global temperature increase caused by human-caused emissions to below 2 °C degrees in the long term and to catch 1.5 °C degrees in the short term (Paris Agreement, 2016). In line with this agreement, many countries have developed different carbon policies to achieve carbon neutrality. One of the goals is to reduce emissions by 50% by 2030 in accordance with the European Green Memorandum of Understanding published by the European Union, and to make all buildings net zero carbon by 2050 (European Green Agreement, 2019). The construction sector has a serious proportion of energy consumption and carbon emissions in the world. For this reason, it is an important issue to carry out renovation works in many structures in order to meet the targets set on a global scale, ensure energy efficiency and reduce carbon emissions.

Today, renovation works have increased in many buildings due to the lack of sustainability, carbon and energy expected performances. Renovations applied in buildings, the wear rate of buildings during the use process, the building materials and systems used, the

external environment, etc. it varies according to different factors (Dahiya & Laishram , 2024). For this reason, renovation applications vary according to the region and technical characteristics of each structure. Buildings are used for raw material acquisition, construction, use, maintenance, repair, renovation, recycling, demolition, etc. they cause energy consumption and carbon emission in all their processes. For this reason, when renovation works are carried out, the life cycle evaluation of all processes, not through a single process, provides a systematic evaluation in the studies (Crawford, 2011).

Life Cycle Assessment has been defined by the International Standards Organization as a method of evaluating, analysing, collecting data, impact assessment and examining the environmental impacts of products in all life cycle processes (TS EN ISO 14044, 2006). Life cycle assessment in buildings is the evaluation of the carbon and energy consumed by each building material constituting the structure in all its processes from the raw material stage to the demolition stage (Anderson & Adams, 2020). Thus, by making a life cycle assessment in the renovation processes of structures, examining the effects of the materials and elements used on nature, it is possible to choose sustainable materials and products with low energy and low carbon emissions (Curran, 1996).

Methods

The methodology followed in this research is based on literature review and analysis of research and development studies, focusing on the life cycle assessment of renovation works carried out for decarbonization purposes in different buildings.

During the literature research, internationally published journals and articles were used. In order to focus on current resources, the studies carried out in the last ten years covering the years 2015 and 2025 were examined. Web of Science, Scopus, Science Direct, Google Schoolar, ResearchGate, DergiPark and ProQuest were used as databases. In the literature review, renovation, life cycle assessment, energy consumption, carbon emission, environmental impact, sustainability, energy efficiency, zero carbon and zero energy were used as keywords. Within the scope of the research, buildings were evaluated on all building types without being separated according to building types. The studies aiming at both decarbonization and energy efficiency from the studies in four different types of buildings, namely school, office, hotel and residential, are explained. the other studies are given in Table 1.

Life Cycle Assessment Method in the Renovation Processes of Buildings

In different types of buildings, energy saving, zero carbon, sustainability, etc. in the renovation works carried out for the purpose, improvements can be made to the existing system or the system can be completely changed (Zimmermann, Rasmussen, & Birgisdottir, 2023). The scope of the renovation, application details vary according to the type of buildings, construction techniques and current situation analyses. The studies included in the literature review emphasize the importance of life cycle assessment and energy saving and decarbonization strategies in improving building performance. However, applications aimed at reducing the energy use of a building can increase carbon emissions, although they provide energy efficiency. For this reason, the life cycle evaluation method is one of the most effective methods for evaluating renovation works in buildings and analysing the entire life and current situation during the implementation processes to select the application that provides the best performance.

In the study conducted by the International Energy Agency (IEA), the process of becoming zero carbon during the life cycle of a structure is classified in 4 sections. The scheme given in Figure 1 has been used as a basis in different studies.

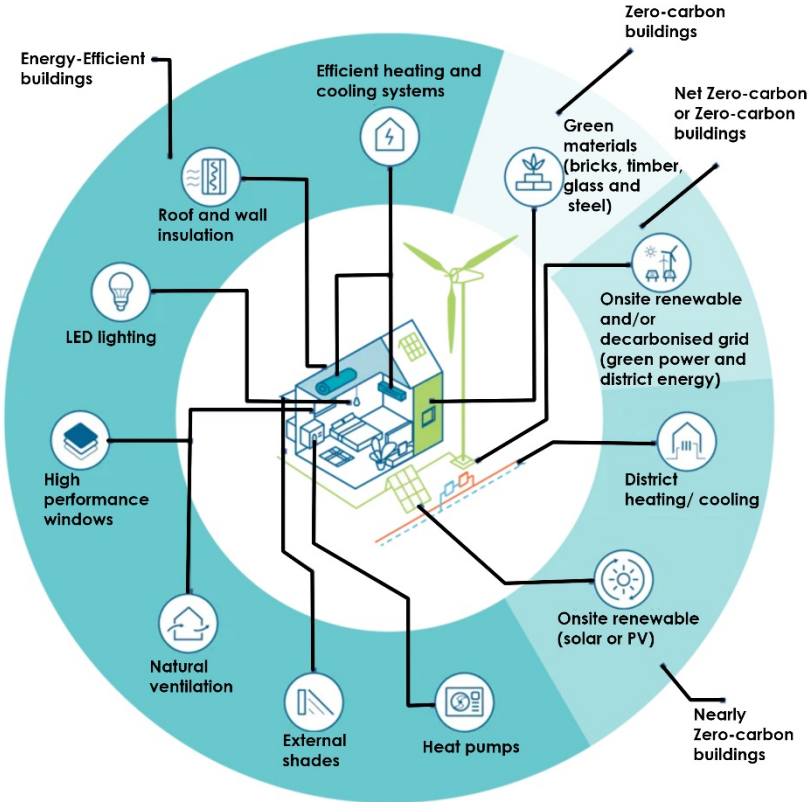

Figure 1. Different levels of zero-carbon buildings (IEA, 2021)

As shown in Figure 1, suggestions for heating, cooling, ventilation, lighting systems are included in order to ensure the energy efficiency of the structures at the first stage. In the second stage, it was stated that sustainable materials should be used to ensure zero carbon throughout the entire life cycle. Thirdly, it was stated that it is necessary to use renewable energy sources for almost zero-carbon buildings and to use district heating-cooling systems. Finally, it has been stated that renewable and decarbonized grid should be used for net zero carbon buildings. The accuracy of this zero-carbon attainment scheme has been confirmed by the methods used in different studies.

The methods used in the studies summarized above are summarized in Table 1.

Table 1. Literature Summary

Types	Writer - Year	Decarbonization	Energy-Saving	Retrofitting Strategies
School	(Li, Chen , & Yu, 2024)	x	x	Wind environment simulation and wall renovations
School	(Xu, and others, 2023)	x	x	Thermal comfort conditions and daylight renovations
School	(Bugenings, Schaffer, Larsen, & Zhang, 2022)		x	Changing windows, thermal insulation
School	(Djukanović, ve others, 2022)		x	HVAC system
School	(Österreicher, 2018)		x	Façade renovations
Office	(Zhang, ve others, 2024)	x	x	Green roof, HVAC system, PV panels
Office	(Aruta, Ascione, Bianco, Iovane, & Mauro, 2023)		x	Façade renovations
Office	(Wang, Yang, Hou, & Tao, 2022)	x	x	Integration of timber construction system, use old recycled concrete and PV panels
Office	(Nedhal, 2022)		x	Windows, thermal insulation, sun shading
Hotel	(Zimmermann, Rasmussen , & Birgisdottir, 2023)	x		Roof, walls, floor coverings, windows, balconies
Hotel	(Delac, Pavkovic, Lenic, & Maderic, 2022)	x	x	Recommendations for HVAC systems
Hotel	(Lingqian, 2022)	x		Lighting and HVAC systems
Hotel	(Cunha & Oliveira, 2020)		x	PV Panels, Lighting and HVAC systems
Residential	(Gonzalez, Escandon, Suarez, & Ascione , 2025)		x	Roof and thermal performance improvements
Residential	(Verellen & Allacker, 2022)	x		Roof, walls and floor renovations

Residential	(Shirazi & Ashuri, 2020)	x	x	Roof insulation and HVAC improvement
Residential	(Sattler & Österreicher, 2019)		x	Façade renovations

When the studies carried out in the four types of buildings determined within the scope of the study are examined, it is seen that the studies were carried out in accordance with the Figure 1 given above:

The study conducted by Li, Chen and Yu (2024) aimed to develop a sustainable proposal for low-carbon energy retrofits of existing campus buildings. Wind simulations and exterior wall renovation scenarios were created in the study. Energy savings of 24% have been achieved with the facade renovation scenario (using EPS insulation material). It has been stated that wind simulations, wind speed and pressure distributions can be optimized with improvements to be made in open areas.

On a smaller scale, a study conducted in a school building in China has created renovation scenarios for an energy-efficient and carbon-neutral life cycle (Xu, and others, 2023). Optimum renovation schemes have been obtained by taking into account thermal comfort conditions and daylight. 14.36 kWh/m² energy was produced by using renewable energy. Carbon emissions of 1,920,853.3 kg have been reduced with the renovation of insulation details.

Another study analysed renovation scenarios aimed at reducing carbon emissions for a life cycle carbon emission assessment of a nearly zero-energy office in China (Wang, Yang, Hou, & Tao, 2022). With the use of high-performance insulation materials and energy efficient HVAC systems, life cycle carbon emissions have been reduced by 86.2%.

The study conducted by Delac and others (2022) aimed to develop recommendations for HVAC systems for zero-energy and low-carbon renovation works of hotel buildings in Croatia. Within the scope of the study, it was stated that the best solution is a heat pump system in which sea water is used as a heat source. It has been stated that the use of a heat pump system that provides air-to-water conversion is an appropriate solution in cases where the use of seawater is not possible.

Finally, looking at the study conducted for residential buildings, it was aimed to conduct a Life Cycle assessment of the embedded energies of renovation works performed in residential buildings in Atlanta (Shirazi & Ashuri, 2020). In the study, renovation scenarios were determined to improve the energy consumption of buildings and comparison was made. It has

been stated that the most environmentally friendly application in the scenarios is with roof insulation and replacement of the HVAC system.

When the studies examined are evaluated at the building scale, the impact of the construction system of buildings and the building materials used on energy consumption and carbon footprint in the building shell is an important ratio. For this reason, studies focus on the structural shell of buildings and energy-consuming systems.

The use of the life cycle assessment method in the studies constitutes a decision-making methodology for the analysis of the current situation and the analysis of the created scenarios. In this direction, it is possible to find the renewal application with the highest performance by comparing the data obtained with different renewal scenarios with current situation analyses using the life cycle assessment method.

Findings and Discussion

In the literature, it is seen that the change of HVAC systems and insulation improvements are at the forefront in the studies conducted for the purpose of decarbonization and zero energy. In this regard, the data obtained from the renovation studies examined and the gaps in the literature are included:

The general LCA framework is described in ISO 14044 (2006), published by the International Organization for Standardization, which specifies the requirements for conducting a life cycle assessment. However, the standards to be applied to evaluate the performance of buildings in terms of energy efficiency are insufficient. In addition, the lack of data on the formation energy of building materials and the carbon emission values realized during the formation phase is an important problem. Evaluation standards should be established according to different climate zones, building typologies and building materials.

Building materials have different formation energy value according to raw materials and production methods. The amount of energy consumed during the renovation phase varies according to the formation energy of the building materials used in the structure. For this reason, attention should be paid to the formation energies when making material selection.

In addition to the amount of energy used to reduce carbon emissions, the source used to produce energy is also important. For this reason, the use of renewable energy sources significantly reduces usage carbon emissions.

The analyses made regarding the optimal renovation scenarios vary according to the climatic region where the buildings are located. This situation causes the insulation materials

and thicknesses of the buildings to change according to the climatic zones, heating and cooling needs.

Increasing the insulation thickness in the renovation studies carried out in the literature has led to reducing the life cycle energy consumption for all climate regions. However, in hot climate regions, increasing the insulation thickness also increases the need for cooling, which leads to an increase in use energy and use carbon.

In the studies in the literature, it is seen that renovation scenarios are created by making minimal intervention to transparent building elements. While the use of heat-insulated glass provides solar radiation gain, it can negatively affect heating and cooling needs.

In this case, it increases the utilization energy and carbon emission. While the movable shading elements to be used on the facades provide maximum benefit from the sun, they also contribute to the formation of thermal comfort conditions in the interior.

The evaluation of energy consumption and carbon emission in buildings within the scope of the life cycle assessment method plays an important role in terms of determining renovation strategies and practicality of implementation. However, there is limited data in the simulation programs and data analysis programs used. It is necessary to increase the scope of the programs used by developing them.

Conclusion

Since a significant proportion of energy consumption and carbon emissions worldwide are caused by the construction sector, renovation works carried out to reduce the environmental impact of buildings are increasing rapidly. In renovation works, it is necessary to evaluate the economic and environmental performance of buildings in holistic processes by selecting appropriate methods in accordance with the parameters that vary according to the analysis of the current condition of buildings. In this direction, it is possible to implement renovation strategies that provide optimal performance by conducting life cycle energy and life cycle carbon analyses of the buildings to be renovated. However, the lack of sufficient coverage of the databases and software used during the analysis makes the evaluation processes difficult. For this reason, it is necessary to develop databases used by increasing incentive studies for the life cycle assessment method worldwide.

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A SOCIO-ECONOMIC AND ENVIRONMENTAL DECISION SUPPORT MODEL FOR THE IMPLEMENTATION OF WHOLE-LIFE ZERO CARBON OFFICE BUILDINGS

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A Socio-Economic and Environmental Decision Support Model for The Implementation of Whole-Life Zero Carbon Office Buildings

Abstract: The climate crisis is mainly caused by human activities and requires a multi-faceted solution. In the scope of climate change mitigation and adaptation strategies, the European Union has set a target of 55% carbon mitigation by 2030 and plans to achieve carbon neutrality by 2050. Türkiye took a similar decision for 2053. In this study, office buildings that can respond to multiple crises are examined for the implementation of whole-life zero-carbon buildings. The aim of the study is to generate real-life data for developing a decision support model that is based on on-site practices. The highest performing office buildings in Türkiye are identified, and the baseline scenarios are analysed from environmental and economic perspectives using the life cycle assessment (LCA), social LCA, and life cycle costing methods. The method is conducted on a one-storey office building in Ankara. It was found that the whole-life carbon emissions decreased by 60% via utilizing a wooden structure with a high-thermal performance façade and a PV-integrated air-sourced heat pump.

Keywords: whole-life carbon assessment, office buildings, case study, nZEB

Introduction

Over the past decade, the number of annual disasters has increased significantly. Most of the damage that occurred originates from human interventions. The climate crisis is caused by human influence and requires a multi-layered solution. In the scope of climate change mitigation and adaptation strategies, the European Union has set a target of 55% carbon mitigation for 2030 and plans to achieve carbon neutrality by 2050 (Wilson et al., 2022). Türkiye took a similar decision for 2053. In this study, office buildings that can respond to multiple crises are examined under socio-economic and environmental factors for the implementation of whole-life zero-carbon buildings. The aim of the study is to provide a scientific basis for a decision support model for low-carbon building design.

Behind such a decision support model lies the zero-carbon target for 2050 and beyond. This goal is not only environmental but also socio-economic. In the construction sector, the concept considers total operational carbon emissions of building use. But an approach that only addresses the use phase of a building is not holistic. During the life cycle of buildings, embodied carbon emissions occur in the material extraction, production, transportation, and construction and end-of-life phases (European Standards, 2011). However, embodied emissions are currently not being regulated. With the EU Green Deal and the Carbon Border Adjustment Mechanism (CBAM), the embodied carbon in building materials turns into a value that creates costs and taxes (EU, 2023). The socio-economic impact of embodied and operational carbon on the stakeholders needs to be addressed.

The concept of nearly zero energy buildings (nZEB) has been driving the transition of buildings for decades (Chastas et al., 2020). In Türkiye, the definition of nZEB was introduced in 2023 for new buildings with a total area of more than 5,000 m^2. In 2025, the threshold was reduced to 2,000 m^2 (T.C. Resmi Gazete, 2022). nZEBs must achieve a minimum class B energy performance certificate, which implies 20% improvement in energy consumption. A renewable energy contribution of 10% is also required. The background of the regulation has been published with an additional guide includes representative figures on the Turkish building stock (T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı, 2020). In this study, a decision-support model for office buildings was explored under three layers:

- Environmental: Embodied and operational carbon emissions, environmental pollution
- Economic: Initial and lifetime cost, total cost of ownership
- Social: Effects on workers, user comfort, impact on the local community

Literature Review

There is an increasing number of studies in the literature that focus on nZEB progress. Some of the studies (Basbagill et al., 2013; Cabeza et al., 2014; Junnila et al., 2006; Ramesh et al., 2010) examined the embodied emissions arising from the production of building materials in buildings, transportation, and construction activities with the life cycle assessment (LCA) method. Such emissions remained a hidden source of carbon until the last decade. While operational carbon emissions have decreased with each improvement in building energy performance regulations, embodied carbon emissions have increased due to the need for more insulation in the building envelope and increased active systems for HVAC (Ajayi et al., 2019; Röck et al., 2020). Consequently, for some implementations (Ilektra Papadaki et al., 2023; Nugent et al., 2022), it is important to address how to incorporate all lifecycle carbon assessments into building performance assessment.

As seen in Figure 1, several countries have already adopted policies to integrate embodied emissions into their regulations. Only a few put forward compulsory limits (such as the Netherlands, France, and Denmark), whereas the EU expects the first limitations by 2030 from the member states. Meanwhile, several initiatives such as IEA EBC Annex 89 (IEA EBC, 2022) combine forces with several countries to explore how the implementation should happen.

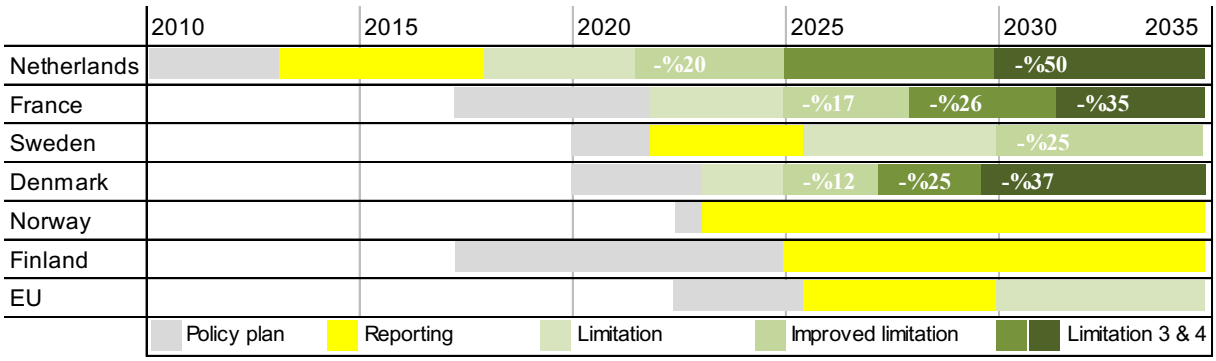

Figure 1. Embodied carbon targets policy development in the EU (Nordic Sustainable Construction, 2023).

Methods

The research methodology is based on a previous study (Kayaçetin & Hozatlı, 2024) and adapted for real-life cases. The highest performing (EPC class A) buildings in Türkiye are identified, and the baseline scenarios are analysed from environmental and economic perspectives using LCA (European Standards, 2011), social LCA (CEN, 2014), and life cycle costing (LCC) methods (ISO, 2017). In this study, a total of 20 office buildings from four different climate zones will be analysed. To ensure balanced representation, five buildings were selected from each representative city (İzmir, İstanbul, Ankara, and Erzurum), corresponding to the four major climate zones. In line with the national nZEB definition, the following criteria were applied:

- A gross floor area between 300 m² and 15,000 m²,
- On-site renewable energy generation meeting at least 10% of the total primary energy demand, and
- A minimum of B-class energy performance rating in the national certification scheme.

Two complementary approaches were used to identify suitable cases. First, data from the BEP-TR national database were analysed, and the buildings that met the above criteria and ranked within the top 10% in overall performance were shortlisted (T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı, n.d.). Second, best-practice examples were identified through the authors' professional networks and contacts with design firms, developers, and facility managers. This combined method ensured that the dataset of 20 office buildings included both statistically representative cases and exemplary pioneering projects that fall beyond today's regulatory nZEB size requirement.

The analysis of the current situation reveals the trends in construction methods in different climatic zones. The characteristics of the climate zones in Türkiye are given below:

Table 1. Scenarios for the building envelope for climatic zones (TSE, 2008)

Climate zone		Representative province	Heating & Cooling		Relative Humidity	Altitude (m)	Solar Radiation (kWh/(m²a))
TS825	Köppen-Geiger		HDD	CDD			
Z1	BSh	İzmir	948	693	66	9	1550
Z2	Csa	İstanbul	1675	208	70	25	1450
Z3	BSk	Ankara	2335	254	64	905	1500
Z4	Dfb	Erzurum	4444	13	64	1923	1600

The zones provide a wide variation in the Köppen-Geiger classification. Z1 is a dry, semi-arid, and hot Mediterranean region (BSh), Z2 is a hot-summer Mediterranean climate (CSa), Z3 is a cold-semi arid climate in Central Anatolia (BSk), and Z4 is a continental region with no dry seasons and warm summer in Eastern Anatolia (Dfb). To draw a practical boundary for this study, a case study approach was adopted,and a single building was analysed in Z3.

These methods are combined with other applications in the literature to form a database for a decision support model. Figure 2 represents the existing nZEB process in Türkiye and the processes for the proposed decision-support model.

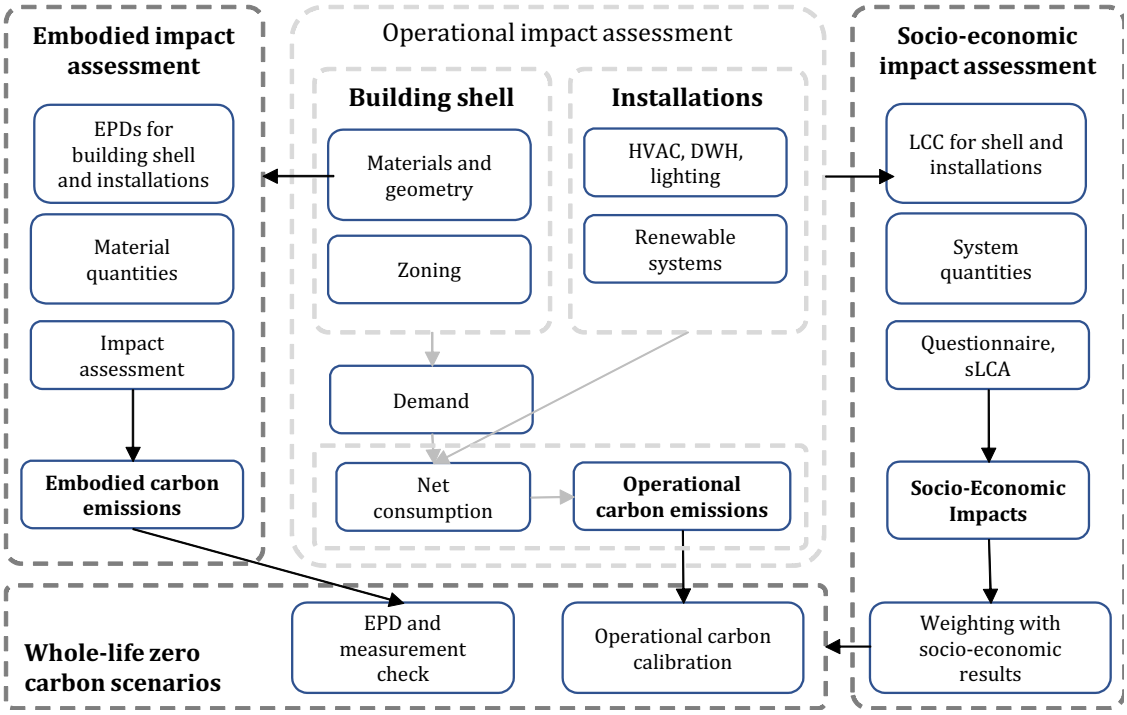

Figure 2. Proposed processes for the decision-support model of zero-carbon office buildings.

A socio-economic analysis is a critical component of the decision-making process for stakeholders of the building, as it enables them to comprehensively understand the implications related to cost and social aspects (UNEP, 2020). The social impact assessment employs a semi-quantitative research method, wherein a social hotspot analysis is conducted via global

databases and then specific data are collected through interviews with constructors, users, and decision-makers. SLCA results are used for providing weighting factors for selecting the optimum environmental and economic components instead of combining with quantitative results. Table 2 presents the stakeholders involved, the impact category, the indicators, and the targets that are used in the socio-economic analysis.

Table 2. Stakeholder, impact, and indicators for socio-economic analysis

Stakeholder	Impact category	Indicators	Target
Contractor	Working conditions	Working hours	h>40
	Professional development	Increased capacity	Higher employment
	Market share	Change in market share	Increased by 10%
Local authority	Healthy and safe living	Construction waste rate	Decreased by 30%
	Local material usage	Local material rate	>50%
	Local job opportunities	Local employment rate	>80%
User	Sustainable use	Comfort and cost of use	Decreased by 20%
	End-of-life responsibility	Waste management plan	Available
	Transparency	Access to building data	Accessible

Findings and Discussion

The method is conducted on a single-storey office building in Ankara (Figure 3), which has a 300 m^2 area with 25 employees. The building is designed with environmental concerns, utilizing bio-based components and innovative construction techniques (such as a screw-pile foundation) for low-energy and carbon targets. The structural system is a lightweight wooden system without using any concrete elements (even in the foundation). The technical systems are completely electrified, including a heat pump for heating and a split-system for cooling, which are supported with a high solar energy contribution.

Figure 3. Photos of Single-Storey Office Building in Ankara (The Hab Projects, n.d.)

The façade and technical systems are evaluated through the parameters given in Figure 4. It was found that the whole-life carbon emissions decreased by 60% (from 604 to 195

$kgCO_2/m^2$) via utilizing a wooden structure with a high-thermal performance façade and a PV-integrated air-sourced heat pump. The building is 'almost' positive energy, using electricity from the grid in only two or three months per year. It was seen that the users are quite comfortable due to increased indoor air quality (IAQ), mainly for a constant indoor temperature and humidity.

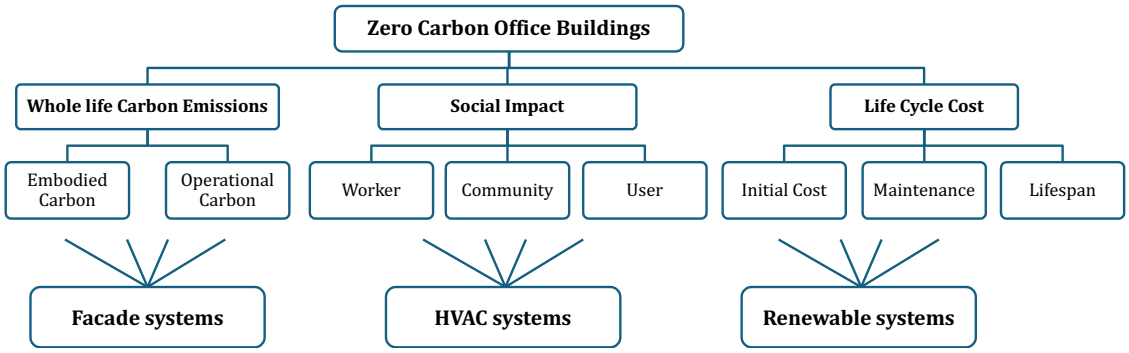

Figure 4. Relationship of parameters in the decision-support model.

Conclusion

This study aims to develop an integrated model that utilizes socio-economic and environmental impact assessment to identify the most appropriate choices for office buildings throughout their whole life cycle in Türkiye. The findings can provide a scientific background for the future recasting of the nZEB definition in Türkiye and neighbouring regions such as the EU and MENA. The current CO_2 mitigation target in the country is 40% by 2030. It is expected that this methodology will be a guide to take steps towards policies that aim to analyse the energy performance of buildings from operational carbon calculations to whole life cycle carbon analysis. The study will be replicated for several offices in different climatic locations. A multi-layered decision support model will be created for buildings that provide guidance in varying climate zones. The model can be replicated for other building typologies. In addition, the studies carried out in this field provide validation for the existing national building performance process and introduce a prospective selection in socio-economic and environmental perspectives.

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COMPUTATIONAL WORKFLOW FOR ENERGY-EFFICIENT BUILDING DESIGN: REVIEW OF CURRENT CHALLENGES AND OPPORTUNITIES

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Computational Workflow for Energy-Efficient Building Design: Review of Current Challenges and Opportunities

Abstract: This study investigates the practical integration of Building Information Modeling (BIM) and Building Energy Modeling (BEM) for energy-efficient building design. This research explores the challenges and opportunities of openBIM-to-BEM workflows by drawing on a literature review and a real-world case study in Östergötland County, typical of the Million Programme, a large public housing initiative in Sweden. Combining tools such as Revit, BlenderBIM, and IDA-ICE, this study documents a modeling-to-simulation pipeline. Key issues such as interoperability and semantic accuracy during Industry Foundation Classes (IFC) exchanges are identified. Findings suggest that while openBIM approaches offer transparency and flexibility, they also demand high technical skills and workflow refinement. This exploratory work prepares for the definition of relevant research questions for a doctoral project aiming to improve ICT-support for energy-efficient building design.

Keywords: design, energy efficiency, building simulation, building information modeling, building energy modeling

Introduction

Building simulation is one of the main approaches for assessing building performance. It assists in understanding how buildings will perform even before they are constructed or renovated. Simulation can be used to examine and improve design decisions and interventions throughout the building life cycle and thus is an important instrument for the management of building energy use and carbon emissions. The integration of simulation has long been a topic of research (Ciardiello, 2024).

Recently, the field has undergone dramatic changes due to the emergence of powerful machine learning (ML) algorithms and the wider developments in artificial intelligence (Geyer and Singaravel, 2018; Geyer et al., 2024). At the same time, some of the classical hurdles such as data exchange (interoperability), complexity of the model, and integration with design workflows remain, with few effective ways to address them. Amongst others, the data exchange between building information models (BIM) and building energy models (BEM) remains far from seamless (Negendahl, 2015; Reinhart and Cerezo Davila, 2016; Richter et al., 2024).

There is uncertainty about the actual role of simulation in building design, as studies have shown that energy simulations are often conducted to meet compliance verification and certification requirements such as LEED, rather than to guide early design decisions in an iterative process (Bazjanac, 2008; Attia et al., 2012; de Wilde, 2018).

This paper reports on the first steps of a doctoral research project aiming to improve workflow in the design and engineering of energy-efficient buildings. To this end, this paper presents an initial literature review of key research areas, along with a case study of a building

project in Sweden. The aim is to explore how present digital tools support the early design and energy analysis process through a BIM-to-BEM workflow.

The main objective of this paper is to document and describe step-by-step progress that takes the case study from 2D drawings to building energy simulation by using different tools such as Revit, BlenderBIM, and IDA-ICE. This approach also helps to identify the challenges, gaps, and opportunities to improve BIM-to-BEM integration. By simultaneously conducting and analyzing the process, this study leads to the definition of relevant research questions for the main PhD project.

Methodology

A case study is set up to evaluate the practical integration of openBIM workflow within a real-world residential building project, directly addressing the interoperability challenges and toolchains identified in the initial literature review. The objective is to assess the performance of different software in linking BIM-to-BEM within an independent, standards-based toolchain.

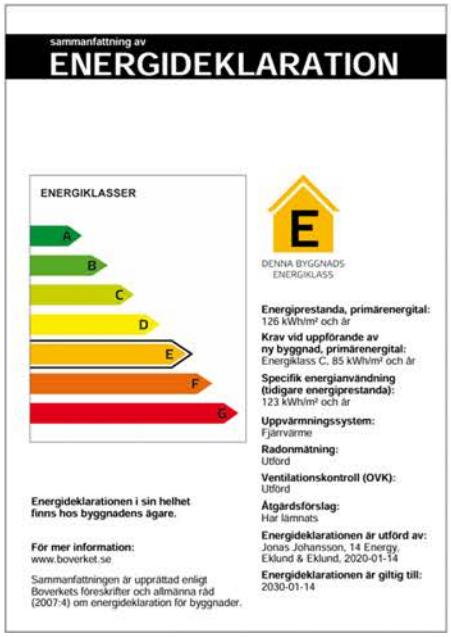
The chosen case study is a four-story residential building typical of the Million Programme in Sweden, selected for its relevance and representativeness to the research objectives. The building exemplifies a common mid-sized residential typology, featuring standard construction and HVAC systems (district heating with radiators and mechanical ventilation using an exhaust system with heat recovery).

According to Yin (2017), a case study is an inquiry that investigates a phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clear. In this study, the unit of analysis is a building project which allows for investigation into BIM-to-BEM integration in a realistic setting.

This study also includes a narrative literature review within the Theoretical Foundation section. This type of review was chosen to provide a broad and critical overview of existing research on BIM interoperability and openBIM workflows. It does not follow a strict method but focuses on summarising and interpreting key studies. The review used databases such as Scopus, Web of Science, and Google Scholar, with search terms like "openBIM", "interoperability", and "BIM-to-BEM". Relevant articles, conference papers, and technical reports were included, while studies focused only on proprietary tools were excluded. The review helped identify research gaps and informed the case study design.

Moreover, an existing and occupied building provides an opportunity for a direct comparison between simulation outputs and actual measured energy consumption for

validation. The building's lifecycle stage, post-occupancy, makes it an ideal case study for future works to explore how openBIM tools can bridge conceptual, technical, and operational phases.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Fjärrvärme
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Sammanfattningen är upprättad enligt Boverkets föreskrifter och allmänna råd (2007:4) om energideklaration för byggnader.

Figure 1. Energy Declaration Document (Energideklaration in Swedish)

Building´s envelope and systems were reconstructed from available drawings and contextual expertise, reflecting typical occupancy patterns and heating demands. According to the Energy Declaration Document (Energideklaration) issued by the municipality, the building has an energy performance rating of **E** (Figure 1), indicating relatively poor energy efficiency. Monthly energy bills for space heating provide data to validate the energy simulation results.

The modeling workflow integrates data from two different sources, combining architectural drawings in .pdf format that are vectorized and cleaned for AutoCAD use and contextual input provided by a researcher at the Department of Biosystems and Engineering at SLU, which clarifies semantic information, HVAC systems, and usage patterns.

A detailed design pipeline was developed to document the time spent on each step, the challenges encountered, the required knowledge, tool limitations, and key modeling decisions. This methodology provided insight into interoperability issues, especially during IFC exchange, and informed necessary simplifications and parametric assumptions. Finally, simulation results were compared to an alternative, simplified energy simulation method, allowing for evaluation of the workflow's accuracy and applicability in energy-efficient building design.

By simultaneously conducting and analysing the simulation process, the case study identifies key points and opportunities for improving BIM-to-BEM workflow.

Theoretical foundation

Design decision-making in architecture and engineering has long been assisted by calculation methods, yet their integration into design practice remains unclear. Augenbroe (2011) provided a framework for understanding how simulation can support performance-based building design, especially by representing uncertainty and enabling comparative assessments. However, many tools are not well adapted into the repetitive and exploratory ways in which design typically develops.

De Wilde and Bleil de Souza (2024) claimed that although simulation tools are widely used, they are often applied reactively, typically for regulatory compliance or post-design verification, rather than as proactive design tools that inform decisions. They emphasize the importance of a wider integration of simulation into the design process, improving accessibility and interpretability for non-specialists.

Earlier foundational works by Hand (1999), de Wilde (2004), McElroy (2009), Augenbroe (2011) and Struck (2012) have provided the groundwork for integrated design support environments. These were further supported by contributions such as Brahme (2001) on performance-based design, Clarke (2007) on simulation-supported decision-making, and Bazjanac (2004) on model-based engineering and interoperability. Despite this progress, significant gaps hinder a seamless workflow between building performance simulation and architectural design. These gaps are not only technical but also organizational, as highlighted by Attia (2012), Reinhart and Cerezo Davila (2016), and Abboushi (2020). Recent reviews by Hong (2018) and Jiang (2025) confirm that current tools often fail to align with the workflows and needs of early design stages.

Building simulation is advancing rapidly in both computational power and methodological scope. Although traditionally grounded in deterministic modeling, there is an increasing shift toward probabilistic and data-driven approaches (Beausoleil-Morrison, 2020; Clarke, 2015; Hensen and Lamberts, 2019). Recent developments also include the use of ML techniques, occupant behaviour modeling, and real-time data assimilation to support more robust and adaptive simulations (Ferrando et al., 2022; Jiang et al., 2025).

Hybrid workflows that combine physics-based simulation with substitute models using machine learning are becoming more common. Researchers such as Ashayeri and Abbasabadi

(2024), Geyer (2024), Geyer and Singaravel (2018) and Rovas (2018) have explored applications in design space exploration, multi-objective optimization, and model simplification. These approaches are represented at recent IBPSA Building Simulation conferences, which also highlight expanding interest in occupant behaviour modeling, urban-scale simulations, and digital twins involving real-time feedback.

BIM has changed how building projects are documented and coordinated. As Sacks (2025) mentioned in the BIM Handbook, BIM is not a software but represents a wider paradigm shift in architecture, engineering, and construction (AEC) practice. However, its functionality remains mostly related to documentation and coordination, with limited integration into simulation-based performance analysis (Sacks et al., 2018).

Challenges in BIM-to-BEM interoperability remain despite efforts by organizations like buildingSMART to improve digital workflows through IFC as a standardized underlying data model and Model View Definitions (MVDs) as complementary mechanisms that specify the required data subsets for particular use cases (Alhammad et al., 2024). A recent developed solution is the Information Delivery Specification (IDS), a complementary machine-readable format designed to define which data must be included in IFC models for specific tasks, such as energy simulation. IDS allows for automated checking of IFC models to ensure they contain the necessary information for a given use case. This makes it a useful tool for improving data reliability and supporting more accurate BIM-to-BEM workflows (Fischer et al., 2024).

The integration of BIM and BEM is seen as a key factor to improve the performance-based building. Nevertheless, BIM-to-BEM integration remains challenging due to both technical and conceptual barriers (Yang et al., 2022). IEA EBC Annex 60 (Wetter et al., 2014) and the ongoing IEA EBC Annex 91 have contributed valuable research on BIM-to-BEM workflows, highlighting issues such as interoperability and data exchange. As expressed by Tomczak et al. (2024) “Interoperability includes data exchange; data exchange does not guarantee interoperability”.

Recent work by Annex 91 and other researchers highlights that challenges such as geometric inaccuracies and element misclassifications persist despite standardized formats like IFC (Ying and Lee, 2019; Schatz and Domer, 2024; Iliadis et al., 2025).

The incorporation of semantic data within BIM environments can improve the accuracy of simulation compared to direct modeling approaches; however, it also adds complexity that can make data translation more difficult and increase challenges related to interoperability and user expertise (Afzal et al., 2023; Ciccozzi et al., 2023; Miller et al., 2025).

In conclusion, the literature points to a landscape where simulation tools are increasingly capable but not yet fully integrated into the design process. Challenges remain in early-stage design, integrative collaboration, and BIM-to-BEM interoperability. However, new processes, such as AI-assisted workflows, openBIM frameworks, and standardization data exchange, present some promising paths for performance-driven design processes.

This review sets the foundation for a newly started doctoral research project, which will investigate whether an openBIM workflow can offer a more effective process in comparison with direct modeling in simulation tools.

Case study: Results

Drawing from the theoretical foundation and the practical implementation of the case study, three main BIM-to-BEM integration strategies were identified:

- Real-time plugins (e.g., Insight360 for Revit)
- Standardized exchange formats (e.g., IFC, gbXML)
- Intermediate tools (e.g., Modelica translators, BlenderBIM)

While each strategy offers certain benefits, they also have limitations, such as workflow rigidity, data loss, and design misalignment.

The BIM-to-BEM workflow has been applied to the case study building through the IFC schema, showing the process from architectural documentation to energy performance assessment. The workflow steps are described with a focus on the stage where the IFC format is exported from Revit. At this stage, issues related to interoperability and data loss are identified. This analysis allows clarifying how the workflow unfolds, while highlighting where improvements may be needed in the integration of digital tools for building energy analysis.

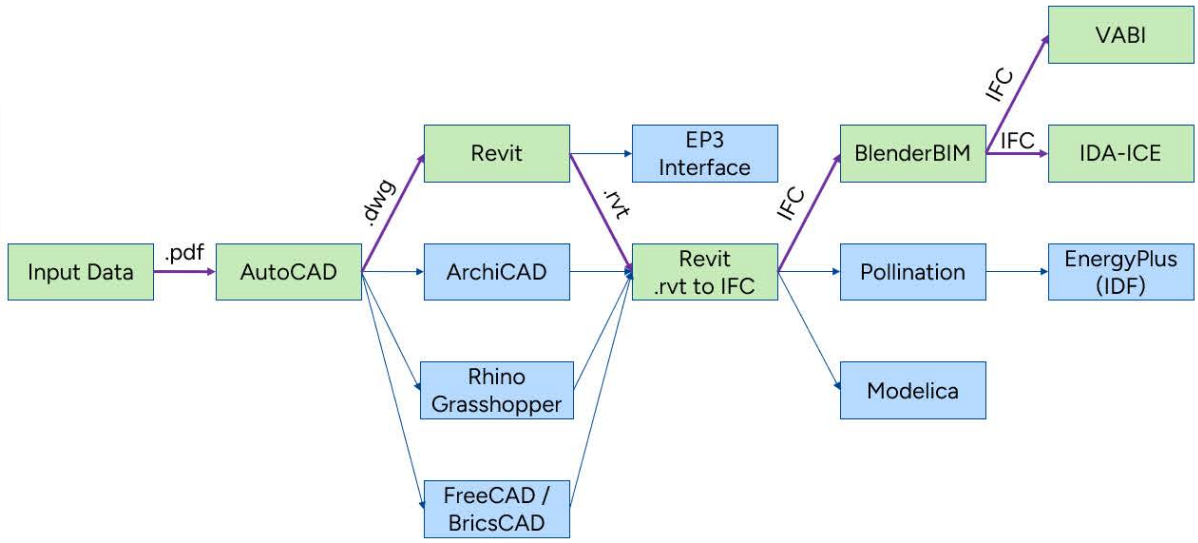

Figure 2. The core modeling and simulation tools (ICT ecosystem) in this case study.

The implemented workflow (Figure 2) facilitates a better understanding of the energy performance simulation process through a series of steps, beginning with the import and vectorization of architectural .pdf files toward AutoCAD, followed by detailed geometry and zoning through 3D modeling in Revit. The model is then exported to IFC format and validated in BlenderBIM to ensure data integrity before being prepared for energy simulation in both IDA-ICE and VABI tools, supporting dynamic and standardized energy analyses. BlenderBIM was used as an intermediary validation step to control data and geometry loss during the rvt-to-IFC conversion, which is a known challenge in openBIM workflows.

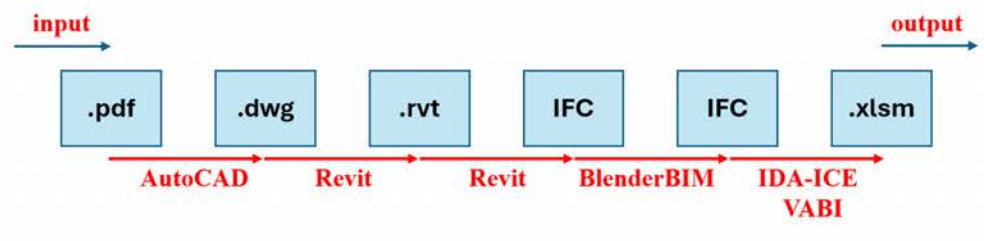

Figure 3. data pipeline

The data pipeline (Figure 3) represents the structured flow of digital information from architectural drawings to energy simulation outputs. It begins with vector based .pdf architectural drawings obtained from the building owner through building archives. These .pdf files are converted into .dwg files to prepare the building geometry for 3D modeling. The CAD files serve as underlays for reconstructing a 3D model in Autodesk Revit. In Revit, architectural elements such as walls, windows, and HVAC systems are assigned appropriate properties. Once complete, the model is exported to the IFC format as an open, standardized format that can ensure interoperability between software platforms.

The IFC model is then imported into Blender using the BlenderBIM add-on (built on IfcOpenShell) for validation and quality control. This step includes checking and correcting geometric and semantic inconsistencies to ensure model integrity. The cleaned IFC file is then imported into IDA-ICE and VABI for dynamic energy simulation.

Simulation results include performance measurements such as annual heating demand, energy use intensity, and system efficiency. These outputs are compared with an independently developed IDA-ICE reference model built by our SLU partner to validate accuracy and consistency.

Discussion

The case study revealed several challenging aspects regarding the BIM-to-BEM workflow. While the overall data exchange flow from .pdf to energy simulation was achievable, several "pain points" were identified, particularly in the conversion and interoperability stages. Minor geometric inaccuracies were detected through the vectorization of .pdf to .dwg files, requiring manual corrections within AutoCAD and Revit. Exporting to IFC and validating the model in BlenderBIM helped identify and fix semantic and geometry inconsistencies; yet the process was time-consuming and demanded advanced software knowledge.

Unexpectedly, while semantic data in the 3D Revit model enriched the energy simulation compared to direct IDA-ICE simulation, it also introduced complexity. This complexity sometimes made straightforward data translation difficult, confirming challenges mentioned in the theoretical foundation about BIM-to-BEM interoperability gaps and learning curve barriers (Afzal et al., 2023; Ciccozzi et al., 2023; Miller et al., 2025). The findings align with prior research highlighting that BIM tools offer rich geometry and semantics but often require supplementary validation steps (e.g. BlenderBIM) to ensure simulation readiness (Bazjanac, 2008; Bouquerel et al., 2021; Xia and Rüppel, 2024).

Moreover, the comparison with SLU partner's direct IDA-ICE model emphasized that openBIM workflows can provide greater flexibility and potential for integrated design support, albeit increased complexity. This case strengthens the idea that real-time connections and IFC data exchange processes are still evolving. Additionally, it also highlights the need for openBIM strategies to strike a balance between tool interoperability and the expertise of users.

Conclusion

This paper advances the understanding of BIM-to-BEM workflows for energy-efficient building design by investigating practical integration steps and challenges through the building case study. The next phase within this larger doctorate project will involve engaging industry leaders and experts in a workshop to validate the current findings, identifying key barriers, and collaboratively redefining the workflow. These results will guide the development of a Stage II case study, potentially focused on the Lund Hospital project, to assess the adaptability of the refined BIM-to-BEM approach in a more complex setting.

Beyond technical integration, future efforts will aim to create semi-automated validation tools that minimize errors and reduce the time and effort involved. User training strategies will also be evaluated to ensure effective tool adoption. In the next phase, the project

will also identify key research areas, such as how ICT can support collaboration between different disciplines and improve the long-term efficiency of BIM-to-BEM workflows. Ultimately, the project aims to define the foundations for establishing transparent and interoperable BIM-to-BEM workflows that empower ICT-support for energy-efficient building design in real-world practice.

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COMPARATIVE ANALYSIS OF LIFE CYCLE ASSESSMENT (LCA)-PROCESS-ORIENTED APPROACH WITH CAMPUS SUSTAINABILITY ASSESSMENT SYSTEMS

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Comparative Analysis of Life Cycle Assessment (LCA)-Process-Oriented Approach with Campus Sustainability Assessment Systems

Abstract: University campuses are of particular importance in sustainability assessments due to their multi-dimensional environmental impacts. This study examines the evaluation approaches of existing systems used in the sustainability assessment of university campuses and compares these systems with life cycle assessment (LCA), which offers a process-oriented approach. While existing assessment systems typically measure campuses' overall sustainability performance using scoring and ranking methodologies, LCA analyses all campus processes and quantifies environmental impacts in detail. While LCA is used in data analysis in some assessment systems, this study demonstrates that LCA offers a different evaluation approach and can structure decision-making processes within a more holistic framework. With its data depth, quantitative measurability, strategic retrofitting potential, and long-term impact modelling, LCA is an approach that can make significant contributions to campus sustainability analyses. By evaluating these contributions, the study highlights LCA's potential for process-oriented assessment.

Keywords: sustainable campus; life cycle assessment; GreenMetric, LEED, STARS

Introduction

Sustainability has become a multi-dimensional goal that is becoming increasingly gaining important today, especially for university campuses. They can now be considered “small cities” because of their populations, size and the many complex activities that occur on campus, which have significant direct and indirect environmental impacts. (Alsuwaikhat and Abubakar, 2008). Therefore, sustainability stands out as a key area for campuses to fulfil their environmental responsibilities.

Assessment systems such as GreenMetric, The Sustainability Tracking, Assessment & Rating System (STARS), and Leadership in Energy and Environmental Design (LEED), developed to measure campus sustainability levels, are widely used by numerous universities. These systems generally rely on scoring and ranking methodologies. It is based on data based on self-reporting or general indicators under specific thematic categories. However, most of these systems focus on measuring outputs rather than processes (Dawodu et al., 2022). This study examines the evaluation approaches of existing systems used in the sustainability assessment of university campuses and compares these systems with life cycle assessment (LCA), which offers a process-oriented approach. While existing assessment systems typically measure campuses' overall sustainability performance using scoring and ranking methodologies, LCA analyses all campus processes and quantifies environmental impacts in detail. This creates limitations in considering the environmental impacts of campus activities in sufficient detail and holistically. This highlights the need to develop more consistent and holistic evaluation approaches for campuses based on quantitative data.

In response to this need, this study examines the potential of the LCA approach in assessing campus sustainability by comparing it with existing systems. LCA is an internationally recognized method based on ISO 14040/44 standards that inventories inputs and outputs at all stages of a product or process, from raw material production to disposal, and quantifies their environmental impacts (Abdelaal et al.,2022). When applied at the campus scale, LCA can holistically assess the environmental impacts of campus activities, such as greenhouse gas emissions, water footprint, and waste generation. Thus, it goes beyond existing systems and reveals the environmental burden of each process. It expresses a campus's sustainability performance in terms of quantitative environmental impacts (Gulcimen et al., 2022). Indeed, in recent years, some assessment systems have incorporated LCA elements into their assessments, aiming to make environmental impacts more transparent and quantifiable (Xue et al., 2020). This approach enables quantitative results to be obtained with a life cycle perspective in sustainability assessments.

The purpose of this study is to compare common campus sustainability assessment systems with LCA approach to demonstrate how LCA can offer a different perspective on campus and enrich decision-making processes. In this regard, study adopts a literature-based comparative analysis approach. Systems such as GreenMetric, STARS and LEED are compared with process-oriented LCA in terms of their data structures, assessment levels and scoring methods. The comparation is based on the systems' official manuals and academic sources. The study's unique aspect is its emphasis on the potential benefits of shifting from scoring and ranking-focused approaches to a process-focused quantitative approach in campus assessments.

Literature Review

Systems developed to assess campus sustainability performance are typically indicator-based and focused on scoring or ranking. Systems such as GreenMetric, STARS and LEED collect institutional-level data on areas such as energy, waste, water management and educational activities to provide rankings or certifications. The scope, criteria and ranking structures of these systems are presented in detail and comparatively in Table 1. Although these systems provide comprehensive frameworks, they are often criticized for their reliance on qualitative indicators, self-reported data, limited data depth, and lack of process orientation (Boiocchi et al.,2023).

Table 1: Campus Sustainability Assessment Systems

	Country, Year	Scope	Criterias	Ratings
GreenMetric	Indonesia, 2010	Campuses	Setting and Infrastructure (15%) Energy and Climate Change (21%) Waste (18%) Water (10%) Transportation (18%) Education and Research (18%)	Sort by score
STARS	USA, 2006	Campuses	Academics (68 p) Engagement (50 P) Operations (86 P) Planning and Administration (46 P) Innovation and Leadership (10 P)	Platinum ≥85 Gold ≥65 Silver ≥45 Bronze ≥25
LEED for Campus	USA, 1998	Campuses	Innovation (6 P) Location and Transportation (16 P) Energy and atmosphere (33 P) Water Efficiency (11 P) Sustainable sites (10 P) Regional priority (4 P) Materials and resources (13 P) Indoor environmental quality (16 P)	Certified≥ 40 Silver≥50 Gold≥ 60 Platinum≥80
BREEAM Communities	UK, 1990	Communities	Governance (9.3%) Social and economic wellbeing (42.7 %) Resource and energy (21.6%) Land use and ecology (12.6%) Transport and movement (13.8%)	Unclassified <30 Pass ≥ 30 Good≥ 45 Very Good ≥ 55 Excellent ≥ 70 Outstanding ≥ 85
GreenStar Communities	Australia, 2002	Communities	Governance (28 P) Liveability (22P) Economic Prosperity (21P) Environment (29P) Innovation (10P)	Best Practice≥ 45 Australian Excellence≥ 60 World Leadership≥75
ASSC	Japan, 2013	Campuses	Management (27 %) Education & Research (10 %) Environment (47 %) Local Community (16 %)	Platinum≥85 Gold≥65
People & Planet	UK, 2007	Universities	Env. Policy and Strategy (4%) Env. Auditing & Management (9%) Managing Carbon (7%) Sustainable Food (4%) Ethical Investment (7%) Ethical Careers (4%) Staff & HR (6%) Workers' Rights (7%) Staff & Student Engagement (5%) Education for Sustainable Development (9%) Energy Sources (7%) Waste &Recycling (8%) Carbon reduction (15%) Water (8%)	Sort by score

LCA stands out for its quantitative analysis of the environmental impacts of campus processes throughout their life cycle. The depth of data, numerical measurability of outputs, and strategic decision support offered by LCA distinguish it from existing systems (Gulcimen

et al.,2022). While LCA is used as a supporting tool in some assessment systems in the literature, it is not central to institutional sustainability assessment systems (Abdelaal et al.,2022). Integrating the LCA approach into campus assessments allows for tracking sustainability performance through absolute environmental impacts rather than pure scores or percentages. This helps campuses achieve their goals on a scientific basis.

Methods

Approaches to assessing campus sustainability performance using a qualitative comparative analysis are examined in this study. GreenMetric, STARS, LEED, BREEAM, GreenStar, People&Planet and ASSC systems were selected within the scope of the analysis. These systems, widely used around the world, have been chosen because they have proven applicability in different geographical regions and have clear evaluation criteria with official manuals. The criteria, scope, data requirements, and evaluation methodologies for each system were systematically compiled from official manuals and academic literature. Table 1 summarizes the key features of these systems. Academic studies focusing on campus-wide LCA implementations were then reviewed, and data collection processes, LCA system boundaries, and reporting formats were examined. Based on the information obtained, existing systems were compared with LCA approaches in terms of data depth, level of analysis, output format, and decision support capacity. Rather than generating direct empirical data, the study serves as a literature synthesis and conceptual framework analysis that brings together existing knowledge. This approach was chosen to highlight the methodological differences between different assessment systems and to examine the potential for integrating LCA into sustainable campus metrics.

Findings and Discussion

The comparative analysis reveals significant methodological differences between campus sustainability assessment systems and the LCA approach. In order to systematically illustrate these differences, the main features of the existing systems and LCA approach are presented comparatively in Table 2.

Table 2: Comparison of Campus Sustainability Assessment Systems and LCA Approach

Criterion / Feature	**Existing Systems (GreenMetric, STARS, LEED etc.)**	**LCA Approach**
Focus	Outputs and indicators, scoring/ranking	Process-based environmental impact analysis
Data Type	Self-reported, qualitative and partially quantitative indicators	Detailed quantitative data (input-output inventory)
Result Format	Total score, certification level, ranking	Absolute environmental impact values (CO_2-eq, m^3 water, etc.)
Level of Analysis	Category-based	Integrated across the entire life cycle
Advantages	Broad participation, ease of communication, visibility	Scientific accuracy, detailed impact analysis, decision support
Limitations	Weak process analysis, trade-offs remain invisible	High data requirements, need for expertise
Decision Support	General guidance	Strategic prioritization and scenario analysis
Long-Term Impact	Short-term-instantaneous performance evaluation	Life cycle perspective

As can be seen from Table 2, while existing systems largely rely on indicator-based checklists, LCA offers a process-oriented method based on calculations and quantitative analysis (Dawodu et al.,2022). This difference provides a significant advantage, particularly in terms of monitoring environmental impacts in absolute terms and is discussed in detail below.

While existing systems utilize numerous indicators for data depth and measurability, these indicators are summary data at the unit level. LCA requires detailed data at the process level. LCA outputs can be presented as a series of environmental impact indicators rather than a single sustainability performance score (Abdellaal et al.,2022). These quantitative outputs help campus scientifically formulate its sustainability goals.

With a holistic and process-focused perspective, LCA treats the campus as a system and analyzes all subprocesses in an integrated manner. Existing systems do not perform an integrated analysis across categories (Gulcimen et al., 2022). For example, poor performance

in the transportation category could be offset by good performance in the energy category, and the overall score could still be high. However, because LCA aggregates transportation-related emissions with energy emissions and adds them to the total carbon footprint, the impact of no area can be ignored. This holistic view also makes potential trade-offs visible. For example, a large solar panel investment to increase renewable energy use on campus and the resulting carbon impact from its production can be analyzed with LCA. If the impact from panel production is greater than the operational phase, the net sustainability performance of this investment can be questioned (Asadollahfardi et al.,2024). While existing systems do not utilize such life-cycle assessments, LCA offers decision-makers a more holistic assessment (Gulcimen et al.,2022). This allows decisions to be made focused on impact reduction rather than score returns.

LCA results quantify the environmental impacts of campus activities, enabling prioritization for strategic retrofittings. However, because existing systems use scores distributed across different categories, the magnitude of the impact may not be directly visible. LCA also serves as a powerful decision-support tool by numerically modeling retrofitting proposals. Furthermore, LCA has the ability to analyze future scenarios. By simulating the impact of campus user growth, campus expansion, or energy changes on campus emissions, LCA can proactively design campus targets. Existing systems do not directly address such projections, providing only periodic monitoring.

The LCA approach and existing assessment systems can be viewed as complementary rather than alternatives. LCA can contribute to existing systems by providing in-depth analysis of environmental impacts (Swe et al.,2025). However, LCA's need for detailed data and expertise makes it challenging to implement on campus. Therefore, interuniversity data sharing, the development of common LCA infrastructures and the expansion of digital monitoring systems are gaining importance.

Conclusion

This study compares the LCA approach with commonly used sustainability assessment systems for campuses, demonstrating the potential of the LCA as a process-oriented, quantitative, and holistic framework. Existing systems are important tools for monitoring sustainability performance and encouraging campus improvement. However, they are largely input-based and operate with generalized indicators. The LCA, on the other hand, focuses on direct impact, quantifying the environmental burdens resulting from each process. This

approach offers different contributions to sustainable campus:

- LCA helps solidify sustainability goals by quantifying a campus's environmental footprint,
- LCA results provide strategic guidance on where resources should be focused, as they quantify the importance of different activity areas on campus,
- LCA provides visibility into lifecycle stages not covered by existing systems,
- In long-term planning, the LCA approach facilitates foresight by simulating the environmental consequences of campus growth and transformation scenarios,
- This foresight-enabled approach allows decision-makers to assess risks and develop preventative measures.

The analysis highlights the importance of LCA as a decision-support tool for policymakers and university administrations in the field of sustainability. As LCA implementations increase on campuses in the future, integration of LCA into existing assessment systems is expected to become more prominent. Consequently, universities can build greener and more livable campuses of the future by applying a process-oriented and data-driven decision-making approach to sustainability management.

Future studies could explore in more detail where the LCA approach can be more effectively applied at the campus level and how it can be integrated into existing assessment systems.

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CIVIC USE LANDSCAPES AS RESILIENT INFRASTRUCTURE: TECHNOLOGICAL STRATEGIES FOR ENERGY COMMUNITIES

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Civic Use Landscapes as Resilient Infrastructure: Technological Strategies for Energy Communities

Abstract: This paper explores the potential of civic use areas as landscape infrastructure for energy transition. Through the adaptation of the NPS- VIA method and the integration of three qualitative indicators – Perceived Landscape Value (PLV), Visual Exposure and Accessibility (VEA), Collective Use Vulnerability (CUV) – the study proposes an operational model for assessing the visual impact and design of Smart Renewable Energy Communities (SREC) in fragile rural contexts. The results, tested in the Molise municipalities chosen as case studies, highlight the effectiveness of a perceptual-functional approach to orienting sustainable and contextualised design choices. The methodology proves useful for promoting landscape and energy co-design strategies based on active participation and collective responsibility, offering replicable recommendations for public policies oriented towards climate neutrality and the enhancement of common goods.

Keywords: Visual Impact Assessment (VIA); Smart Renewable Energy Communities (SREC); Civic use areas; Resilient technological design; Energy landscapes.

Beyond preservation: the landscape as energy and cultural infrastructure

This study is part of the PRIN-PNRR research project COMECO: "From Common Goods to Ecological Resources", which explores the potential of civic use areas in the rural inland areas of Molise (a region in southern Italy) as strategic spaces for energy transition and landscape regeneration. The main objective of the research is to define a methodological and operational model for the resilient and climate-neutral transformation of these territories through the integration of Smart Renewable Energy Communities (SREC) and contextualised technological and environmental design strategies (European Commission, 2024).

Civic use areas represent a collective heritage that is often underutilised but has high landscape, ecological and social value. In this context, the recent Law 101/2024 provides important regulatory support, recognising the central role of renewable energy, energy efficiency and climate resilience in landscape planning. This paper aims to analyse how energy co-design, the enhancement of local resources and the adoption of integrated evaluation tools can contribute to the sustainable conversion of civic use areas, while safeguarding their traditional functions, social role and identity value.

The study is based on a solid theoretical foundation, built through a critical analysis of international literature on Visual Impact Assessment (VIA) (Cilliers et al, 2023), the governance of energy communities (Giannobile et al, 2024), and context-sensitive landscape design. In particular, reference was made to the NPS-VIA, Caltrans and Landscape Institute methods, adapting them to the specific contexts of Molise through a set of qualitative and

quantitative indicators: Perceived Landscape Value (PLV), Visual Exposure and Accessibility (VEA), and Vulnerability of Collective Use (VCU).

The aim of the work is twofold: on the one hand, to outline a replicable methodology for the evaluation and design of SRECs in fragile areas, and on the other, to contribute to the definition of national guidelines for the integration of landscape, energy and communities. The study is experimental in nature and focuses on six municipalities in Molise as pilot case studies – Agnone (IS), Bojano (CB), Capracotta (IS), Colletorto (CB), Gambatesa (CB), Morrone del Sannio (CB), Isernia – selected for their environmental and social characteristics. The main limitations concern the transferability of the results to non-rural contexts and the need for further validation on a larger scale. However, the preliminary results offer significant insights for rethinking civic use areas as genuine landscape devices for sustainable innovation.

Literature Review: environmental design, visual impact and energy communities

Scientific literature on Visual Impact Assessment (VIA) (Meyer et al, 2024) and environmental design has undergone significant evolution in recent years, moving from descriptive and quantitative approaches to predictive, interpretative and participatory models that integrate perceptual, cultural and functional components of the landscape. Among the most relevant references are the Caltrans VIA Handbook (CVH) Guidelines (2023) and the NPS-VIA methodology (Sullivan et al, 2014) developed in the context of US national parks, which proposes an interpretation of the landscape as a receptor and experiential space. The CVH has provided a regulatory and procedural basis for the evaluation of the visual impact of linear infrastructure and energy facilities, proposing replicable performance -based metrics for the analysis of visual contrast and perceptual sensitivity. At the same time, the Landscape Institute guidelines (TGN 02/21 - Landscape Institute, 2021) emphasise the need to recognise the perceived value of landscapes that are not formally protected, especially in rural and extra-urban contexts, where visual quality is often underestimated in decision-making processes.

Furthermore, Palmer's studies (2023) highlight the importance of scientifically validating visual evaluations, emphasising the importance of rigorous criteria to ensure consistency and transparency in technical judgements, with fundamental implications for the scientific legitimacy of VIAs in public debate and environmental planning.

This assessment basis is complemented by the framework of environmental design (Gangemi, 2001), understood as a discipline that addresses “the construction of habitat through complex processes and adaptable architectures” (Losasso, 2017), in which technology and

design interact to guide the transformation of the territory (Attaianese et al, 2022). The systemic approach of environmental design is not limited to mitigating impacts but takes on a proactive role in defining scenarios of climate resilience, ecosystem integration and social sustainability. It "can only have an organising role", as Maldonado (1990) points out, and is a cultural and technical response to the "disordered complexity" generated by the interaction between environmental crises and settlement patterns. The introduction of qualitative and quantitative tools that assess perceived landscape, visual accessibility and vulnerability of civic use is part of this methodological evolution. This paper proposes a model that combines the rigour of VIA metrics with the interpretative flexibility of environmental design, helping to bridge the gap between perceptual evaluation and functional analysis. Energy communities emerge in this context as devices for social and landscape innovation, which can activate new civic governance formats and strengthen the link between territory, energy, and collective identity.

From a more strictly energy- oriented perspective, studies on the integration of renewable sources and the landscape context (in particular agrivoltaics) emphasise the need for design solutions that are not limited to the evaluation of technical compatibility but also take into account social and identity dynamics. However, despite the growing attention to public participation in ecological transition processes, there remains a lack of methodologies capable of integrating perceptual indicators, territorial data and visual simulation tools in a coherent manner that is applicable to local contexts. In this scenario, the research work stands out for its goal of bridging the methodological gap between perceptual evaluation and functional analysis of territories, while contributing to the definition of new standards for environmental design (Hausladen et al., 2017) underlying the design of energy communities with low landscape impact (Gianaroli et al, 2024; Gray et al, 2024).

The integrated NPS-VIA model for civic use areas

The methodology adopted in this research project combines territorial analysis tools (GIS), visual assessment (NPS-VIA) and environmental design, with the aim of developing a replicable model for the sustainable design of Smart Renewable Energy Communities (SREC) in civic use areas. The method is divided into four main phases:

- WP1. Mapping of systemic flows (pre-post CER-S): the environmental and social flows active in the territory (energy resources, land consumption, presence of civic uses) were surveyed before and after the hypothetical introduction of a CER-S. This phase used territorial and socio-demographic data, organised according to an input-output logic.

The use of GIS enabled data management on a territorial scale in the six Molise municipalities included in the sample: Agnone (IS), Bojano (CB), Capracotta (IS), Colletorto (CB), Gambatesa (CB), Morrone del Sannio (CB) and Isernia.

- WP2. Visual scoping and landscape inventory: identification of publicly accessible and visually representative key observation points (KOPs), such as viewpoints, civic routes and rural roads, selected on the basis of visibility requirements, symbolic significance and frequency of use.
- WP3. Narrative analysis of visual impact: assessment of visual impact using the NPS-VIA method, adopting a qualitative approach that evaluates both the impact on users and the impact on the landscape as a bio-cultural receptor (the park as receptor). Each KOP was assessed through georeferenced visual simulations, using pre- and post-intervention scenarios, and the impacts were classified according to intensity levels (negligible, moderate, high, very high). For each KOP, the frequency method was applied to a series of qualitative indicators (Tab. 1), including the Perceived Landscape Value (PLV), which indicates the aesthetic and symbolic importance attributed to the place; Visual Exposure and Accessibility (VEA), which measures how visible the project is from points accessible to the community; Collective Use Vulnerability (CUV), which assesses the relevance of the place for civic or community activities.
- WP4. Mitigation and co-design: the environmental design of civic areas takes on an adaptive and integrated character. The solutions developed include, among others, vegetation screens with native species, minimisation of reflective surfaces, use of camouflage colours, reversible technologies and low-impact agrivoltaic configurations (Janota et al, 2023; Widmer et al, 2024; D'Ambrosio et al, 2025). The approach adopted promotes responsive design, capable of integrating environmental needs, cultural demands and regulatory requirements, while strengthening shared landscape governance and the social acceptability of transformations.

In WP3, a specific study was dedicated to the classification of users (Tab. 2), used as a basis for mapping visual sensitivity, constructing user-impact matrices, and structuring participation in Living Labs.

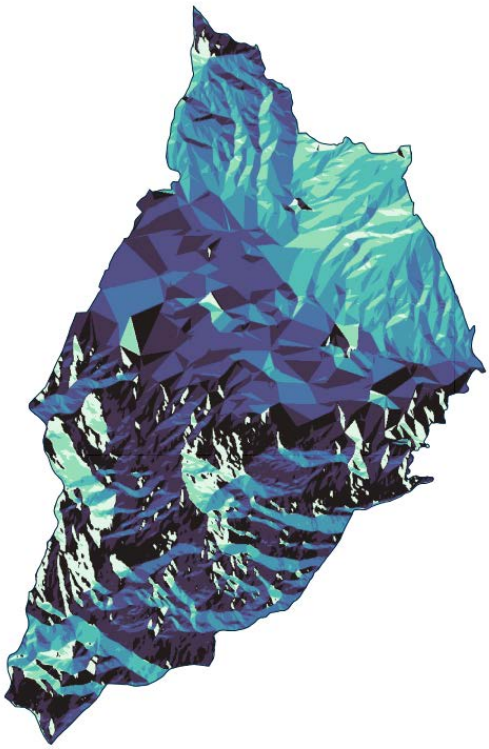
Table 1. The Indicators system

Code	Indicator	character
ID	KOP	*n.*
Coord.	GPS coordinates	*Lat - Long.*
Us	Type of consumer user	*Cfr. Tab. 2*
T	Observation time	*Breve/Prolungata*
VA	Visual expectations	*alta/media/bassa*
PLV	Perceived landscape value	+++>++>+
EVA	Exposure and visual accessibility	+++>++>+
CUV	Collective use Vulnerability	+++>++>+
CVS	Calculated visual sensitivity	*Metodo delle Frequenze*
I	Intactness	+++++>++++>+++>++>+
U	Unity	+++++>++++>+++>++>+
V	Vividness	+++++>++++>+++>++>+
VC	Visual Change	*Negligible/Weak/Moderate/Strong/Severe*
VS	Viewer Sensitivity	*Low/Medium/High*
GVIC	Global Visual Impact Class	*Low/Medium/High*

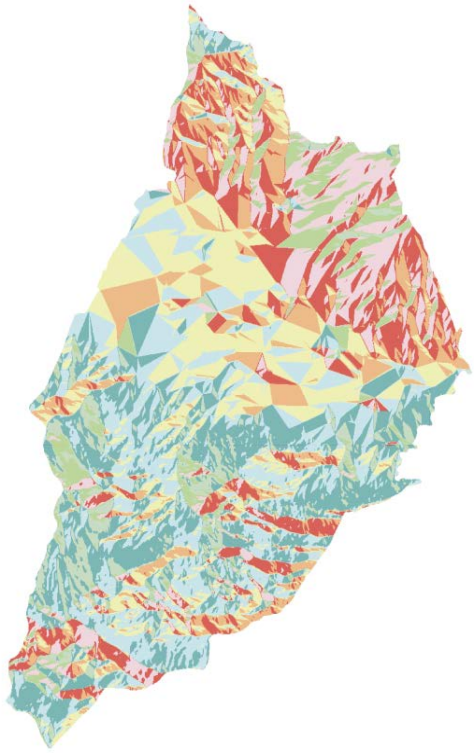
Table 2. Classification of users/consumers

N.	Users/Consumers	Typology
1	URBAN/METROPOLITAN AREA RESIDENTS (indirectly involved in the infrastructure landscape and/or energy beneficiaries)	Residents of the historic city: individuals with a strong sense of identity and perception of the surrounding rural landscape.
		Residents of the established city: permanent citizens, potentially indirect users of the energy produced and occasional observers
		Residents of peripheral areas: physically closer to the civic use area, they may perceive the infrastructure with greater continuity
		Residents of satellite urban centres: linked by commuter flows, visually exposed to varying degrees
2	DIRECT USERS of collective facilities, tourists and cultural users	Users of educational, health, commercial and administrative services: permanent residents who frequent public places
		Users of green spaces, hiking trails and recreational areas: in direct visual/functional relationship with the rural environment
		Users of historical, cultural or religious sites: they attribute a high symbolic value to the landscape context
3	EMPLOYEES involved in economic, productive and research activities	Agricultural and forestry operators (involved in the management and/or monitoring of civic areas or the infrastructure itself)
		Artisans
		Technicians
		Researchers
4	LOCAL WORKFORCE	Local labour employed on construction sites or in routine/extraordinary maintenance of the infrastructure (continuous and direct visual fruition)
5	DIRECT USERS of transport infrastructure	Private transport users (with a view of the areas)
		Public transport users
		Pedestrians and cyclists (slowly visual fruition)
6	INDIRECT USERS AND INSTITUTIONAL/SOCIAL STAKEHOLDERS	Residents of neighbouring rural and peri-urban areas, with visual exposure and indirect impact on landscape uses and values
		Private, collective or public entities: local authorities, civic associations, energy cooperatives, territorial committees, with an active/passive role in decision-making and social monitoring

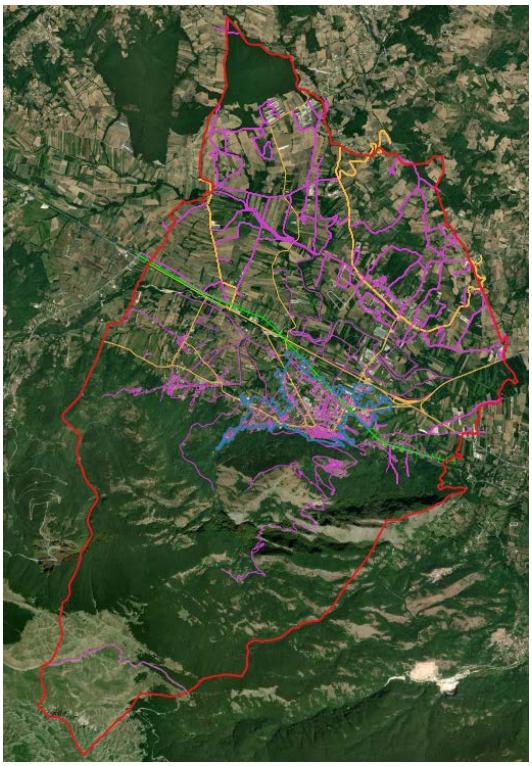
Examples of maps developed during WP1 and WP2 relating to the municipality of Boiano can be found below.



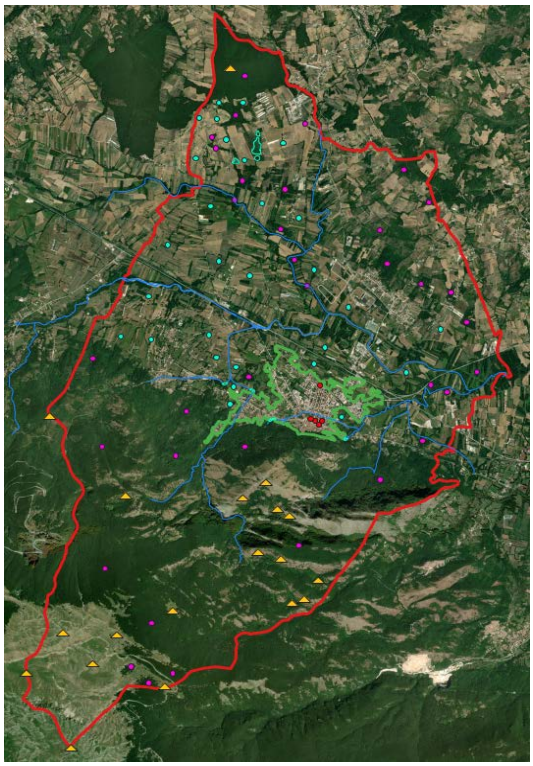
PREVAILING WIND



SOLAR EXPOSURE



ROAD INFRASTRUCTURE NETWORK



NATURAL ELEMENTS

Figure 1. Analysis of the Boiano area in preparation for the visual impact assessment.

Towards adaptive, resilient and energy-efficient design

The final results show that even small-scale photovoltaic systems can have a significant impact in contexts of high symbolic value (Hilker et al, 2024), while situations with low vulnerability of collective use can tolerate more visible interventions. The integration of the assessment with GIS tools and participatory processes has strengthened decision-making transparency and collective awareness, making the landscape not only an object of protection but also an active device for innovation and citizenship. In this study, GIS was used not only as a tool to support localisation and visual simulation, but also as a real design control interface, capable of integrating perceptual, morphological and functional analyses (Ashkezari et al, 2018; Mai et al, 2019). Reference was made to the concept of Visual Magnitude, adapted to routes and viewpoints that are significant for the community (Chamberlain et al, 2013), in order to calculate not only what is visible, but how what is visible can influence the observer's perceptual judgement and emotional response.

The experimental application of the proposed methodology in the case studies demonstrated the effectiveness of an integrated approach to visual impact assessment, based on contextualised qualitative indicators. The results confirmed the importance of visual quality as a parameter supporting design decisions, especially in contexts with strong landscape characteristics and social connotations. The use of indicators made it possible to articulate the assessment not only in terms of visual compatibility, but also in terms of the identity and functional relevance of places for local communities. In particular, the Perceived Landscape Value highlighted the deep link between aesthetic quality and collective memory, while Visual Exposure and Accessibility showed how the perceived impact strongly depends on the visibility of the project in places that are regularly frequented. Finally, Collective Use Vulnerability highlighted the relationship between visual impact and potential loss of civic use function. The intersection of these indicators made it possible to construct visual sensitivity maps integrated into a GIS environment, which are useful for guiding the location, configuration and mitigation strategies of community photovoltaic systems.

The methodology also highlighted the potential of the NPS-EIA approach in promoting transparent and inclusive decision-making processes, in which the perceptual dimension is not treated as a subjective and marginal factor, but as a structural component of the project. Co-design with the community, combined with the adoption of low-impact technological solutions (agrivoltaics, low-reflectance materials, native plant screens), has helped to outline an adaptive

design model capable of combining climate resilience, energy efficiency and landscape protection.

Ultimately, the results suggest that civic use areas, if addressed with tools capable of managing data complexity and integrated and participatory approaches, can be transformed into energy infrastructures without losing their social nature and can be capable of promoting innovative models of sustainable resource use. This approach, which can be replicated in other fragile contexts, represents an operational contribution to the construction of resilient and socially inclusive landscapes, in line with the principles of Law 101/2024 and with the decarbonisation strategies promoted at European level.

Conclusions: Resilient landscapes as civic infrastructure for climate neutrality

The results of this research confirm that, if properly managed, civic use areas can constitute a strategic civic infrastructure for addressing the challenges of energy and climate transition. The integration of perceptual assessment and environmental design has shown that the landscape, particularly in marginal rural contexts (Shi et al, 2024), should not be interpreted solely as an element to be protected, but can be an active resource for energy production, strengthening social cohesion and territorial regeneration. The methodological model based on the NPS-VIA approach has made it possible to develop a structured interpretation of visual impact, with particular attention to the relationship between perception, function and the identity value of places. The classification of visual sensitivity has been an effective tool for differentiating design and mitigation strategies, avoiding standardised approaches and promoting contextual, resilient and shared solutions. Simulations applied to case studies have also shown that landscape impact is not a direct function of the scale of the intervention, but of its location in relation to local usage dynamics and meanings.

Among the most relevant theoretical implications is the need to broaden the concept of landscape sustainability to include perceptual and social dimensions that are often overlooked by conventional assessment protocols. In practical terms, the work provides a solid basis for the development of replicable guidelines for the implementation of Smart Renewable Energy Communities (CER-S) in civic use areas. The main recommendations concern: the construction of visual sensitivity maps integrated into authorisation processes; the adoption of low-impact design solutions; the activation of collaborative governance tools based on transparency, participation and shared responsibility.

However, the study also presents some critical issues, linked to the need to validate the method on a larger number of territorial contexts and to integrate the model with quantitative visual perception data (e.g. eye tracking, digital surveys). Further developments in the research could explore the role of immersive digital technologies for public communication of landscape impact and the construction of shared transition scenarios. In conclusion, the work offers an original contribution to the definition of a new design paradigm that considers the landscape as civic infrastructure, capable of combining climate neutrality, visual quality and social equity on a territorial scale.

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BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

EVALUATION OF SOLID-STATE LIGHTING ACCORDING TO BIOPHILIC DESIGN PRINCIPLES

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Evaluation of Solid-State Lighting According to Biophilic Design Principles

Abstract: Biophilic design is a design approach that supports users' physical and psychological well-being by incorporating natural elements into interior spaces. With increasing urbanization, people have started to spend most of their time indoors. This has led to limited access to natural light, one of the key criteria of biophilic design. With technological advances, solid-state lighting (SSL) has emerged as a viable alternative for mimicking natural light in interior environments. This study evaluates the role and advantages of SSL within the context of biophilic design. A current literature review discusses the importance of biophilic design and its relationship with lighting, the working principles and features of SSL, and the innovations it brings. The findings indicate that properly implemented SSL systems fulfill biophilic design criteria and are sustainable, human-centered, and compatible with circadian rhythms.

Keywords: biophilic design; solid-state lighting; light and health; circadian rhythm; sustainability

Introduction

Human health, comfort, and psychological well-being are gaining increasing importance in interior design. The intense stress of modern life and artificial environmental conditions have brought the impact of spatial experiences in these areas to the forefront. In this context, the biophilic design approach aims to strengthen the human connection with nature and support physical and mental health by integrating natural elements into spatial design. The growing population, rapid urbanization, and spaces adapting to new technologies have gradually weakened and, in some cases, severed the human connection with nature. As this disconnection deepens, numerous academic studies have emphasized the importance of re-establishing the human-nature bond (Beatley, 2016; Joye & van den Berg, 2011). Biophilic design emerges as an interdisciplinary approach that aims to strengthen the human connection to nature and integrate this understanding into modern architectural practices. It reconstructs the bond between humans and nature by incorporating plants, natural light, water, organic forms, and natural materials into interior spaces. Numerous studies have shown that biophilic design positively impacts psychological and physical health (Wilson, 1984; Kellert & Calabrese, 2015; Karaman & Avci, 2022). These studies present biophilic design as an aesthetic choice and a spatial strategy that activates sensory and cognitive responses (Kellert, 2008).

In recent years, advancements in lighting technologies—particularly Solid State Lighting (SSL) systems that are energy-efficient, flexible in aesthetics, and adaptable to user needs—have significantly contributed to the spatial experience of biophilic design. SSL lighting is an environmentally friendly alternative that enhances user comfort through uniform light distribution, adjustable color temperature, and human-centered design while supporting

sustainability. In this context, this study explores the intersection between SSL technologies and biophilic design, evaluating their potential to create sustainable and healthy interior environments. Within a qualitative research approach based on a literature review, the technical and user-centered characteristics of LED and OLED systems in interior design are examined alongside biophilic design's health, psychological, and spatial experience dimensions. Drawing from national and international sources, the study analyzes how contemporary lighting solutions align with biophilic design principles. It investigates the integration of artificial lighting into spaces in terms of user comfort, psychological-physiological effects, and sustainability.

The Relationship Between LED and Biophilic Design

LED lighting systems are becoming increasingly central to biophilic design due to their ability to mimic natural light patterns and their positive effects on human health. With controllable features such as color temperature, light intensity, and directionality, these systems bring the dynamic qualities of daylight into interior spaces. In doing so, they enable lighting scenarios that align with users' biological rhythms, promoting better sleep quality, reduced stress levels, and enhanced concentration.

For example, warm-toned lighting during evening hours enhances the sense of calm, while cooler tones preferred during the daytime support alertness and mental focus (Figueiro et al., 2016). Figure 1 illustrates a circadian lighting chart designed to support the circadian rhythm. Studies have shown that LED lighting with low color temperatures—such as 1900K or below—significantly increases melatonin secretion. LEDs are human-centered and health-conscious lighting solutions, so they are considered an integral component of biophilic artificial lighting design (Lin et al., 2019).

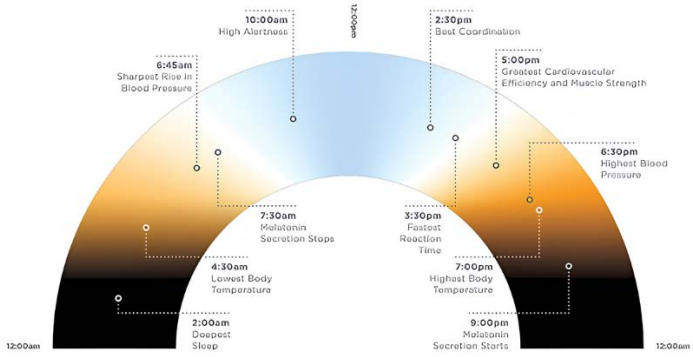

Figure 1. Circadian Lighting Chart (Figueiro et al., 2016).

LED lighting has brought about a significant transformation in interior design regarding energy efficiency and user comfort. Compared to traditional lighting systems, LEDs consume considerably less energy, thereby reducing operational costs and contributing to environmental sustainability. When integrated with technologies such as motion sensors, daylight-responsive systems, and dimming controls, energy savings can reach up to 80% (Tsao et al., 2010). A comparison of the energy efficiency of LEDs with other artificial lighting sources is presented in Figure 2.

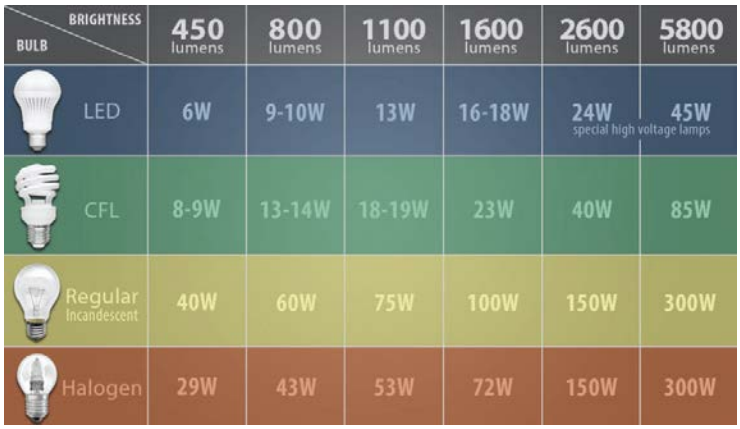

Figure 2. Artificial Lighting Sources and Energy Efficiency Performance (Steyer, 2020).

Another key advantage of LED systems is their ability to provide lighting that aligns with biological rhythms. The adjustable intensity and color temperature of light allow for a range of lighting scenarios-from cool tones that enhance focus to warm tones that promote relaxation. This flexibility increases comfort and well-being in various settings, including homes, offices, and patient rooms in healthcare facilities (Figueiro et al., 2016). Moreover, advanced LED systems can respond to environmental factors, enabling synchronization with natural daylight throughout the day. This improves energy efficiency and enhances user experience, making LED technology an essential component of contemporary building design (Figueiro et al., 2016).

The Relationship Between OLED and Biophilic Design

Due to their slim, lightweight, durable, and semi-transparent characteristics, OLEDs offer great potential for use in architecture, interior design, and portable electronic devices. They play a crucial role in balancing energy efficiency and user comfort within indoor environments while enhancing the space's aesthetics and ambiance by providing tailored lighting solutions that complement the design. However, challenges like high manufacturing costs and sensitivity to environmental conditions like humidity still exist. Nevertheless,

advancements in production technologies and materials science are expected to overcome these limitations (Avci, 2024; Pode, 2020).

Reineke et al. (2009) noted that OLEDs are preferred in interior spaces due to their uniform light distribution and flexible design possibilities. Avci (2017) emphasized that OLEDs enhance visual comfort thanks to their low heat emission and color quality, resembling natural lighting. Zhang (2019) found that OLEDs, with their homogeneous and warm light sources, are compatible with biophilic design approaches and improve user experience. Li (2019) also observed that artificial lighting, like natural light, positively affects human biological rhythms and psychology. In this context, OLEDs provide benefits not only on a visual level but also psychologically and biologically.

Biophilic design aims to strengthen the connection with nature in built environments. OLED lighting mimics natural light and is considered a salutogenic (health-supporting) design element. It positively influences interior spaces' social, psychological, physical, and behavioral patterns (Avci, 2024). Such lighting supports the circadian rhythm, enabling users to lead more productive, healthier, and balanced lives (Terrapin Bright Green, 2014; Hawes et al., 2012). Studies by Yassein and Ebrahiem (2018) and Demirkol and Önaç (2024) have also shown that environments applying biophilic design principles reduce stress, increase motivation, and enhance overall well-being. In this respect, OLED lighting offers innovative, nature-integrated, and health-conscious solutions for interior space users.

When OLED panels are laminated onto wall or ceiling surfaces, they emit a soft and diffuse glow reminiscent of natural daylight. Compared to the harsh and point-like light emitted by traditional LEDs, this creates a much more natural and calming atmosphere in the space. Since the OLED light source is not perceptible, it produces a compelling visual illusion as if natural light enters the interior through a window (Terrapin Bright Green, 2014).

The minimal heat emission of OLED technology makes it ideal for use alongside delicate natural materials such as wood, textiles, and live plants. This feature provides great freedom in designing lighting fixtures inspired by leaves, waves, or other organic forms. Designers can create fixtures that maintain aesthetic integrity and strengthen biophilic connections (Hawes et al., 2012). From an aesthetic perspective, OLED panels are nearly invisible when off, and when activated, they emit uniform light without causing shadows or glare. This characteristic allows smooth transitions between task-focused and natural lighting scenarios that create ambiance. Moreover, these transitions occur without noticeable color shifts, enhancing visual consistency and psychological comfort (Hawes et al., 2012; Terrapin

Bright Green, 2014). Overall, OLED technology enables spaces to be illuminated more ergonomically, aesthetically pleasing, naturally, and sustainable. This elevates the built environment's quality visually, emotionally, and environmentally (Reineke et al., 2009; Peretti, 2013; Zhang, 2019).

Discussion and Conclusion

The findings of this study demonstrate that biophilic design is a holistic approach aimed at creating healthy, comfortable, and sustainable spaces. In areas with limited or insufficient access to natural light, artificial lighting must be compatible with this approach. In particular, solid-state lighting systems (LED and OLED) have laid the foundation for biophilic artificial lighting. These systems not only meet the spatial requirements but also support the psychological and physiological well-being of users, thereby enhancing the creation of biophilic interior environments. LEDs' energy efficiency, compatibility with circadian rhythms, and ability to be equipped with intelligent control systems, along with OLEDs' homogeneous, soft, and natural light quality, make both technologies strong candidates for biophilic design. They offer valuable solutions in interiors concerning both health and sustainability.

Despite its potential, OLED technology faces limitations such as a shorter operational lifespan compared to LEDs, high initial costs, and complex manufacturing processes, which restrict its widespread adoption. However, ongoing research in materials and production techniques holds promise for overcoming these barriers. Research on the long-term effects of biophilic artificial lighting designs remains limited, indicating a need for interdisciplinary and comprehensive studies in this field. It is anticipated that, in the near future, the use of SSL technologies will contribute to the proliferation of sustainable, human-centered, and nature-aligned spaces.

Biophilic design and SSL are both current and evolving topics. In the future, biophilic lighting will include natural lighting and artificial lighting solutions as critical components of this concept. The use of SSL technologies should be encouraged across all areas of life through policy support, certifications such as WELL and LEED, and integration into architectural education. Implementing biophilic artificial lighting systems should become mandatory, especially in public buildings like educational and healthcare facilities.

In conclusion, based on all findings and recommendations, it is evident that SSL systems are currently essential lighting technologies that enhance living environments within the

context of biophilic design. SSL represents a technical advancement and a philosophical shift in how we understand the role of light in shaping human experience. This approach, which combines technology and nature, offers a significant opportunity to redefine the sensory and ethical dimensions of interior architecture.

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BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

FROM GREY TO GREEN: RETHINKING URBAN IN-BETWEEN SPACES THROUGH ROOFTOP AGRICULTURE AND CLIMATE DESIGN

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BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

From Grey to Green: Rethinking Urban In-Between Spaces through Rooftop Agriculture and Climate Design

Abstract: Urban in-between spaces, often overlooked in conventional planning, present untapped opportunities to address climate change through spatial reactivation. This paper explores the potential of rooftop agriculture as a climate-responsive strategy to convert residual urban surfaces into productive green infrastructures. Grounded in the concepts of climate-sensitive design and nature-based solutions, the study discusses how rooftops can contribute to urban decarbonization. By examining the ecological, social, and spatial dimensions of rooftop agriculture, the research proposes a reconfiguration of urban metabolism based on multi-functional land use. The aim is to offer a contribution that integrates architecture, agriculture, and climate resilience, transforming the urban fabric from grey to green. The paper contributes to the discussion on climate-neutral cities by highlighting the strategic role of in-between spaces in sustainable urban transformation.

Keywords: rooftop agriculture; climate design; urban farming; in-between spaces; decarbonization

Introduction

Cities must adopt a holistic perspective to strengthen resilience against future climate and health-related crises, fostering greener, smarter, more equitable, and efficient urban environments (WEF, 2021). Prioritizing human well-being in this process is essential for mobilizing collective support for climate mitigation (UNEP, 2020). The primary challenge lies in enhancing urban adaptive capacities while advancing a circular and green economy in the built environment—shifting from reactive responses to proactive strategies that address the causes of climate risks (WEF, 2021).

In this context, green infrastructure has increasingly been recognized as a pivotal strategy for embedding ecological functionality into urban environments. Defined as a coherent system of natural and semi-natural spaces designed and managed to deliver a wide range of ecosystem services, it contributes to improving air quality, reducing the urban heat island effect, managing stormwater, and enhancing urban biodiversity (Kabisch et al., 2016).

Within the urban system, in-between spaces are increasingly recognized as potential connective elements and microclimatic regulators. Historically marginalized as “leftovers” of urban morphology, their inherent spatial ambiguity positions them as transitional environments that mediate between built form and social use, embodying flexibility and temporality (Carmona, 2010). They could be pertinent to buildings, indoor or outdoor, between buildings or a network of different spaces. If strategically designed, in-between spaces can be repurposed as multifunctional ecological platforms that contribute to both environmental performance and urban liveability, as a strategic design tool to reframe the relationship between architecture and ecological systems, contributing to decarbonization and climate neutrality.

Rooftops, given their prevalence in dense urban contexts, represent a critical resource for climate-sensitive retrofitting (Shahmohammad et al., 2022). Rooftop greening enhances passive energy performance by improving building insulation and regulating microclimatic conditions, including the reduction of urban heat islands and mitigation of stormwater runoff (Berardi, 2016). Beyond these technical benefits, rooftop green spaces can foster social inclusion and cohesion by creating opportunities for community interaction, collective urban gardening, and environmental education.

Transforming unused roof surfaces into productive landscapes by introducing vegetated surfaces in dense urban contexts, contributes to climate resilience strategies, strengthening the adaptive capacity of cities in the face of increasing climate variability and extreme weather events (Zölch et al., 2017).

Ranging from intensive greenhouses to extensive green roofs for vegetables or herbs and implemented through climate design principles, rooftop green infrastructure can serve as an enabling infrastructure for low-carbon, adaptive, and inclusive cities, boosting the socio-ecological integration within the built environment, enhancing environmental performance, such as stormwater retention and CO_2 sequestration, and contributing to food security, community engagement, and local economic development (Specht et al., 2014).

This paper explores the intersection of rooftop agriculture and climate-sensitive urban design within the framework of in-between spaces. Its objective is to examine how architectural interventions on rooftops can contribute to the broader agenda of urban decarbonization. By analyzing both theoretical and applied perspectives, the study aims to offer a design-oriented contribution to the discourse on sustainable urban transformation.

Methodology

This research adopts a multi-step methodological approach that combines theoretical inquiry with empirical analysis.

First, a comprehensive literature review was conducted, examining the state of the art at both national and international levels. Academic sources, scientific reports, and institutional documents were analyzed to trace the evolution of discourses on urban resilience, climate-sensitive design, and building-integrated agriculture. This phase provided the conceptual and theoretical foundations for framing the role of in-between spaces, and specifically rooftops, as enabling infrastructures for sustainable urban transformation.

Second, the study engaged in a systematic review of policy frameworks and sectoral reports. By integrating global, European, and local-scale documentation, this stage assessed how policy directives, regulatory instruments, and institutional agendas are currently addressing rooftop greening, urban agriculture, and climate-adaptive infrastructures. This step allowed for identifying both enabling conditions and governance gaps in the implementation of rooftop farming practices.

Third, an analytical investigation of selected case studies was undertaken. International best practices of rooftop agriculture and green infrastructure were examined, with particular attention to their design strategies, technical feasibility, and socio-ecological impacts. Cases were chosen to reflect a diversity of scales, typologies, and contexts, ranging from experimental research centers to large-scale commercial farms and community-based initiatives. Comparative analysis enabled the identification of transferable design principles and context-dependent variables.

Finally, the insights from the literature, policy review, and case study analysis were synthesized into a design-oriented framework. This interpretive step aimed to articulate how rooftop farming and climate-sensitive strategies for in-between spaces can contribute to urban decarbonization and resilience. The resulting framework underpins the discussion and conclusions of the paper, offering a structured contribution to the ongoing discourse on sustainable architectural and urban design.

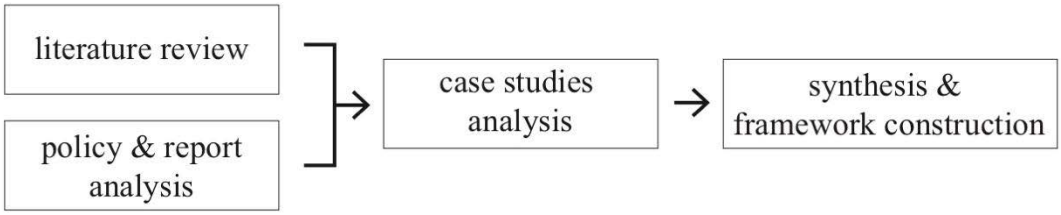

Figure 1 – Four steps of the methodological framework

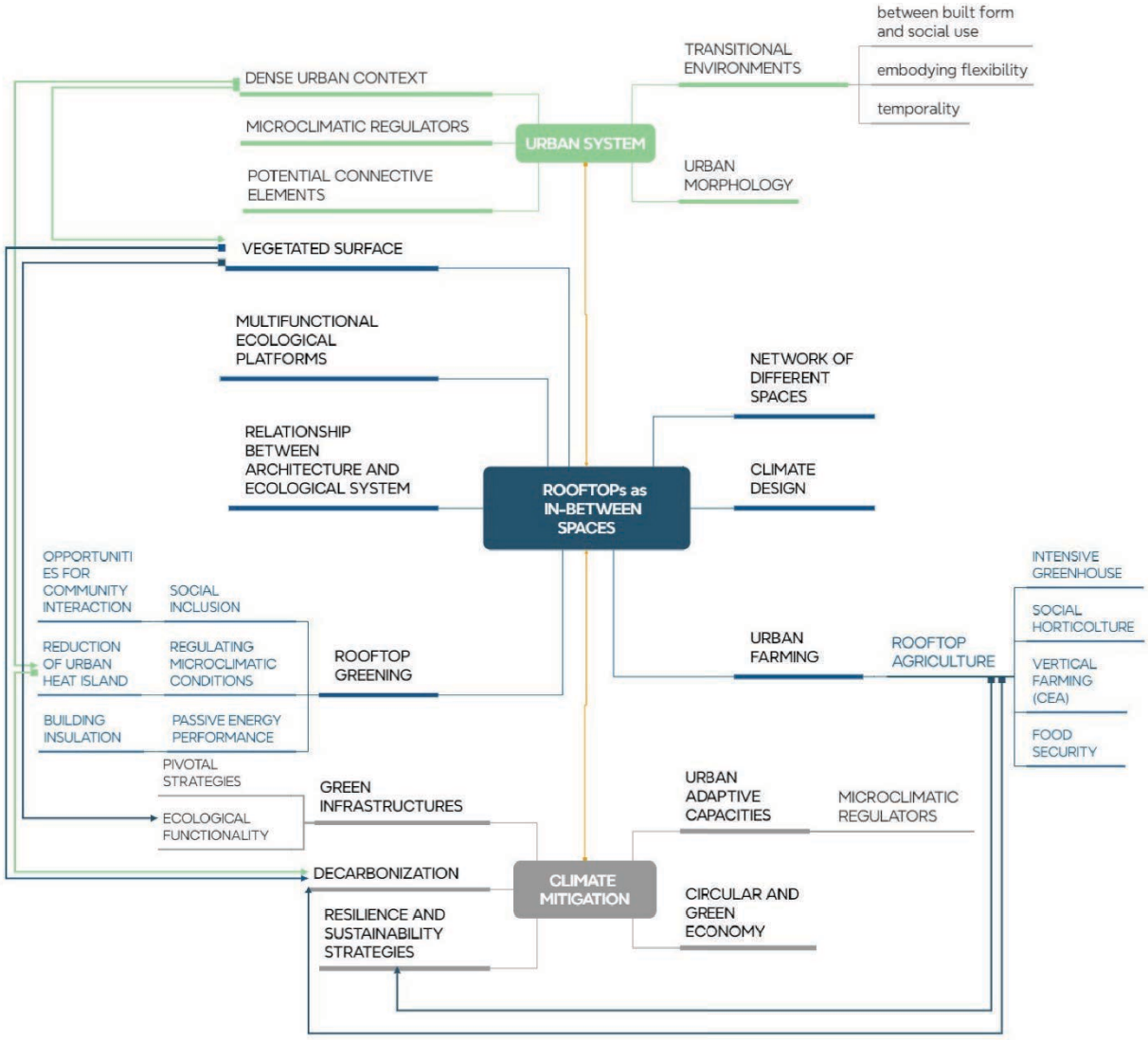

Figure 2 – Scheme of the methodological process to describe the connection between rooftop topics, urban system and climate mitigation.

Food production and building-integrated agriculture

With the high growth rates of urbanized areas, food systems can play an important role in increasing their resilience and sustainability, taking on a role in shaping land use patterns, consumption, and waste disposal, as well as their substantial contribution to climate change, fostering food production, social inclusiveness and new spatial realities within urban fabrics.

The urban demand for food coverage is met at the local level by Local Food Policies, in opposition to the global process of production-distribution-consumption system deterritorialization, to which both social and environmental needs are linked (Di Iacovo, 2008).

The spatial relationship between the built environment and food production occurs through urban and peri urban agriculture and the implications related to land consumption and the reuse of brownfield sites (Resilience Alliance, 2007). Urban agriculture, in all its forms and variations, promotes encounters, the creation of social mixite and relationships, and therefore a sense of community, becoming a resilient tool for social inclusion and rehabilitation within communities, whether neighborhood, local, or condominium based.

Cities must consider a holistic territorial approach to food systems that involve both the region and cities, connects urban and peri-urban areas to rural areas, thereby recognizing that urban agriculture and soilless systems, such as hi-tech farms and vertical farming, are not sufficient to meet food demand (ICLEI, 2019).

The spatial scale of implementation also affects impact. Beyond the building scale, green rooftops influence broader urban systems, as an integral part of the urban socio-economic and ecological system (Mougeot, 2000) and varies from city to city, depending on size, actors involved, intra-urban or peri-urban location, private or public, types of products, types of economic activities, and markets.

The most common form is to place a commercial production activity on an urban rooftop farm, where the building must be adaptable to this function, in terms of vertical connections, dimensions and structural characteristics.

Urban building-integrated agriculture (Caplow and Nelkin, 2007) consists of adapting and integrating soilless cultivation techniques such as hydroponics or aquaponics into buildings to exploit synergies between buildings and agricultural activities.

Urban roof farming must contend with automated and digital soil-less systems and sustainable development, in particular with human capital as a productive opportunity and catalyst for economic, environmental, social, and cultural interests, including new forms of governance and farm management, that change systems, zero-kilometer production chain and eating habits towards an ever-increasing consumption of vegetable proteins.

Climate design strategies for green roofs

A climate-sensitive design approach for in-between spaces prioritizes the reduction of greenhouse gas emissions and the enhancement of local environmental quality. Central to this strategy is the concept of decarbonization, which involves minimizing the carbon footprint of buildings and urban systems. The reactivation of underutilized rooftops through green

infrastructure contributes to this agenda by enabling passive climate regulation, reducing energy consumption, and promoting carbon sequestration (Getter & Rowe, 2006).

Passive climate-responsive design strategies (such as the use of thermal mass, natural ventilation, strategic shading, and vegetative layering) can be effectively integrated into rooftop configurations to enhance energy efficiency and occupant comfort without relying on mechanical systems. These strategies support a microclimatic balance, reduce cooling loads, and increase surface albedo, thus mitigating the urban heat island effect. In parallel, nature-based solutions (NbS) offer an integrated framework for advancing climate-responsive design by embedding natural processes directly within the built environment. Rather than treating environmental mitigation as an add-on, NbS incorporates ecosystem functions (e.g. shading from vegetation, evapotranspiration, soil-water interactions, and biodiversity corridors) into architectural and urban contexts. This approach facilitates a transition from static, technologically driven systems to adaptive living infrastructures capable of responding dynamically to environmental fluctuations (Frantzeskaki, 2019). When applied to in-between spaces like rooftops, NbS support multiple co-benefits: they regulate thermal performance, improve air and water quality, reduce run-off, and create microhabitats for urban flora and fauna. Moreover, their multifunctional nature makes them suited for dense urban contexts where space is limited but climate adaptation pressure is high. NbS become not merely ecological interventions, but spatial strategies that reconnect built form with environmental processes, while simultaneously enhancing urban resilience and livability.

Roof spaces are technically capable of hosting green and productive functions, due to the presence of water supply and storage rooms. These functions are amplified when vegetation types are selected for evapotranspirative performance, productivity and local adaptability. Vertical farms act as an adaptive and resilient element within urban farms, when installed on urban rooftops, thanks to a subset of integrated or stand-alone green infrastructure systems, indoors and outdoors, whether for self-consumption, commercial purposes, or simply for design.

The widespread adoption of green roofs can lower ambient temperatures at the city level and reduce energy load peaks (Susca et al., 2011). However, it is necessary to understand the scale of the vertical farms, micro or medium, and their location for the extension of cultivation areas: near outdoor spaces, adjacent to buildings, or in interstitial and/or appurtenant or ancillary spaces.

An example of this networked approach is the concept of "green corridors", which link rooftop and vertical gardens into continuous ecological pathways. These systems promote biodiversity, enable pollination routes, and support peri-urban connectivity. In densely built environments, the use of rooftops for such purposes is often the most viable option for expanding green space.

Design tools such as performance simulation, GIS-based mapping, and participatory co-design methods can guide spatial planning and stakeholder engagement, by combining environmental data with socio-economic indicators. Policies that incentivize green retrofits through subsidies, density bonuses, or regulatory mandates play a crucial role in mainstreaming rooftop agriculture (Oberndorfer et al., 2007).

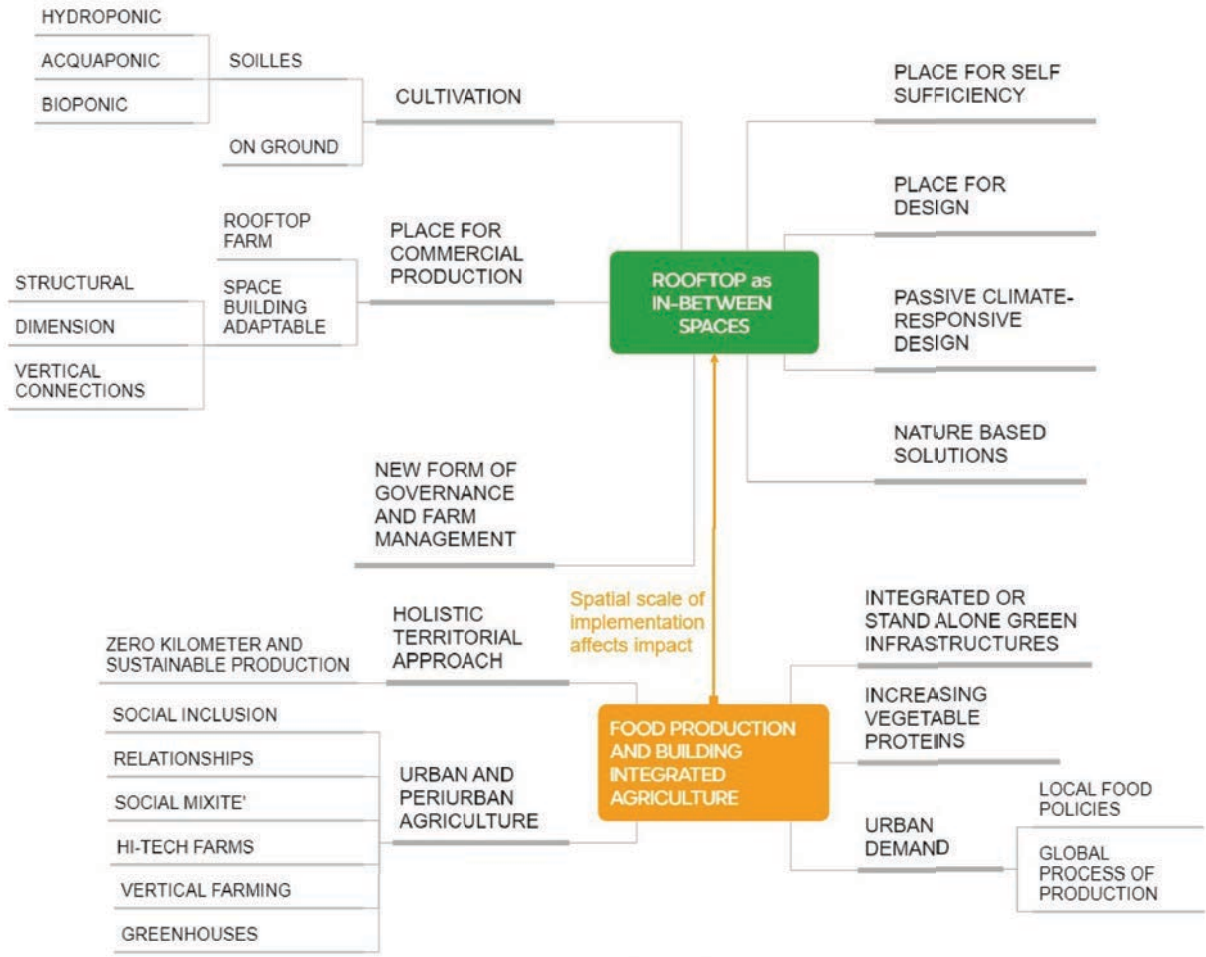

Figure 3 – Scheme of the design-oriented framework to describe building integrated agriculture on rooftops.

From roof to resource: rooftop agriculture as climate infrastructure

Green roofs perform a suite of ecological functions that are pivotal for climate adaptation and mitigation in urban environments, particularly in cities facing intensifying climate-related stressors such as prolonged heatwaves, extreme precipitation events, and drought conditions. As vegetated systems integrated into building envelopes, they intercept and retain precipitation, attenuating peak stormwater flows and reducing the burden on conventional drainage infrastructure (Shafique et al., 2018). Their substrate layers and vegetation act as biofilters, capturing airborne particulate matter and absorbing gaseous pollutants, thereby improving local air quality. Additionally, by providing structurally diverse habitats, green roofs can enhance urban biodiversity, supporting pollinators, birds, and invertebrate species otherwise excluded from densely built environments. In Basel, Switzerland, green roofs are mandatory on new buildings since the early 2000s, while in Paris, rooftop gardens have been incorporated into the city's Plan Biodiversité, illustrating the role of design regulation in promoting ecological integration.

Acting as distributed "miniature ecosystems", green roofs buffer thermal fluctuations, increase evapotranspirative cooling, and contribute to carbon sequestration. In doing so, they reduce dependence on resource-intensive grey infrastructure while strengthening the ecological resilience of the urban fabric. The multifunctionality of green roofs positions them as a key component in climate-responsive urban design strategies, where adaptation and mitigation goals intersect within a single architectural intervention (Mihalakakou, et al., 2023).

From a food systems perspective, rooftop agriculture introduces productive capacity into urban cores. It addresses issues of food access and environmental justice by providing locally grown produce, reducing food miles, and supporting circular economy practices. Urban farming initiatives can repurpose organic waste into compost, recover water, and shorten supply chains. Such integration fosters a regenerative metabolism within the urban system.

Considering best practices of greenhouse systems as a roofing plan with food production, on existing or new residential or commercial buildings, the building-integrated agriculture may vary depending on type of productions, indoor spaces organization, presence of controlled environmental agriculture (CEA) environments and the capacity to accumulate and transmit energy to the building

The ICTA-ICP research center in Barcelona, was built with a greenhouse on the rooftop, with horizontal structure for food production (not commercial). Collaborating with the atrium

for ventilation, the greenhouse allows the reuse of accumulated heat and CO_2 concentration, improving the energy efficiency of the building itself.

The REWE Green Farm in Wiesbaden, Germany, is a medium farm on a shopping center roof. For its building typology, the vertical farm occupies a large surface, enabling production suitable for zero-kilometer sales. As the greenhouses are not directly connected to the atrium, they are CEA environment spaces that can also accommodate aquaponic systems.

The UF002 DE SCHILDE urban farm in Rotterdam was a rooftop greenhouse, added to the roof of a residential building. It was intended as a medium-sized farm for commercialization acting as a buffer zone on the top of the building, hosting hydroponic and aquaponic systems.

Socially, rooftop farms support community cohesion and education, providing spaces for engagement, learning, and co-creation. Brooklyn Grange in New York and Lufa Farms in Montreal demonstrate how rooftop agriculture can function at a commercial scale while maintaining community-oriented programs, highlighting the scalability of climate-resilient design within the economic and regulatory constraints of cities.

Local implementation strategies depend on climatic, cultural, and infrastructural contexts: in Mediterranean cities water-efficient agriculture and drought-resistant vegetation are prioritized; in East Asian metropolises hydroponic rooftop systems are increasingly adopted due to space constraints. These variations demonstrate the adaptability of rooftop agriculture across global urban conditions. Furthermore, emerging technologies such as smart irrigation, IoT-based soil monitoring, and vertical farming systems can enhance productivity and reduce environmental impacts.

Technical feasibility and social innovation are key to the long-term success of rooftop farming. Cooperatives, non-profits, and social enterprises often lead such projects, bridging gaps in knowledge, funding, and management.

Discussion and Conclusion

The revalorization of in-between spaces—especially rooftops—offers a transformative strategy for climate-responsive urbanism. By shifting their role from marginal voids to productive ecosystems, cities can recover unused surfaces for environmental benefit.

A critical reflection on this transition reveals both opportunities and constraints. On one hand, rooftop agriculture enables decentralized infrastructure that responds to local needs and enhances spatial equity. On the other hand, challenges such as structural load capacity, water

availability, maintenance, and social acceptance must be addressed. The successful integration of green roofs and urban farms requires collaborative governance, technical expertise, and financial support mechanisms.

The implications extend beyond architecture and urban planning into public health, climate policy, and food systems. By embedding productive green infrastructure in in-between spaces, cities can foster resilience to environmental stressors, economic and social disruptions. Green rooftops can support physical and mental well-being, reduce food insecurity, and promote sustainable behaviours at the community scale.

Future perspectives should investigate cross-scalar impacts, from building to district to metropolitan levels, integrating design tools such as spatial mapping, performance simulation, and participatory planning, to support the implementation. Moreover, interdisciplinary collaboration between architects, ecologists, policymakers, and citizens is essential to advancing this vision.

In conclusion, shifting from grey to green roof and roof farming exemplifies a design-driven approach to climate neutrality. It challenges conventional zoning and land use paradigms, encourages multifunctional thinking, and reconnects the built environment with ecological processes. As cities strive toward sustainability, the green transformation of grey spaces emerges not only as a necessity, but as a powerful opportunity.

Acknowledgments

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SUSTAINABILITY IN THEORY

Theoretical Frameworks for Sustainable Design
Philosophical Approaches to Sustainability
Critical Perspectives on Sustainability Practices
Theory of Resilience in Urban and Architectural Contexts
Interdisciplinary Research in Sustainability Theory

NEW LIFE ON M.A.A.R.T.E.

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New life on M.A.A.R.T.E.

Abstract: This work reflects on the role of forgotten or unfinished urban spaces, considered not only as voids to be filled but as potential sites of transformation. These "lastscapes" preserve memory and possibility, inviting a project that does not impose but rather listens to and reinterprets the complexity of the context. In this scenario, cultural architecture, and museum architecture in particular, emerges as a privileged tool for regeneration, where the museum is no longer a closed building-object, but a porous public infrastructure capable of connecting the city, generating relationships, and catalyzing meaning. This establishes an international vision that places sustainability, memory, and dialogue with the local area at its core. The museum of the future is conceived as a widespread laboratory, an educational space, and a means of belonging. On this basis, this research focuses on the application of design within the abandoned area of the former Ma.C.Ri.Co in Caserta, as an opportunity for symbolic, social, and cultural regeneration. Specifically, the area designated as an exhibition space by the masterplan was analyzed.

Keywords: reuse, unfinished, urban space, regeneration, second hand.

Introduction

In the heart of contemporary cities, places emerge that seem to escape the linear time of planning. Forgotten spaces, suspended between past and future, which urbanity has relegated to the margins without entirely erasing. They are territories of the unfinished, the invisible, the waiting: residual landscapes that, in their liminal condition, hold the potential to generate new visions. These last-scapes, as defined in recent theories, are not simply a problem to be solved, but a threshold to be crossed: urban fragments that preserve a silent memory and, at the same time, a promise of transformation.

Working in such contexts means facing the challenge of a project born from complexity and not from emptiness: a project that listens rather than imposes, reinterprets rather than erases. Here, architecture oriented toward cultural production—and particularly toward spaces for art—presents itself as a practice capable of mending the territory with its symbolic and collective dimension. The museum, no longer a rigid typology but a porous and adaptable organism, becomes an emblematic tool for questioning the city and experimenting with new forms of regeneration. It is not conceived as an isolated building-object, but as a relational element, a public infrastructure, a catalyst for meaning. Museum architecture opens itself to the city: it ceases to protect and delimit, becoming a connection, a threshold, a crossing. The museum intertwines with the landscape, assumes multiple configurations, and becomes part of an urban ecosystem that seeks not only redevelopment but full regeneration—physical, social, and symbolic.

This perspective aligns with an international trend that places sustainability, memory, and dialogue with context at the center of cultural architecture. The contemporary museum—

and even more so the future—is not limited to exhibition, but becomes a territorial laboratory, an educational site, a device for belonging. Not just a home for art, but an architecture that activates citizenship, symbolic exchange, and shared visions. An architecture of the possible, built on the margins, which embraces uncertainty and turns it into an operational field. Within this framework, the thesis investigates cultural architecture as a tool for urban regeneration through the design of a museum in the abandoned central area of the former Ma.C.Ri.Co in Caserta. Thus was born the M.A.A.R.T.E. – Museum of Art, Architecture and Regeneration for the Territory and Heritage, conceived to restore form to a forgotten space and activate new affective and civic geographies, generating unprecedented connections between culture, memory, and design.

Figure 1. Detail of Ma.C.Ri.Co, Caserta, Italy.

Figure 2. Site Context

Figure 3. Axonometric view of Ma.C.Ri.Co.

Figure 4. Detail of an abandoned building inside Ma.C.Ri.Co.

Literature Review

Contemporary urban complexity requires a perspective capable of interpreting the city as a historical stratification and a composite space. This intermingling has accustomed us to observing the city and its surroundings with the eye of an archaeologist; to understand that the different historical layers—the ancient center, the modern city, its suburbs, the fragmentation and dispersion of the contemporary city—have blended together as if after an earthquake: what we find on the surface is not necessarily the most recent layer, what we find after lengthy excavations is not necessarily the oldest layer (SECCHI, 2000). This reflection invites us to consider the city not as a linear or ordered organism, but as an accumulation of experiences and traces, where the past coexists with the present and the future can only be glimpsed through signs. The critical gaze of the urban planner and architect must grapple with this complexity and the awareness that every intervention is part of an already stratified system, where design becomes an opportunity for dialogue rather than imposition. In this scenario, the concept of contemporary space as bricolage becomes central.

"The stories of places are bricolages. They are made with the remains of the world" (DE CERTEAU, 2001, p.163). With this statement, de Certeau defines the composite space

of the contemporary, made of fragments that oscillate between beauty and disorientation, memory and oblivion, built and abandoned. The contemporary city thus becomes a palimpsest, where heterogeneous elements interweave and where creative intervention can transform the unfinished into an opportunity for design and regeneration. Reflection on the unfinished has led to practices that valorize what is normally considered marginal, operating on cultural, symbolic, and social levels and redefining the relationship between architecture and community. The focus on upcycling and second lives for incomplete architectures has sparked growing interest among scholars, artists, and professionals; the valorization of what is interrupted becomes resistance to the ephemeral consumption of urban space and recognition of the symbolic power of material memory.

In Italy, one of the most significant studies is *Incompiuto Siciliano*, which evolved into *Incompiuto. The Birth of a Style* (Humboldt Books, 2018). Through this work, the Alterazioni Video and Fosbury Architecture group highlighted a concrete problem while developing strategies to transform the unfinished into an aesthetic experience, introducing the "aesthetics of the incomplete". This approach overturns the traditional association between the unfinished and the unsightly, proposing a critical reading that recognizes beauty and potential where common perception sees decay, and resonating internationally by foregrounding marginal elements that stimulate new spatial interpretations.

Beyond aesthetics, a practical urgency emerges: understanding the fate of architecture born from unfinished and potentially reactivable needs. "Anthropologists," Marc Augé wrote in 2004, "today find themselves faced with a vast swathe of history that extends across the entire planet. They sense that the inventory of ruins is not an end in itself, and that what truly matters is invention […] Humanity is not in ruins, it is under construction. It still belongs to history. A history that is often tragic, always unequal, but irremediably common" (AUGÉ, 2004, p. 16). His reflection invites us to read the unfinished not as failure, but as possibility: ruins and construction sites—both war and civil—become poetic spaces in the etymological sense, where incompleteness holds promise.

Augé's notion of promise, unlike prophecy, implies commitment to reality and openness to the concretely achievable. From this perspective, regenerating unfinished or abandoned architecture is not merely technical, but a poetic act restoring dignity and meaning to spaces symbolizing decadence and loss of values. The city itself becomes the recipient of this concrete poetry, an urban fabric reinterpreted through practices attentive to memory, sustainability, and participation.

The project on the former Ma.C.Ri.Co. in Caserta fits into this perspective. The intervention does not simply propose a new function for the abandoned space, but aims to be an open device, capable of responding to community needs and activating cultural, social, and symbolic processes. Regeneration here is not physical restoration alone, but a redefinition of the relationship between architecture and community, between built and lived space. Architecture becomes a vehicle for shared meanings and a catalyst for cultural experiences, transforming the unfinished into an opportunity for participation and dialogue.

This approach finds parallels in international theories on urban and cultural regeneration, where attention to marginal spaces, urban voids, and incomplete architecture becomes an opportunity for experimentation. The upcycling of spaces, the recovery of the unfinished, and the valorization of ruins are no longer marginal but practices capable of generating new forms of citizenship and participation. The city, interpreted as a stratification and palimpsest of memories and potential, offers fertile ground for experimenting with strategies attentive to sustainability, culture, and community. The growing interest in unfinished and abandoned buildings testifies to architecture's ability to transform perception: unfinished projects and urban ruins become spaces of possibility where design intervenes with intelligence and creativity.

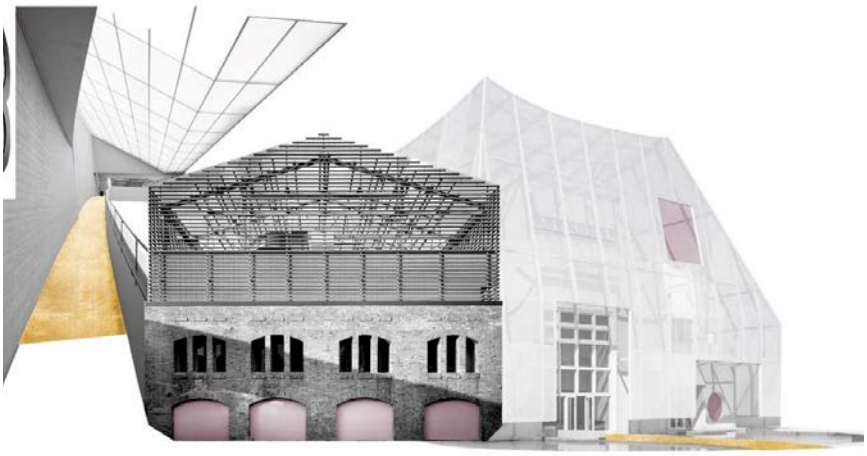
In short, the analysis of latent buildings and the project on the former Ma.C.Ri.Co. exemplify how theory and practice converge to transform limitations into opportunities. The unfinished, far from being a simple failure, becomes a tool of knowledge, a laboratory of aesthetics, and a device for regeneration. The promise it holds offers architects the chance to intervene with awareness, restoring meaning, function, and symbolic value to forgotten spaces. The city thus presents itself as a living, layered organism, open to new ideas and capable of transformation through practices attentive to memory, culture, and collective well-being.

Figure 5. Scatole, digital collage, 2025

Methods

The former Ma.C.Ri.Co site in Caserta, encompassing over thirty-three hectares in the heart of the city, was historically allocated to military functions. For decades, this vast portion of urban land remained segregated from civic life, despite its central location, and was rendered almost invisible. Its paradoxical condition—simultaneously internal yet detached—has preserved its transformative potential, positioning it today as a privileged locus for interrogating memory, reappropriation, and prospective vision. Within the regeneration process promoted by the Diocesi of Caserta and articulated through the Masterplan developed by Alvisi Kirimoto in 2022, the site has been reconceptualized as a common good. The comprehensive plan, *Campo Laudato Sì*, is informed by principles of integral ecology and

social justice, foregrounding the theme of care—conceived not only as environmental stewardship, but as a civic and designoriented act. Against this backdrop, the thesis project concentrates on the south-western sector, designated as the "Park of Art." Within this area, seven buildings protected by the ABAP Superintendence—material testimonies of a concluded military epoch—become the starting point for a reflection on the role of culture, art, and architecture in shaping a renewed urban imaginary. Designing a museum like MAARTE, which integrates art, architecture, and regeneration, requires engagement with experiences that have translated synesthesia, memory, and atmosphere into architectural form. In this sense, three emblematic projects offer valuable insights for developing a strategy attentive to perception and the relationship between body, space, and narrative. The 2014 redevelopment of the Ex-Fornace di Riccione, curated by Pietro Carlo Pellegrini, exemplifies how intervention can establish a sensitive dialogue with historical material without nostalgia. Based on a principle of active respect, the preexisting structure is not merely preserved but reinterpreted through a discreet grammar that reactivates its latent potential. Pellegrini demonstrates how industrial heritage can be valorized through balance between memory and innovation. The additions engage with the existing structure without camouflage, generating a tension between what has been and what may become. Through light, materials, and calibrated spaces, history is rendered visible, producing an environment where stratification becomes perceptive intensity.



The Kiasma Museum, designed by Steven Holl and inaugurated in 1998, remains a reference in reflecting on museum space as a dynamic and perceptive device. Holl's "spatial

parallax" translates into a fluid composition offering multiple viewpoints and non-linear paths. The exhibition is conceived not as fixed order but as experiential field, where the body is continually stimulated to redefine its position. Light, geometry, and materiality interact to amplify the synesthetic dimension, while natural light—changing with weather and season—directly influences perception. The architecture is configured as an immersive organism, open to unpredictability and responsive to environmental conditions. For MAARTE, Kiasma suggests a design centered on perceptual mobility, corporeal centrality, and spatial narratives that make the museum a landscape to be traversed.

The 2024 Flickering Peak CP·SUN RIVER Art Gallery, designed by Wutopia Lab, proposes a radical reflection on the experience of art and the role of architecture as a constructor of imaginaries. Here the building itself becomes a narrative, a material and symbolic tale that evokes atmospheres and expands perception. Set in Sichuan, the gallery establishes an intimate relationship with its landscape, translating environmental qualities through the poetics of fading. Perforated steel and opal glass filter light to create an ever-changing environment in which interior and exterior merge. The project challenges museum conventions—neutral chromaticity, controlled climate, uniform lighting—and valorizes instability as a resource. Architecture becomes co-protagonist: atmosphere, scenography, and narrative machine at once. For MAARTE, this suggests a design approach that transcends exhibition, privileging complex narrative and perceptual experiences.

Drawing from these reflections, MAARTE is configured as a museum where architecture becomes an instrument of relationship, storytelling, and sensorial engagement. The aim is not to replicate models, but to translate principles such as synesthesia as integrated experience, spatiality as narrative form, and memory as generative material.

The valorization of the void as relational space is a guiding principle: interstices between buildings, often overlooked in masterplans, become places of crossing and encounter. A second strategy concerns functional hybridization: buildings are reinterpreted as flexible spaces where exhibitions, laboratories, performances, and educational activities coexist. The third principle is atmospheric materiality: calibrated use of natural light, materials, and surfaces produces environments in which visitors perceive time, transformation, and landscape. Opaque and porous surfaces interact with translucent ones; openings frame views, while overhead light becomes narrative tool. Additional elements reinforce this approach: exhibition modularity ensures adaptation to diverse content, with reversible and mobile displays fostering curatorial autonomy. Finally, participation is

embedded as a methodological foundation: architecture is not presented as a finished form but as an activatable platform. Co-design sessions, grassroots exhibitions, and workshops with local schools and associations make the museum a catalyst for cultural energy and a participant in constructing a renewed collective identity.

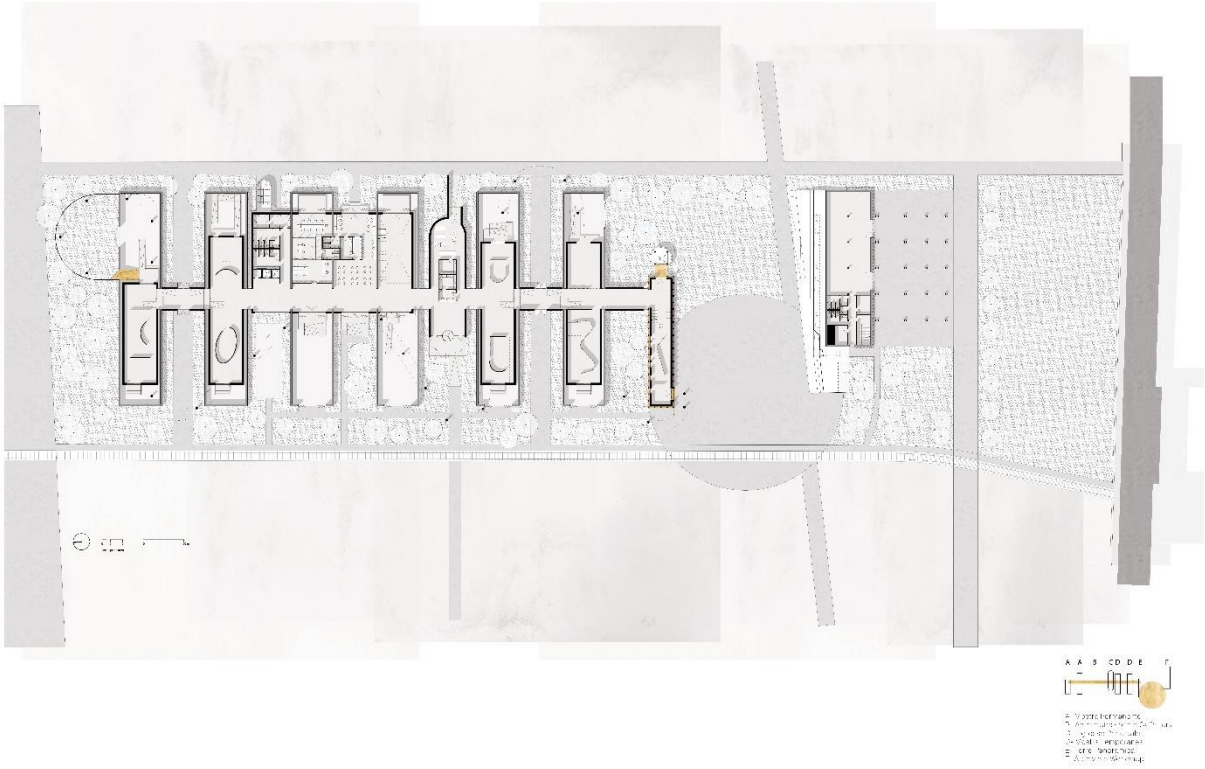


Figure 7. Masterplan—MAARTE, 2025

Findings and Discussion

The MAARTE project is based on an in-depth reflection on scale, conceived not only as the physical dimension of interventions but also as a narrative and perceptual tool shaping the relationships between architecture, the body, and the landscape. Scale is treated not as a simple metric, but as an organizing principle capable of generating spatial hierarchies, perceptual rhythms, and connections between existing and new architecture. From this perspective, the project is structured according to a "tailor-made system"—S, M, L, XL—that guides the reading of the built fabric and defines a coherent approach to complexity, where each intervention responds to a specific and calibrated design gesture.

The "S" interventions are expressed in the exhibition pavilions, derived from the rigid outline of the existing slats. Pure, defined volumes are grafted onto this grid, extending on the

roof through calibrated inclinations and projections. The resulting architecture is essential yet never banal, developing vertical light wells that direct the gaze upward, expand perception, and transform interiors into luminous resonance chambers. Light, treated as an architectural material, sculpts surfaces and guides the visitor through an immersive experience.

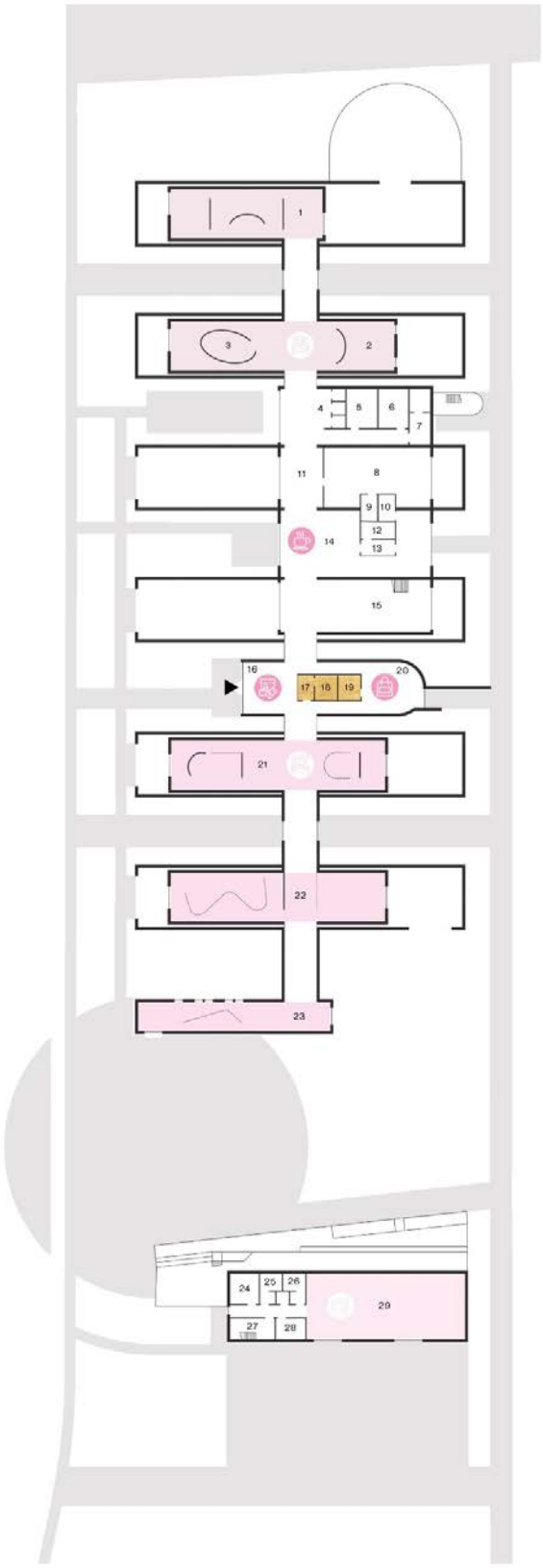
This attention to verticality continues in the "M" intervention, represented by the entrance pavilion. Here, the compositional principles of the smaller pavilions are reworked and amplified, extending proportions and gradually introducing visitors to the museum's complexity. The new pavilion expands in height and depth while maintaining a welcoming quality through materials and transparency. Acting as a threshold, Pavilion "M" mediates between the urban context, the park, and the existing industrial buildings, preparing visitors for the experience of the complex.

The "L" intervention, corresponding to Pavilion "F" dedicated to the archive, emphasizes verticality to meet functional requirements: accommodating large-format works, ensuring efficient storage, and providing flexibility. The large external canopy extends activities outdoors, reinforcing its public and participatory function. Here, scale translates into accessibility, offering spaces where visitors can interact with both the building and the community.

The "XL" interventions are expressed in Pavilion "B" and the panoramic tower, structures deliberately exceeding the dimensions of the original buildings to create new spatial and perceptual reference points. The central pavilion, with its complex volumes and diverse functions, constitutes the museum's epicenter, while the tower functions as an observation and orientation point, redefining the site's perceptual geography. These volumes engage with the existing structures without negating them, contributing to an evocative scenario in which architecture acts as both symbolic gesture and meaningful infrastructure.

The entire complex is based on a relational conception of space, emerging from thresholds, pathways, and open areas connecting city, park, and buildings. Empty spaces become devices for passage and encounter, producing a continuum in which relationships between architecture, landscape, and the visitor's body are constantly redefined. Functional flexibility is central: buildings are not intended for a single use but are reinterpreted as multifunctional environments.

Exhibition halls coexist with workshops, performance areas, and educational spaces, reflecting the museum as cultural and social infrastructure.



1. Permanent exhibition
2. Permanent exhibition
3. Exhibition alcove
4. Elevators
5. WC
6. WC
7. Technical room
8. Administration and management offices
9. WC
10. WC
11. Exhibition corridor
12. Storage
13. Bar
14. Cafeteria
15. Main hall
16. Entrance
17. Ticket office
18. Storage
19. Storage
20. Shop
21. Temporary exhibition
22. Temporary exhibition
23. Temporary exhibition
24. Technical room
25. WC
26. WC
27. Storage room
28. Service room
29. Archive and co-laboratory

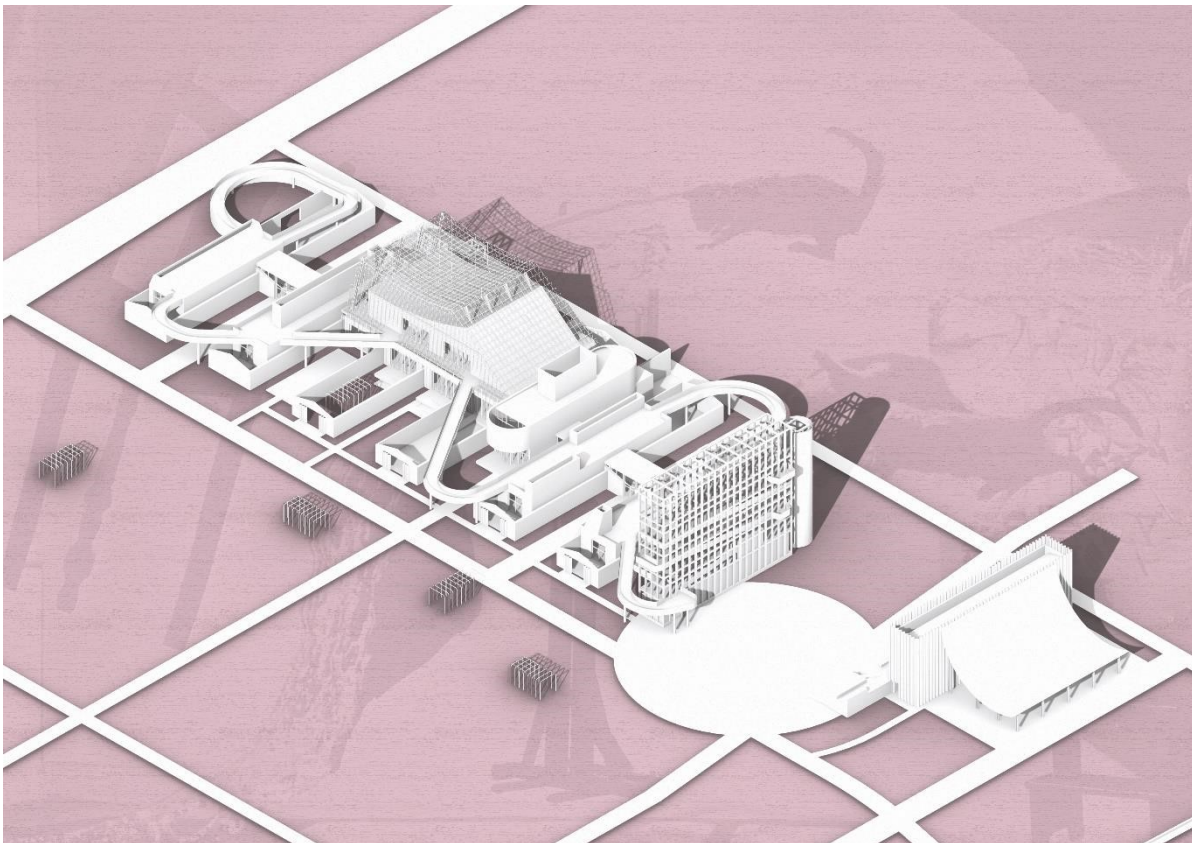


Figure 9. Axonometric view of MAARTE, Caserta, Italy.

Figure 10. Aerial view of MAARTE, Caserta, Italy.

Figure 11. Exterior view of MAARTE, Caserta, Italy

Conclusion

The MAARTE project emerged from the convergence of an unresolved urban challenge and a cultural vision capable of discerning an opportunity for collective redemption within the neglected fabric of the former Ma.C.Ri.Co area. Its aim is to transform this suspended space into a laboratory of meaning, where architecture interprets a latent demand for space, identity, and future possibilities. Rather than functioning as a thematic container or isolated gesture, the museum is conceived as a relational device, a cultural infrastructure, and a living organism capable of fostering belonging.

The design adopts a narrative approach, making the space receptive to transformation and reinterpretation. The architecture is porous and plural, attentive to light as a material, respectful of preexisting structures, and oriented toward generating perceptual experiences. MAARTE is not a finished artifact but an activatable framework, capable of incorporating time and uncertainty as design tools, extending into the park and the surrounding urban fabric while redefining public space. Its carefully calibrated and at times unexpected geometries provoke curiosity and emotional engagement, crafting an architecture conscious of cultural responsibility.

The project dialogues with international precedents while remaining firmly grounded in its local context, mediating rather than imposing, and creating open-ended scenarios for encounter. In essence, MAARTE is conceived as a space of in-betweenness, where the city

reflects on itself, culture is actively practiced, and architecture reclaims its role as a generous, civic, and visionary act. Through this approach, the project articulates a sensitive, relational, and adaptive strategy that integrates art, architecture, and urban regeneration into a coherent and immersive whole.

Figure 12. Detail of one of the patios of MAARTE, Caserta, Italy

Acknowledgments

The M.A.A.R.T.E. project summarizes the work of Vittorio Vernazzani's thesis, in continuity with the researches “Building on the Build”, “Second Hand Architecture: for a New Theory

of Reuse" by Concetta Tavoletta, and the "SHArch project", P.I. Concetta Tavoletta. Supervisor: Prof. Luca Molinari, co-supervisor: Prof. Concetta Tavoletta. The drawings and photographs are made by Vittorio Vernazzani.

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FROM SCREEN TO SKYLINE: HOW CINEMA IMAGINES BIOPHILIC FUTURES ON SUSTAINABLE CITIES

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From Screen to Skyline: How Cinema Imagines Biophilic Futures on Sustainable Cities

Abstract: Architecture is crucial for sustainable futures, where human activity has emerged as a geological force affecting ecosystems and climate. Speculative cinema offers a medium for exploring the conceptualization, critique, and reconfiguration of architecture and urbanism. This study examines the role of movies as cultural laboratories for conceptualizing biophilic and sustainable futures, concentrating on three case studies: Black Panther (2018), Her (2013), and Tomorrowland (2015). The research employs a qualitative methodology that integrates visual analysis, semiotic coding, and pattern recognition, drawing on the theoretical frameworks of biophilic design, semiotics, and utopian studies. The mise-en-scène, architectural motifs, and spatial composition are analyzed to discern biophilic aspects along with their symbolic and ideological roles. The findings indicate that each film expresses distinct perspectives on ecological urbanism. Through the visualization of aspirational sustainable design, movies influence collective perspectives, stimulate professional creativity, and contribute to worldwide discussions on ecological futures.

Keywords: biophilic design, cinematic architecture, sustainable futures

Introduction

Architecture plays a vital role in shaping sustainable futures. As the global climate crisis deepens, architecture is increasingly called upon not only to reduce its environmental footprint but also to rethink the ways we inhabit the planet (McLennan, 2004; Van der Ryn & Cowan, 1996). Architects are not only designers of physical spaces; they must also protect the future of the planet. Latour (2014) argues that human-nature relationships must be rethought, especially in the Anthropocene era. The Anthropocene is a geological epoch that refers to the profound impact of human activities on Earth's systems (Crutzen & Stoermer, 2000). Therefore, every architectural decision carries political, ecological, and logical consequences.

Cinematic space has long been considered a vehicle of ideological inscription (Bordwell & Thompson, 2016; Nichols, 2010). As Manovich (2001) asserts, the language of cinema has become the dominant cultural form of the 21st century, surpassing text-based narratives in shaping how people perceive the world. Architectural environments in science fiction films function as "laboratories of the future," visualizing urban possibilities and anxieties (Boyer, 1996). Films not only reflect social values through their immersive worlds and symbolic mise-en-scène but also shape collective expectations regarding space, identity, and the future.

These cinematic constructs often represent contemporary fears as well as aspirational ideals like harmony with nature, community resilience, and technological utopia. According to Pallasmaa (2001), architectural imagination is closely tied to cinematic imagery; filmic environments stimulate spatial perception, emotional response, and design thinking. Thus,

cinema is not merely a passive reflector but a semiotic and symbolic generator of architectural futures.

Semiotics allows us to analyze how meaning is constructed in these films—how symbols, forms, and spatial arrangements convey ideologies of sustainability (Eco, 1976; Peirce, 1998). Architectural imagery in cinema often serves as a signifier of cultural, political, and environmental values. This study examines how cinematic representations encode ecological values through mise-en-scène, spatial composition, and narrative symbolism. Three movies are analyzed—Black Panther (2018), Her (2013), and Tomorrowland (2015)—according to their representation of fictional urban landscapes. By examining the affective and symbolic dimensions of cinematic biophilia and utopia, this research aims to deepen our understanding of how media shapes architectural imagination and sustainability ethics. This analysis helps us to understand how futuristic movies visualize biophilic and sustainable architecture and what these cinematic imaginaries can teach architects, educators, and policymakers about designing sustainable urban spaces that have ecological harmony and technological integration.

Literature Review

Biophilic design, developed by Kellert, Heerwagen, and Mador (2008), integrates natural elements into the built environment, drawing on humans' evolutionary connection to nature. The concept of 'biophilia,' introduced by Fromm (1973) and expanded by Wilson (1984), refers to humans' innate affinity with natural systems. By incorporating natural light, water, greenery, and biomorphic forms, biophilic design counters the disconnection from nature caused by dense urbanization (Kellert & Calabrese, 2015). Biophilic designed spaces support mental health, stimulate creativity, and foster sustainability awareness (Terrapin Bright Green, 2012; Alvarsson, Nilsson & Wiens, 2010).

The features of a biophilic environment can be exemplified as direct nature (e.g., vegetation, water), indirect nature (e.g., natural materials, organic forms), and space-place conditions (e.g., refuge, prospect, mystery). According to Browning et al. (2014) and Ryan et al. (2014), these biophilic elements improve cognitive functions, reduce stress, and enhance ecological awareness. Direct nature allows physical engagement, indirect nature conveys symbolic meanings, and space-place conditions shape users' psychological relationship with their environment (Kellert, 2005). At the societal level, the structures that support human-nature

interaction create positive transformations in individuals' relationships with their environment and strengthen sustainability consciousness (Salingaros, 2015; Heerwagen, 2006).

The aesthetic dimension of biophilic design has restorative experiences (Joye, 2007), and nature-based parameters in urban planning shape health-oriented city design (Ryan et al., 2014). Biophilic-designed cinematic spaces construct immersive worlds through mise-en-scène, and biophilic cues within these worlds can convey ideological narratives about sustainability, community, and well-being (Joye & van den Berg, 2011). Representations of naturally lit interiors, rooftop gardens, or water-integrated public spaces serve not only as aesthetic features but also as visual signifiers of social values such as psychological well-being, cultural continuity, and environmental ethics (Kellert et al., 2008; Browning et al., 2014). These images shape audiences' minds to internalize design ideals, shaping architectural imagination and public demand for sustainable futures.

Semiotics (the study of meaning and signs) helps analyze how cultural products are structured and generate meaning. The signifier and the signified concepts founded by Ferdinand de Saussure (1916) affected cultural criticism (Roland Barthes, 1972). Charles S. Peirce (1998) offered a more ontological approach as a triadic model of the sign (sign, object, interpretant). According to Peirce, signs have a triadic structure:

"icon," which signifies through resemblance

"index," based on a causal or physical connection.

"symbol," which relies on social conventions

Umberto Eco (1976) asserts that cultural products don't convey only narratives; they are filled with multilayered semiotic codes. He views every cultural work as an "open text" that the audience can interpret in multiple ways. In this context, semiotic analysis allows for examining not only the aesthetic qualities of architectural forms but also their cultural, political, and environmental meanings.

Mise-en-scène is a term for all visual elements within a film frame (space, lighting, color, composition, costume, and set design) for giving an intentional arrangement. The sets create specific emotions, associations, and social codes in the viewer's mind; therefore, the portrayal of urban spaces serves as integrated cultural signifiers within the film's narrative structure. According to Nichols (2010), in fictional cinema, the physical environment is an essential component that shapes the film's ideological foundation rather than scenery.

This study also intersects with utopian theory, which examines fictional futures. The idea of utopia has served as a space for questioning the limitations of existing social structures

and imagining alternative futures (Vieira, 2010). Bloch (1986) and Levitas (2013) contend that utopias serve as critical frameworks that illuminate current limitations and suggest revolutionary alternatives. In architecture, utopias are perceived as both physical spaces and experimental settings for visualizing alternative social structures, value systems, and human-nature interactions.

Biophilic design, semiotic analysis, and utopian theory provide a systematic framework for analyzing how films depict and conceptualize the architecture of sustainable futures. These frameworks guide the following case study analyses.

Methods

This study uses a comparative case study combining semiotic analysis and biophilic pattern recognition to examine how science fiction depicts sustainable urban futures. Three films—Black Panther (2018), Her (2013), and Tomorrowland (2015)—were selected for their distinct architectural narratives, integration of nature-based design, and optimistic ecological visions, which provide a contrast to dystopian depictions and enable a nuanced exploration of sustainable design in cinema.

The analysis integrates:

Semiotic Reading—The analytical approach combines semiotic analysis and biophilic pattern identification. Drawing on Charles S. Peirce's triadic sign model—icon, index, and symbol (Peirce, 1998)—and Roland Barthes' (1972) theory of myth, the study interprets the symbolic and ideological meanings embedded in the mise-en-scène of each film. Emphasis is placed on architectural motifs, spatial organization, and visual metaphors that construct ecological narratives.

Biophilic Pattern Mapping—Biophilic design principles, as outlined by Kellert et al. (2008) and Ryan et al. (2014), guide the identification of natural elements—such as vegetation, natural light, water features, and spatial forms like refuge and prospect—that evoke emotional resonance and suggest ecological values.

The visual elements were systematically coded using a matrix that aligns visual cues (e.g., green roofs, reflective pools) with biophilic patterns (e.g., material connection to nature, dynamic water) and semiotic functions (e.g., cultural symbolism, emotional resonance). This coding matrix is adapted from Gillian Rose's (2016) framework for visual methodologies, which emphasizes the layered nature of visual meaning through compositional interpretation, discourse analysis, and site-specific reading. In this study, her model is translated into a three-

column coding matrix to enable biophilic indicators with symbolic readings within the architectural mise-en-scène of speculative cinema.

- Visual Cue (mise-en-scène element)
- Biophilic Pattern (Kellert/Ryan typology)
- Semiotic Function (Peirce/Barthes)

For each film, architectural and urban features were first identified visually, then mapped to biophilic categories, and finally interpreted for their semiotic significance.

Case Study Analyses

Black Panther (2018): Wakanda's Techno-Natural Urbanism

In Black Panther, the Wakanda "Golden City" is shown as a place that mixes designs from many ethnic traditions and African building styles with modern technology. Instead of removing the natural surroundings, it blends them into the city, highlighting a close link between people and nature, especially the mountains, waterfalls, and green areas around it. The city is an example of how nature, city design, and technology can work together: tall modern buildings stand alongside magnetic trains and nanotechnology without harming the environment. Its public areas are open and welcoming to everyone, so this design reflects fair and equal city planning.

Wakanda's Golden City is portrayed as a riverside urban environment in which expansive green spaces occupy a substantial portion of the city's surface area, while the façades of its vertical architectural elements are animated by vertical gardens. The overall composition showcases an organically conceived urban plan that seamlessly integrates the built form and natural landscape into a harmonious whole. Whereas most futuristic science fiction films tend to depict vertical architecture through rigid, geometric structures, Black Panther offers a distinct visual language, embedding curves, flowing lines, and other organic forms within its high-rise design.

Visual Cue	Biophilic Pattern	Semiotic Function	Scene	Scene Context
Terraced Golden City skyline with rooftop gardens	Integration with topography, Vegetation on façades	Symbolizes balanced co-existence of technology and ecology; projects a model of sustainable urban futurism	Aerial approach to Wakanda Mise-en-scène 00:13:13	
Market plazas with vertical greenery & shaded walkways	Human-scale walkability, Embedded greenery	Connotes community cohesion, cultural resilience, and ecological stewardship	Street-level market scenes Mise-en-scène 00:33:21	
Circular tower bases with thatched-texture façades	Biomorphic forms, Material connection to place	Bridges ancestral architectural traditions with futuristic urban forms (Afrofuturism)	Close-up architecture shots Mise-en-scène 02:00:33	
Elevated pedestrian networks	Prospect pathways, Visual connection to natural elements	Suggests ecological mobility, low-carbon transit, and pedestrian-centric design	Overhead market/pedestrian shots Mise-en-scène 00:33:13	
Use of earthy tones & local pattern motifs	Material connection, Cultural symbolism	Embeds heritage identity into urban morphology; resists homogenized global modernism	General city shots Mise-en-scène 00 35 54	

Figure 1. Black Panther (2018) – Biophilic/Semiotic Coding Matrix (Prepared by author).

Her (2013): Intimacy, Minimalism, and the Quiet Biophilic City

Spike Jonze's *Her* (2013) presents a subtle and emotionally resonant depiction of a near-future Los Angeles that prioritizes emotional well-being and environmental softness. Rooftop gardens and light wood textures offer a gentle interpretation of biophilic design (Joye & van den Berg, 2011). In *Her*, the city is envisioned as a human-centered, livable near-future metropolis with softened vertical architecture and spaces that resonate emotionally. The film presents efficient spaces with public transport, greenery, and civic areas, creating urban density without alienation. The film's emotionally driven architecture supports themes of privacy in the digital age, uniting the public and private realms into a non-threatening urban design.

In "Her" set design, the use of muted color palettes serves to reinforce the narrative, enabling a seamless conveyance of the intended emotional transitions to the audience. Quiet plazas enriched with native plantings establish a sense of calm and place. Within buildings, interiors are defined by tactile materials such as wood and wool, fostering warmth and sensory engagement. Rooftop green spaces are integrated into daily life, extending the city's connection to nature into its vertical dimension.

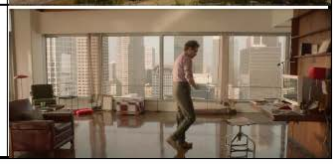
Visual Cue	Biophilic Pattern	Semiotic Function	Scene	Scene Context
Rooftop terraces with lush plantings	Direct nature, Refuge	Suggests intimacy and sanctuary within the urban density; symbolizes personal connection to nature	Theodore's apartment exterior shots Mise en scene 01:30:07	
Diffuse daylight interiors with wood finishes	Natural light, Material connection to nature	Evokes warmth, mental clarity, and emotional grounding; reflects minimalism as a calming design philosophy	Apartment and office interiors Mise-en-scène 00:03:04	
Pedestrian skybridges with integrated greenery	Prospect, Embedded vegetation	Represents ecological urban mobility and connectivity without reliance on cars	Cityscape transitions Mise-en-scène 00:15:41	
Public spaces lined with planters and shade	Human-scale greenery, Visual connection to nature	Connotes inclusivity and well-being in urban public life	Walkway and public park sequences Mise-en-scène 01:04:27	
Earth-tone furniture and organic textures	Material connection, Biomorphic forms	Creates sensory familiarity; symbolic of emotional intimacy in personal environments	Theodore's home scenes Mise-en-scène 00:43:53	

Figure 2. Her (2013) – Biophilic/Semiotic Coding Matrix (Prepared by author).

Tomorrowland (2015): Green Technotopia and Optimistic Urban Futures

Brad Bird's *Tomorrowland* (2015) envisions a retro-futuristic utopia based on collective technological optimism. A group of scientists intent on constructing an alternative world envisions it as a solution to urgent contemporary problems such as climate change and conflict. The story follows a young woman who enters this realm. The city is composed of vertical architectural forms supported by steel construction, their transparent glass façades opening toward expansive views. Green terraces are woven into the urban environment, and agricultural terraces span multiple vertical zones, allowing food production to coexist with dense urbanism alongside frequent water element incorporations. Skyways and solar towers are integrated into public squares for energy generation. Communal spaces are animated by kinetic water features and sculptural vegetation, underscoring the city's commitment to harmony between technology, nature, and human habitation. Unlike the subdued tones of *Her*, this world is brightly lit, signaling confidence in ecological innovation (Harvey, 2000).

Visual Cue	Biophilic Pattern	Semiotic Function	Scene	Scene Context
Expansive green plazas at city core	Open green space, Direct nature	Symbolizes utopian openness, communal well-being, and accessibility	Wide establishing shots of Tomorrowland Mise-en-scène 00:31:38	
Vertical gardens and terrace agriculture	Vegetation integration, Material connection	Projects ecological self-sufficiency and sustainability	Mid-level cityscape shots Mise-en-scène 00:31:43	
Water channels running through urban spaces	Water presence, Prospect-refuge	Conveys life, movement, and a cooling effect in the urban ecosystem	Street-level views of canals Mise-en-scène 00:33:34	
Pedestrian mobility networks	Prospect pathways, Human-scale design	Emphasizes walkability, social interaction, and low-impact transport	Sequences of characters moving through the city Mise-en-scène 00:32:25	
Curvilinear architecture inspired by organic forms	Biomorphic forms, Natural geometry	Evokes futuristic elegance while remaining visually and emotionally accessible	Close-ups of signature Tomorrowland structures Mise-en-scène 00:31:22	

Figure 3. Tomorrowland (2015)– Biophilic/Semiotic Coding Matrix (Prepared by author).

Findings and Discussion

The comparative analysis of Black Panther (2018), Her (2013), and Tomorrowland (2015) reveals distinct yet converging approaches to biophilic and sustainable urban futures, positioning cinema as a speculative laboratory for ecological urbanism. A central pattern across all three films is the integration of nature—from intimate, tactile connections with materials and light (Her) to city-scale integration of vegetation and topography (Black Panther, Tomorrowland). The representation of water emerges as a potent ecological and cultural symbol. Water functions as a key ecological symbol: Black Panther uses waterfalls to signify cultural continuity, Tomorrowland integrates canals for livability, while Her emphasizes light and material warmth instead. This demonstration shows that ecological meaning can be encoded through different sensory modalities.

Black Panther integrates cultural heritage with ecological design, "Her" promotes emotional ecology through minimalist interiors, and Tomorrowland envisions innovation-driven environmental optimism. While Her and Tomorrowland highlight pedestrian, low-carbon urbanism, Black Panther blends technology with cultural identity, reflecting different ideological emphases.

Black Panther draws on African vernacular architecture to affirm cultural self-

determination, Tomorrowland adopts a universal techno-utopian aesthetic, and Her portrays emotionally minimalist urbanism focused on psychological well-being.

Conclusion

This study found that speculative cinema provides more than just imaginative escape; it also serves as a critical cultural arena for visualizing, testing, and communicating sustainable future scenarios. Through the examination of the similarities and differences between Black Panther (2018), Her (2013), and Tomorrowland (2015), it becomes clear that the depictions of biophilic architecture and ecological urbanism in films have the potential to influence the collective ideas of what a future that is both livable and sustainable might look like.

Architectural representations broaden the conceptual repertoire of architects, planners, and politicians, inspiring thought about how ecological principles may be established in the built environment at various scales.

Filmic images like this create a feedback loop between cultural imagination and built reality as they circulate the world, impacting both public expectations and professional discourse. Cinema, in this regard, remains not just a mirror of our aspirations but an active architect of the worlds we might one day inhabit.

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PROJECT OF LIBERATION

THE CRITIQUE OF DOMESTIC SPACE AS A CRITIQUE OF POWER STRUCTURES

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Project of Liberation.
The critique of domestic space as a critique of power structures

Abstract: A research project in the form of a diary offers an opportunity to reflect on the ways, tools, and materials for practicing the critique of space as a critique of power structures, with particular reference to domestic space and the condition of women, and with a particular interest in the practices of everyday life. Drawing on literature and design examples, and with reference to a tradition of gender studies in architecture addressing this topic, the research, which takes a non-neutral approach and contemplates personal involvement, investigates the power structures implicit in the configuration of the home, revealing and criticizing patriarchal structures, in perspective of liberation of the space through the culture and tools of design. The diary is the method and the result of the work, conducted with a tentative and inventive approach: a creative research practice and a free accumulation of materials pave the way for a design critique of the dominant orders that condition the use and space of the home[1].

Keywords: Power structures; domestic space; everyday practices; architectural design; gender studies in architecture.

Introduction

This contribution, which is part of a research line on space and society initiated within a teaching course and a thesis lab in architectural theory at the Department of Architecture and Industrial Design of the University of Campania Luigi Vanvitelli[2], offers an interpretation of the topic of sustainability through the lens of spatial justice/injustice. This is explored in the relationship between space and ways of inhabiting it, with particular focus on domestic space and the dynamics inherent in the family dimension, with a strong interest in gender issues. Starting from the hypothesis that spatial arrangements reflect social and power structures, the research investigates the power dynamics embedded in the configuration of the home, unveiling and critiquing patriarchal structures from a perspective of spatial liberation through architectural culture and design tools. Focused on spatial critique, aimed at design, attentive to everyday life practices, and informed by the disciplinary debate on domestic space - especially through the lens of gender studies in architecture - the research moves at the intersection of different disciplinary fields and knowledge areas. It pursues an engaged and personal

[1] This paper draws on Annalaura De Rosa degree Thesis, "Domestic Space. A Diary", supervised by Professor Fabrizia Ippolito, co-supervisor Ilenia Mariarosaria Esposito, Department of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, Aversa, Italy, marzo 2025.
The content of this contribution is entirely agreed upon and the responsibility is equally shared between the two authors, Fabrizia Ippolito and Annalaura De Rosa. In the final writing, Abstract, Introduction, Findings and Discussion are by Fabrizia Ippolito; Literature Review, Methods, Conclusion are by Annalaura De Rosa.

[2] Teaching Course in Theory and Technique of Architectural Design, degree Thesis laboratory in Theory and Technique of Architectural Design Professor Fabrizia Ippolito, academic years 2023-2025.

interpretation of the topic, with both investigative and design-oriented intentions. The liberation of space - understood as liberation from roles and power structures, functional assignments and layout conventions - is the core objective of this work. More broadly, it aims at recognizing the critical and subversive potential of architectural design in relation to ways of inhabiting.

Literature Review

The research situates itself within the disciplinary and interdisciplinary debate focused on the relationship between space and society, particularly on the critique of power structures embodied in space. In particular, it draws from gender studies in architecture that have focused on domestic space (among others: Beecher 1869; Woolf 1929; Effe Rivista Femminista 1970; Belotti 1973; Hayden 1981; Mies 1986; Scott Brown 1989; Colomina 1996; Kuhlmann 2013; Aureli, Giudici 2016; Brogi 2022; Forino 2019; Bassoli 2023; Cossutta 2023), identifying it as a crucial terrain for critiquing patriarchal structures and as a site of potential design revolution. Another key reference is the culture of the everyday – from the production of space through usage practices (Lefebvre 1977; De Certeau 1980), to the inventory of ordinary objects and places (Perec 1994), to the engagement with personal experiences (Cigarini 2022) - which, by highlighting unexpected creativity and inventiveness, encourages the rethinking of space and social arrangements through modes of dwelling. Methodologically, the work draws from an opportunity-based method (Corboz 1998) and is guided by theories and practices of situated knowledge (Haraway 1988). This approach allows the construction of a research path that, while pursuing a vision, values the uniqueness of individual experiences and the plurality of attempts. The work, grounded in scientific literature and design culture but driven by personal elaboration, seeks not so much to systematize the state of the art as to use it as a tool and material for a creative research practice conceived as a design action.

Methods

The coherence between the content and the form of the work is a central aspect of this research, which takes the shape of a diary. In particular: being attentive to the design potential of everyday practices, the diary is conceived as a progressive practice; following a method which is defined by themes and by opportunities, it employs a tentative approach; being rooted in the field of architecture but nourished by other disciplines, it combines narrative, graphic, and visual tools; being conducted from a non-neutral standpoint and aimed at taking a position, it involves personal implication.

The diary is organized both chronologically and thematically, and it is therefore accompanied by two indexes, one arranged according to dates, the other arranged according to themes. From the chronological point of view, the work is built up through the daily accumulation of heterogeneous materials, including projects, reflections, spaces, architectures, exhibitions, books and articles, all of which contribute to illustrating the relationship between space and ways of inhabiting. From the thematical point of view, the work collects the materials under some main titles/chapters: Rooms (kitchen, bedroom, bathroom, living room); Special Houses; Furnishings (carpets, seating, objects, curtains); Autobiography; and Other, which contains additional material.

A review of examples can serve to illustrate some of the themes that emerge from the different chapters of the diary.

Rooms. Among the Rooms, the kitchen is one of the most symbolically charged domestic spaces: it is a place of care and female exclusion, but also a space for potential emancipation throughout design tools, such as the outsourcing of reproduction tasks to experts, which frees women from domestic labor, as in the Home Without a Kitchen of Charlotte Perkins Gilman, 1898; the institution of centralized kitchens and shared care spaces, which reduce women's workload, as in The Next Step Alice Costance Austin, 1935; the functionalization and rationalization of the kitchen in order to increase efficiency, as in the Frankfurt Kitchen Margarete Schütte-Lihotzky, 1926; the design of self-sufficient modules as symbols of a flexible and futuristic vision of living, among which the Minikitchen Joe Colombo, 1963. A paradigm shift turns the kitchen into an urban and political prototype that breaks the boundary between public and private, such as Urban K-Type by Studio Maio, 2023. Examples of community kitchens can be found in Tokyo, as well as in Perù and Mexico, where Comedores Comunitarios are self-organized women's groups that prepare collective pots of food.

Another significant Room is the bedroom. Being thought as an inaccessible place, it is the space of intimacy and symbolic control over the female/reproductive body, traceable in various configurations: the bed as a theatrical center and power instrument reflecting male dominance, as in The Playboy Townhouse; the bed as a dominant element of the space in a play of seduction and possession, as in the bedroom of Casa Devalle by Carlo Mollino, 1940; the bed as an iconic object which is placed at the center of the room as well as at the center of the couple life, being a symbol of love against power, potency and presumption, as in the room for making Love in La Casa Abitata by Ettore Sottsass, 1965.

The bathroom can be a space of social control, such as the milanese ringhiera bathrooms photographed by Basilico for the project Milano. Quartieri Popolari, 1970 - 1973, or a service space for domestic workers that limits rights and autonomy (Tings 2017). In 26 Bathrooms by Greenaway, 1985, an ironic and critical reading of private habits and their cultural implications is offered.

Special Houses. Among the design responses which are exemplified in the diary by Special Houses, the flexible space represents a way to overcome the limits of traditional housing: open, transformable living areas, such as the ones of the Alloggio Unilaterale per quattro persone by Gio Ponti, 1956; transparent partitions that create permeable zones of interaction, such as the movable glass walls in the Casa Manifesto by Marta Lonzi, 1972-73; separation between shared and personal spaces, enabling free choice rather than necessity in cohabitation, as it happens in the Progetto Domestico by Cini Boeri, 1986.

Furnishings. Among the Furnishings, curtains stand out as a design tool that defines space by dissolving its boundaries: drapery creates space just to destroy it, with installations where the display elements are textiles hanging from straight and curved steel pipes, as in Café Samt und Seide by Lilly Reich, 1927; rendering mobile those elements that are traditionally static, as in the Maison Floirac Revisited by Petra Blaisse, 2019.

Other. Among the Other materials collected in the diary are examples where critical inquiry into domesticity has also taken the form of artistic practice, explicitly associating built space with power dynamics by assigning creative value even to acts of destruction, as in Destroy She Said by Monica Bonvicini, 1998, or reinterpreting home spaces through installations that denounce the confinement in the roles of mother, daughter, wife and expressing resistance by transforming the space of subordination into one of action and political narration, as in Womanhouse by Judy Chicago and Miriam Schapiro, 2019.

Autobiography. Among the Autobiography's materials: a family shopping list, evoking habits and ways of dwelling; a critical reading of one's own home, highlighting the merits and limits of standardized residential building which, while ensuring the right to housing, has become disconnected from the evolving needs of the families; a description of the grandfather's house during Sunday lunch, relating space to family roles and behaviors.

Through a cross-reading of Rooms - kitchens, bedrooms, bathrooms - and an analysis of Special Houses and design devices - curtains, movable walls - a layered archive of architectural research, gradually collected in the diary, shows how spatial critique can coincide

with the critique of power systems. To rethink the home can mean to rethink the roles, identities, and hierarchies it embodies.

Findings and Discussion

The first result of this work is the revelation and critique of the power structures embodied in the space of the home; the second result is the identification of design themes and tools aimed at subverting these established structures through spatial liberation actions. Regarding the first result, the research confirms the hypothesis of a correspondence between power systems and spatial systems and reveals the persistence of patriarchal structures in the organization of daily life that are reflected in the spatial organization of the home. In this sense, for example: the hierarchization and separation of spaces seems to correspond to the hierarchization and separation of social and family roles; the fixed functional assignments of the rooms seems to correspond to the fixed tasks of family members; the canonicity of furnishings seems to correspond to a canonical conception of daily life habits.

Regarding the second result, the research confirms the possibility of acting through design towards subverting the dominant orders which are reflected in the consolidated arrangements of domestic space. In this sense, for example: the design of some special houses by known authors suggests different conceptions of social and family life, focusing on flexibility and interchangeability in the layout and functional uses of spaces; the critical rethinking of certain rooms, traditionally linked to a condition of female subordination, opens ways for new possibilities for women's subjectivism; the adaptability of certain furnishings facilitate the variability of uses; the innovative use of some elements, such as curtains, enables freedom of behavior through the free configuration of the home.

Through the daily collection of examples and reflections, the diary proposes methods and tools for revealing the power structures embodied in the space and for their subversion through the culture and tools of design.

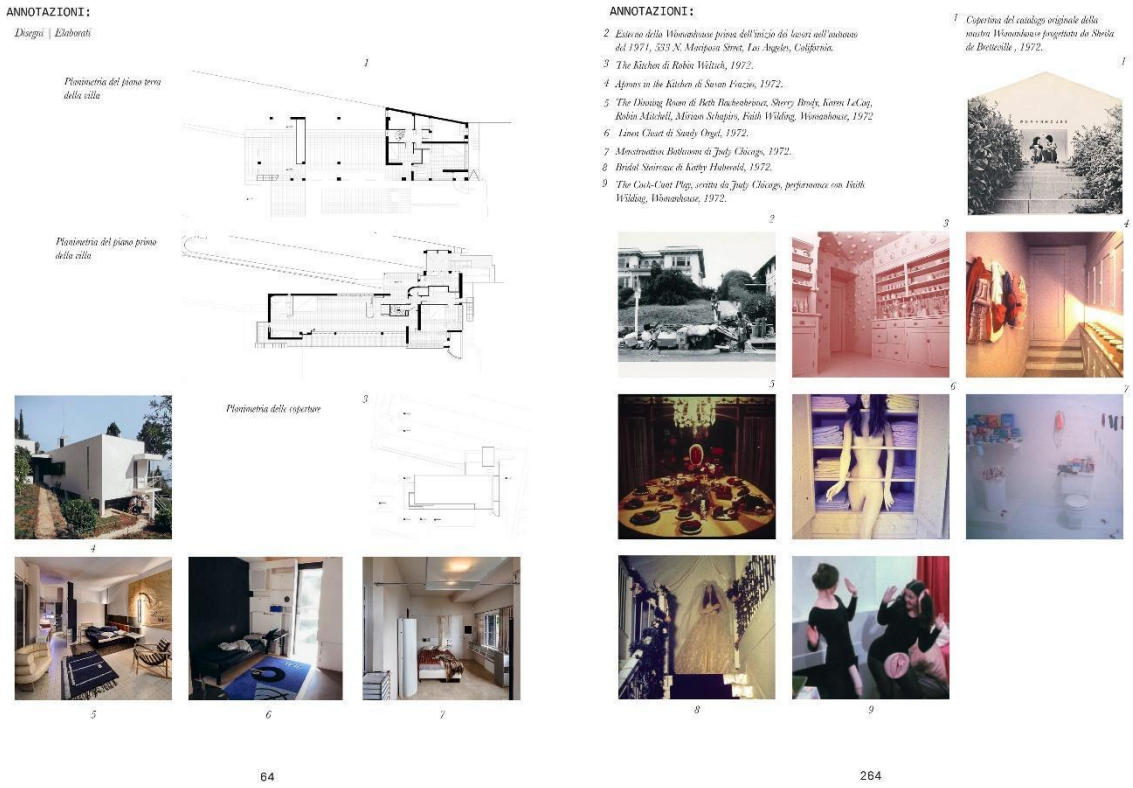

Figura 1. De Rosa A., Case speciali, in “Spazio domestico. Un diario”, degree Thesis in Architecture, supervisor prof. F. Ippolito, co-supervisor Ilenia Mariarosaria Esposito, Università della Campania Luigi Vanvitelli, 2025.

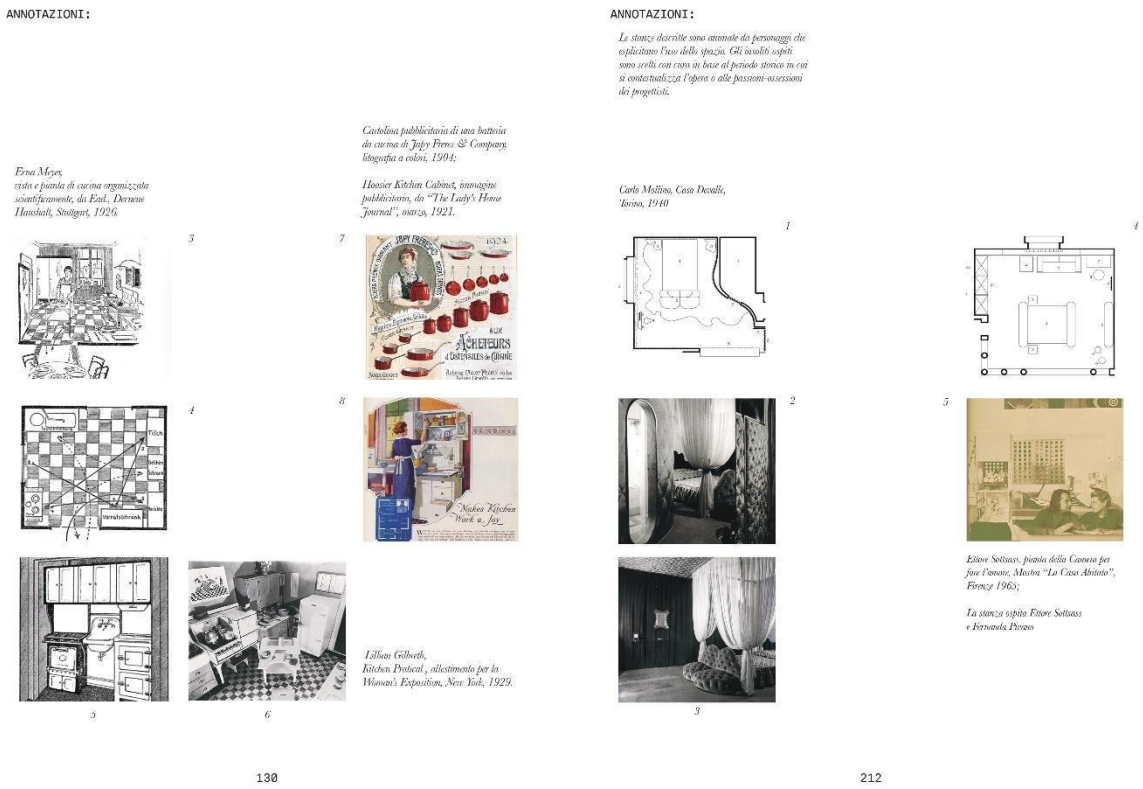

Figura 2. De Rosa A., Stanze in "Spazio domestico. Un diario", degree Thesis in Architecture, supervisor prof F. Ippolito, co-supervisor Ilenia Mariarosaria Esposito, Università della Campania Luigi Vanvitelli, 2025.

Conclusion

The research does not so much aim for a conclusion as to open a discussion that focuses on a critical rethinking of the design of the home. At a time when sustainability debate seems to primarily look for efficient responses to pressing questions, which in the case of housing mainly concern performance and functionality, an interpretation of sustainability in the perspective of spatial justice, with particular reference to gender issues, can lead to a radical rethinking of the topic, in both social and design terms. Questioning the configuration of the home can mean questioning the power structures that are reflected and reproduced in that space; acting through design can help liberate it from dominant models, making it a more equitable and inclusive place. In this perspective, the home can emerge as a political space to be deconstructed and critically reimagined through research.

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COLLECTIVE SPACE

PROJECT OF MOBILIZATION

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Collective space. Project of mobilization

Abstract: The paper presents a contribution to the debate on the collective space and the collective dimension of design, aimed at the present and based on a still active heritage of knowledge. The research, which is conducted within a teaching course and a thesis laboratory in architectural theory at the Department of Architecture and Industrial Design at the University of Campania Luigi Vanvitelli (20192025) and was reworked and exhibited as part of the AMA Festival of the Municipality of Maddaloni (2025), aims at providing a starting point for a critical reflection on the topic of sustainability from a perspective of mobilization through culture and design tools. Being rooted in the architectural debate of the second half of the twentieth century and projected into the present, being focused both on the relationship between space and society and between theory and design, the work interprets architecture as a field of thought and positioning on current issues. If collective space is a creative, critical, plural space, a laboratory and repository of projects and visions, an architecture of engagement can find in this space, and in the debate that has passed through it, the basis for a project of mobilization.[1]

Keywords: Theory and Design / Collective Space / Project of Mobilization.

Introduction

At a time when design culture seems to be limited to a pragmatic approach to the questions of the present, an experimental laboratory of theory and design, interpreted as a collective critical space founding on the construction of a shared cultural heritage, is the place for a reflection on architecture in relation to the city and society. The laboratory places collective space and the collective dimension of the project at the center of its research, looking at it from a perspective of mobilization, drawing on a heritage of experimentation and visions rooted in the recent past and still active. As mobilization is defined as the activation of a multitude towards a shared direction, the term mobilization, transferred to the debate on the city and architecture, indicates the activation of the multitude of resources (theories, projects, politics and practices) that make up the cultural background of the discipline towards a radical change of perspective in handling the present.

[1] The contribution draws on the research work carried out within the Course in Theory and Technique of Architectural Design, Prof. F. Ippolito, tutor I. M. Esposito, Degree Course in Architecture, University of Campania Luigi Vanvitelli, a.a. 2018-2025. The work, with the name *Spazio collettivo*, was presented, at its beginning, at REDS Legacy International Conference (Matera 2019 European Capital of Culture, publication *Abitare la terra* n. 50, 2019); it was developed in subsequent years and was recently exhibited within *AMA_Arte_Maddaloni_Architettura, Biennale delle Arti per la rigenerazione della città di Maddaloni* (curator L. Molinari, 2025). This paper reworks, updates and completes the work initially published on *Abitare la terra*.
The content and responsibility of the contribution are fully agreed upon and equally shared between the two authors.

The reflection aims at facing the most controversial aspects of the present by referring to those theories and projects which use controversies to fuel an interpretation of architecture as a critical gaze on the world.

The working hypothesis is that both the conditions of cities, landscapes, and society - being affected by economic, social and environmental crisis - and the issues of the design debate - concerning the role of architecture and the architect in these situation -, prompt a project of architectural mobilization. Rather than trying to find urgent answers to the demands imposed by the crises, the mobilization seeks to conduct a radical critique of the conditions. The field of investigation is the collective space, understood as the basis of mobilization: a critical, plural, and conflictual space, a repository of projects and visions, it is a place of potential innovation.

Literature Review

The cultural framework of reference is the interpretation of the collective in the disciplinary debate of the last fifty years: the city as a collective construction and the design of urban architecture, the right to use space and the user participation in the project, the dystopias implicit in the reality and the design of concrete or radical utopias, public space and standardization and collective space and the project open to events and exceptions, the common good and the new collaborative design practices, the power structures embodied in spatial structures and the critique of space as a critique of society . In the background, there is the idea of an architecture that takes a stand, combining theory and design, confronting itself with context and users and with the transformations and visions of the city and society.

Methods

A repertoire of examples nourishes the discussion, combining past and present experiences, architectural projects and projects by uses, theoretical visions and design works, large and small scale, in a review of variations on the theme of collective space and the collective dimension of design. Gathered in a book of books, each dedicated to a specific aspect of collective space, they are elements of an open collection. In the collection: collective space is the space of the common, understood as the space of municipal autonomy, as in the projects of the administrations of Tirana (Edi Rama), Medellin (Sergio Fajardo), Curitiba (Jaime Lerner) and Barcelona (Ada Colau), which link architecture and society by proposing the city as a laboratory of visions, drawing in some cases (Medellin, Curitiba) on the legacy of Italian culture of urban design and the idea of the city as a collective project (Rossi, 1966); it is a

common good to be safeguarded, according to the theories on the governance of collective goods (Ostrom 1990), the battles over cultural heritage (Settis, 2017) and the practices of active citizenship (No TAV, Valle di Susa), which reflect new cultures of the environment (Latour ,2018), of the landscape (from the European Landscape Convention, 2000) and of urban activism (Harvey, 2012); it is an opportunity for building communities around architecture, as in recent regeneration projects (R. Montiel, Common Unity, Mexico City, 2015; G 124, Ex Edison, Marghera, 2016), in which the idea of designing with users re-emerges, with new declinations (De Carlo, 1970). On the contrary, it is a space sponsored by private individuals, as in the projects of large companies and great authors who grant facilities to the city (in Milan Fondazione Prada, R. Koolhaas, 2015, or Feltrinelli, Herzog and De Meuron, 2016); or a commodified space, as in the touristic city of Venice (Settis, 2014) or in the simulated world of Disneyland and other *non luoghi* (Augé, 1997), overturned into the dystopia of Banksy's Dismaland (Bristol, 2015). It is a divisive space, like that of the rich against the poor in the quartz city of Los Angeles (Davis 1990) or of the Israelis against the Palestinians in the architecture of occupation in Palestine (Weyzman, 2007), or even that of men against women in the domestic place (Hayden, 1981), or a violent one, like that investigated by an architecture that proves war crimes (Forensic Architecture, since 2010), or represents the wounds of bombs (Woods, 1993) or mimics combat systems (B. Khoury, B 018, Beirut 1998), but it is also a space of resistance to segregation, like in the architecture against Apartheid (Noero Architects, Red Location Cultural Precinct, New Brighton, in progress) or against the walls (T. Cruz, F. Forman , UCSD Cross- Border Initiative , 2012). It is a critical space, which takes reality to its extreme consequences, as in the projects of the city of voluntary prisoners (R. Koolhaas, Exodus, 1972) or the social assembly line city (Archizoom, No Stop City, 1970), which reemerge in recent references to the relationship between politics and architecture (Aureli, 2016; Biraghi, 2018), or it nullifies it, as in the images of superspaces for a new life (Superstudio, Supersuperficie, 1972), which return, depleted of their subversive force, in much of today's designed architecture. It is a space for transgressive behaviors, as in the architecture of avantgarde clubs (Gruppo 9999, Space Electronic, Florence, 1969) or in the theories that link event space and movement (Tschumi, 1994); or, on the contrary, a space that expels transgression from entertainment in the globalized city (Sorkin, 1992). It is an autarchic space, like the design school without students or professors (Global Tools, 1973-1975) or the museum without exhibitions (MAAM, Rome 2009), or self-built, according to DIY manuals (Mari, 1974; Friedman, 1976), or recipes for circumventing the laws (Recetas Urbanas, since 2007). It is a potential space, like that of the approximately 800 unfinished Italian public works,

interpreted as a national style (Alterazioni Video and Fosbury Architecture, 2018) at a time when the life of waste (Lynch, 1991) is under the attention of a renewed culture of recycling, which becomes a form of architecture (Recycle, Maxxi, 2011) or a process of landscape regeneration (Landscape Urbanism, 90s). It is contaminated natural space (J. Corner, Fresh Kills, New York, 2001), uncultivated (G. Clément, Parc Citroen, Paris, 1985), urbanized (R. Koolhaas, Parc de la Villette, 1983), which belies the idea of the park as an island of greenery, already dismembered in the modern archipelago city (Ungers, 1977). It is an interstitial space, where it takes place the attitude to the reinvention of residual places (A. Van Eyck, Playgrounds, Amsterdam, 1947-1955) or the invention of unexpected places (B. Tschumi, Le Fresnoy, Tourcoing, 1991-1997), inherent to the city. It is a popular space, a vindication of the right to ugliness (L. Bo Bardi, SESC Pompeia, São Paulo, 1977-1982) in the mass architecture of the modern city, defused by commercial aesthetics in the contemporary era (Venturi, Scott Brown, Izenour 1972). It is a space of revolutions and movements, such as those that in 1968 poured into the city from the university and were reflected in university structures that mimicked or internalized urban complexity (G. De Carlo, Collegio del Colle, Urbino, 1962-1966; G. Candilis, A. Josic, S. Woods, Free University of Berlin, 1963-1973), or made education an experience of exploration and construction (Ciudad Abierta, Ritoque, from 1970), leaving traces that are still active in the unconscious of the institution.

Findings and Discussion

Exploded into a myriad of phenomena, subjects and materials, interpretations and visions like these, collective space is the space of the multitude that animates the mobilization. 100 definitions of collective space, 100 images of collective spaces and 100 statements on the collective dimension of the project are the elements of a collection and the materials for a reflection on the relationship between theories and projects and between architecture, city and society, with a particular focus on the architectural debate of the last fifty years. Composed of three manifestos (all the definitions, all the images, all the quotations), they offer a varied portrait of design culture; linked by location (a definition, an image, a quotation), they present 100 declinations of collective space. On display, the manifestos are accompanied by 100 books of sixteen pages each; each one - by a single author – exploring, through literature and projects, a single declination of collective space.

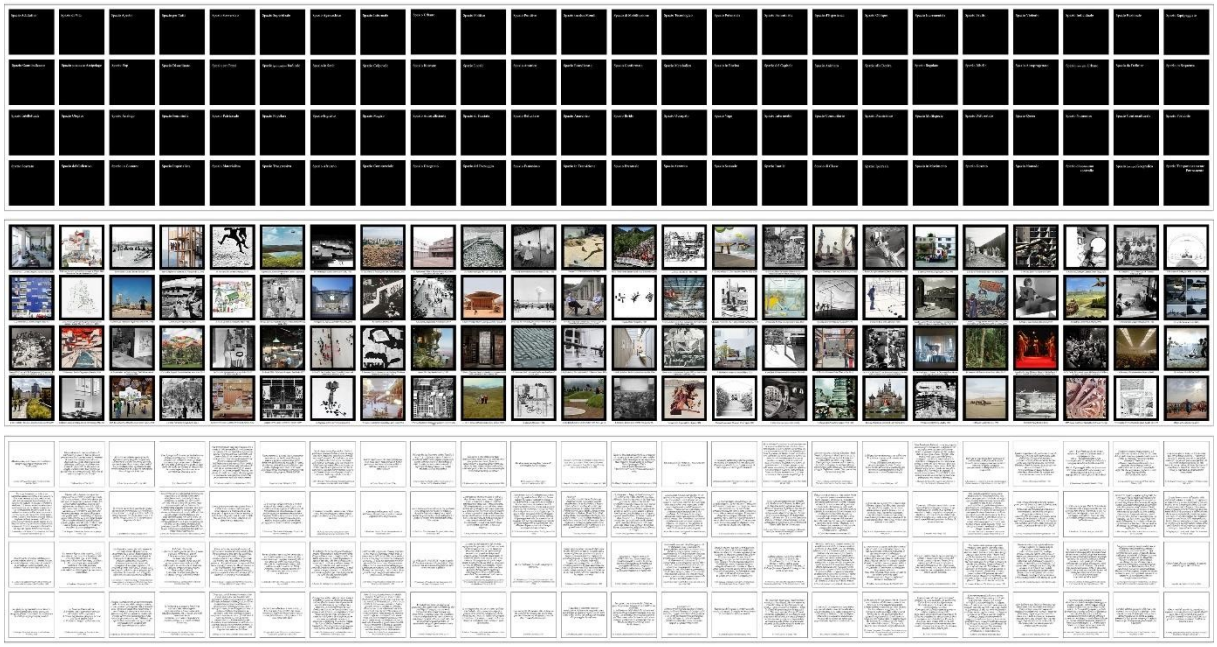

Figure 1. Ippolito, F., Esposito, I. M., (2025). *Spazio Collettivo. 100 definizioni, 100 progetti, 100 citazioni.*

Figure 2. Ippolito, F., Esposito, I. M., (2025). *Spazio Collettivo. 100 definizioni, 100 progetti, 100 citazioni,* in *AMA_Arte_Maddaloni_Architettura, Biennale delle Arti per la rigenerazione della città di Maddaloni,* curated by L. Molinari*,* Municipality of Maddaloni, Department of Architecture and Industrial Design of the Luigi Vanvitelli University of Campania. Convitto Nazionale Statale "Giordano Bruno", Maddaloni (CE), Italy, March 28 - April 27, 2025.

Conclusion

If collective space is creative because it is critical, plural, and confrontational, a mobilization based in this space, even before responding to current challenges, can prompt their reformulation. Facing with issues such as economic hardship, environmental degradation, and social injustice, assimilated into the rhetoric of crisis, the mobilization project questions the perspective of mitigation by subverting the work plan. Beyond responding to critical issues with virtuous practices - from participation, to the use of lightweight technologies and the internet, to green spaces, to building recycling - which define a sustainable, intelligent, and resilient city, but also beyond responding to marginalized conditions with emergency resources, from projects open to manipulation by residents, to low-cost interventions, to the use of local materials and labor, which identify a solidarity based architecture, a radical critique of existing conditions raises a question on the reasons of the project, rather than on the methods. Reformulated from the collective space, the challenges of the present place the collective at the centre as the subject of planning: a field for experimenting with projects and comparing visions, the collective space is the place of daily renegotiation of the right to the city.

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BEYOND ALL LIMITS 2025**:** 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

ARCHITECTURAL RESILIENCE THROUGH ADAPTIVE REUSE: SALA BECKETT AS A MODEL OF LAYERED SUSTAINABILITY

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Architectural Resilience through Adaptive Reuse: Sala Beckett as a Model of Layered Sustainability

Abstract: This paper explores the concept of architectural resilience through adaptive reuse, using the Sala Beckett in Barcelona, designed by Flores & Prats, as a case study. The project represents an example of how architecture can maintain its identity while adapting to new functions, ensuring both material and cultural continuity. The research analyses theoretical frameworks of resilience such as layering, reversibility, and flexibility, and investigates how these concepts are applied in the project. Through analysis of design strategies and specialized literature, it is argued that adaptive reuse is not only a sustainable practice but a profound expression of care, memory, and time in architecture. Sala Beckett thus stands as a resilient design model supporting social cohesion, environmental responsibility, and the dynamic life of buildings over time.

Keywords: Resilience, Adaptability, Layering, Reversibility, Temporality

Introduction

In the current context characterized by challenges such as climate change, uncontrolled urban growth, and depletion of natural resources, the field of architecture must deeply reconsider methods of design, construction, and management of buildings. Resilience has emerged as a crucial paradigm, going beyond mere technical robustness to embrace cultural, social, and temporal adaptability of built spaces.

Architectural resilience is therefore configured not only as the ability to withstand extraordinary events but especially as the capacity to adapt to changing uses and functions while maintaining an identity continuity over time. This approach is particularly evident in the adaptive reuse of existing buildings, which represents a sustainable practice to extend the useful life of properties, preserve material and cultural memory, and reduce environmental impact.

This study focuses on Sala Beckett, a building located in the Poblenou district of Barcelona, redeveloped by Flores & Prats as a theater and dramaturgy school. The project represents an interesting example of how architectural resilience materializes through design strategies based on layering, reversibility, and permeability, and how these strategies can also be interpreted through Italian theoretical perspectives on sustainability and restoration.

The methodology adopted is based on an in-depth theoretical review, detailed architectural analysis, and critical interpretation of design choices, using primary and secondary sources, aiming to demonstrate that resilience in architecture is a practice integrating environmental, social, and cultural dimensions. Within this framework, the adaptation of existing buildings is seen not only as a response to ecological urgency, but also as a form of architectural responsibility that fosters continuity and regeneration.

Literature Review Case Study: Sala Beckett, Barcelona

Architectural resilience is defined as the ability of buildings to respond and adapt to environmental, social, and functional changes over time. The most significant theoretical contributions come from international authors such as Stewart Brand, Jeremy Till, and N. John Habraken, who propose visions of architecture as an open and dynamic system.

Brand, in his book *How Buildings Learn* (1994), introduces the concept of "shearing layers," in which different building components—site, structure, skin, services, space plan, and stuff—change at different rates. This model emphasizes the idea that buildings are not static entities but evolving systems that transform alongside their users, functions, and contexts.

Jeremy Till, in *Architecture Depends* (2009), argues that architecture must embrace uncertainty and contingency, rejecting the pursuit of absolute permanence in favor of an open approach to change and social interaction. Till highlights the importance of designing with temporal and social dynamics as integral parts of the process.

Habraken, with his theory of "supports" (1972), distinguishes between the structural framework and elements modifiable by users, promoting active resident participation in space transformation and greater building longevity.

These international contributions resonate with Italian reflections that deepen the theme of resilience linked to place identity and sustainability. Sergio Magnaghi (2010) highlights the concept of "place consciousness" as a key element for resilient design, arguing that the historical and cultural layering of a site must be valued as a design resource.

Francesco Musco (2016) connects architectural resilience with urban regeneration, highlighting how space adaptability contributes to social and environmental sustainability in cities. In parallel, authors such as Ferrante (2012) and Torricelli et al. (2001) have examined the technological and methodological aspects of adaptability in architecture, emphasizing integrated strategies for upgrading existing building stock through flexible and environmentally responsible interventions.

This corpus of theoretical reflections outlines the conceptual framework within which the Sala Beckett project is analyzed, interpreted as a concrete expression of resilient architecture integrating material, social, and cultural aspects.

Methods

This research follows a qualitative and interpretative approach based on an extensive review of international and Italian literature, alongside a detailed architectural analysis of the Sala Beckett project. The study relies on project documents, published architectural journals, monographs, and online sources related to the building and the architects Flores & Prats. The analysis focuses on the design strategies adopted, interpreting them through the lenses of layering, reversibility, and permeability, and evaluating the building's capacity to support functional, social, and cultural continuity over time.

The methodology seeks to connect theoretical discourse with practical implementation, examining the extent to which spatial choices, material techniques, and formal language can be read as resilient responses to change, memory, and context.

Findings and Discussion

Sala Beckett is located in the Poblenou neighborhood, an area characterized by a strong postindustrial identity and urban transformation processes. Originally built in 1924 as the Cooperativa Paz y Justicia, it was a social center for workers and, after decades of use, was abandoned in the 1980s and temporarily occupied in the 1990s.

The redevelopment project, entrusted to Flores & Prats, proposes a reactivation of the building rather than traditional restoration, focusing on respect for the existing fabric and traces of time.

Sala Beckett hosts multiple functions: theaters, classrooms, rehearsal studios, offices, and a public café. The design avoids imposing a rigid spatial scheme, favoring flexible and multifunctional environments. The large central foyer acts as a visual and physical connection element between spaces, promoting interaction and an atmosphere combining domestic and public aspects. This space becomes a meeting point, cultural and social exchange hub, consistent with Musco's ideas on resilience in urban contexts.

Contemporary interventions were conceived as a "second skin," independent and easily removable elements that do not damage the original structure. Use of materials such as metal, glass, and lightweight partitions creates a clear visual dialogue between old and new, allowing future flexibility and easier maintenance.

The design values historical traces, preserving imperfections, cracks, and signs of time that narrate the building's history. Physical layering thus becomes a material narrative, where each element expresses memory, in line with the idea of integrating past and present as a

strategy of resilience. The palimpsest becomes a manifesto of continuity that does not erase the past but incorporates it into the present with coherence and sensibility.

The building is permeable, with access points and visual connections integrating its presence into the urban and social fabric. This openness encourages community participation and local cultural life, emphasizing the importance of social dimension in architectural resilience, as noted by Musco.

The architects' approach was to accept and enhance the state of decay, turning it into a design resource. Material incoherence and imperfections become authentic signs carrying meaning and authenticity, testifying to a design logic rooted in reality and temporal complexity.

Sala Beckett represents a virtuous example of architectural resilience that goes beyond mere environmental sustainability to include social and cultural dimensions. Material conservation, functional flexibility, transparency, and the valorization of material memory combine to create a building capable of living, transforming, and dialoguing with the community.

The project contrasts with an urban paradigm based on demolition and replacement, proposing instead a model of slowness, care, and continuity. The adoption of reversible elements and flexible spaces increases adaptability and reduces environmental impact, supporting urban vitality.

Moreover, the material and spatial narrative of Sala Beckett serves an educational function, transmitting values of memory, imperfection, and transformation—fundamental aspects for resilience that is not only physical but also cultural.

Adaptive reuse, in this case, emerges as an innovative and creative strategy where constraints become design stimuli, generating new aesthetics and ways of experiencing space.

Conclusion

The adaptive reuse project of Sala Beckett demonstrates how architectural resilience can be practiced through a strategy integrating layering, reversibility, and permeability. The building maintains memory and material continuity while adapting to new functions and stimulating social participation, offering a replicable model for sustainable and responsible architecture.

This study emphasizes that resilience is not mere survival but a design ethic recognizing the temporal, social, and cultural complexity of buildings. In a constantly changing world,

examples like Sala Beckett teach us that architecture can evolve without losing connection to the past, accompanying communities and territories in transformation.

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OSCILLATING BETWEEN SUSTAINABLE UTOPIA AND DYSTOPIA: NEOM CITY

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Oscillating Between Sustainable Utopia and Dystopia: NEOM City

Abstract: This paper aims to indicate some questions about recent sustainability projects via using the case NEOM City that is launched as a sustainable urban utopia in Saudi Arabia. NEOM City as being a macro intervention on desert suggests an ecosystem in the dead earth to show of the power of Saudi Arabian government. Is it sustainable to create that bigness in the middle of dessert, where life is survived in minimum levels? Does the earth need such an intervention, which claims to suggest a sustainable future? What is the reason behind to spend such amounts of sources to create NEOM city? Why such huge amounts of sources/money invested for the NEOM city? As in the case of NEOM City, is sustainability used a tool for legitimacy of the neoliberal-autocratic politics?

Keywords: Sustainability; Utopia; Dystopia; Neoliberal Politics; Architecture

Introduction

Architecture has a significant role and vital indicator on sustainable policies. After 1990s, with an utmost acceleration, sustainable architecture had been used by the governmental policies for the powerful representation of dominant ideologies. As being a current example of this representation, NEOM City is chosen as a case of this paper that aims to show of how sustainability used as a key factor of power relations.

Is NEOM City, which was launched as a sustainable urban utopia by Saudi Arabian government at 2021, truly sustainable or not? This question is the major impulse to write this paper. NEOM City as being a macro intervention on desert suggests an ecosystem in the dead earth to expose the power of Saudi Arabian government. Is it sustainable to create that bigness in the middle of dessert, where life is survived in minimum levels? Does the earth need such an intervention, which claims to suggest a sustainable future? What is the reason behind to spend such amounts of sources to create NEOM city? Why such huge amounts of sources/money invested for the NEOM city? As in the case of NEOM City, is sustainability used a tool for legitimacy of the neoliberal-autocratic politics?

For an in-depth gaze to conceive the reasons behind to construct NEOM City, it is decided to investigate a deep examination on the web page of NEOM City (NEOM, n.d., URL1), which is the official interface of the project. This research is essentially a critical analysis and a reading of official web page of NEOM City in order to discover why and how this project claim to be a sustainable urban environment.

The explicit claim of the paper is that NEOM City is a pseudo-utopian sustainable settlement of Neoliberal ideology within the shadows of autocracy; NEOM city is actually not a sustainable utopia, its building processes caused an additional load on climate crisis.

Utopia: "NEOM, The land of the future"

"NEOM is the land of the future where the greatest minds and best talents are empowered to embody pioneering ideas and exceed boundaries in a world inspired by imagination." (URL2)

In the official web page of the NEOM City, NEOM City is described as the land of future, while it has been launched as an urban sustainable utopia. The naming of NEOM City is also loading the adjective "new" to the word "future"; it is derived from two words: Neo+Mustaqbal. This combination- New Future- is frankly unravelled that the establishing idea states to be a utopia.

Although the major claim observed at the web page of NEOM City is constructing a new land of the future, it is remarkable to recall that every utopia comes with its implied dystopia (Gordin, et. all. 2010). In the entropic increment of the universe, mostly the designed utopia has a potential to turn into dystopia, because of the traces of the lived experiments. (Gordin, et. all. 2010). When the utopia is realized or materialized, it calls for its dialectical other, dystopia; this encounter is a network of perfectly planned and perfectly unplanned. (Gordin, et. all. 2010). In this controversial position, a question raises that could the case, NEOM City, which is under construction at the present, be a utopia at the end?

When it is thought that utopia is the history of the present (Gordin, et. all. 2010), the NEOM City represents the ideology and the policies of the present government of Saudi Arabia; this approach exposed that all the Neoliberal policies under the shadow of autocratic regime will somehow be legitimized by the creation of the NEOM City. It is possible to read the construction of the NEOM City as an implicit ideological legitimization process of present government of Saudi Arabia.

Utopia aims to model an ideal society (Baba, 2022; Kumar, 2005). This construction of the ideal society is not a transformation of a current societal structure, rather utopia suggests a radical reproduction of the society (Baba, 2022). This modelling process is not only for one case but also repeated for many; the procedure could be read as transformation of a utopia to dystopia (Baba, 2022). From this stand point, it is significant to conceive the claim of NEOM city, which is to make a revolution in civilization, for creating or reproducing a new society. If Utopia is a modelling of an ideal society (Baba, 2022; Kumar, 2005), what kind of society is under construction under the umbrella of NEOM City?

Linear city: "The LINE, The future of urban living"

"A cognitive city stretching across 170 kilometres, from the epic mountains of NEOM across inspirational desert valleys to the beautiful Red Sea. A mirrored architectural masterpiece towering 500 meters above sea level, but a land-saving 200 meters wide. THE LINE redefines the concept of urban development and what cities of the future will look like." (URL3)

As Harvey (1988) stated that the form of the city determines the human behaviours. NEOM City is planned as a linear city that consider the health and well-being of inhabitants (total 9 million), which are accommodated on 34 square kilometres footprint. It is designed as pedestrian-friendly city without cars and roads; residents will access all daily essentials in five-minute walk and additionally a high-speed rail is designed for 20 minutes' transition on The Line. Transportation and infrastructure reduce to minimum levels for the sake of preserving nature that is 95% of the land. The ideal climate of the NEOM City will be supplied by 100% renewable energy.

NEOM City is designed as an ideal linear city, which may become a compositional prototype for the urban planning of sustainable cities of the future (Paszkowska-Kaczmarek, 2021). Although physical context is ignored in the design process of The Line, it is possible to claim that social context is egalitarian because of the homogenous character of the linear city. One of the design principles of The Line, linear city at the NEOM Project, is to be a homogenous structure that has been constituted with modules without special centres; this feature supplies equality in social structure (Paszkowska-Kaczmarek, 2021). However, the geographical conditions of structure of The Line, for example to be near the sea, or, to be at the valley etc., break the egalitarian character of the linear city. Four distinctive landscapes form the sub-sections of the linear city (Coastal, Coastal-Desert, Mountain and Upper Valley); these ecozones create an imbalance on the homogeneity of the linear structure (Paszkowska-Kaczmarek, 2021). The three vertical layers, which are pedestrian layer, service layer and spine layer, support the linearity, in order to emancipate The Line from the automobiles. With the implementation of smart technologies, the problems of linearity try to be solved.

Sustainability: "NEOM Values"

"We aspire to leave our environment better than we found it. We act responsibly, encouraging a culture of honesty, integrity and ethical sustainability." (URL4)

Main branding narratives of NEOM City are future, environment and people (Aly, 2023). One of the main branding narratives of NEOM city- environment is directly matching with sustainability that is the planet-wide ecological phenomenon; urban sustainability is central to the development of The Line- the Linear city of The NEOM Project (Tan, 2024). Actually, sustainability could be seen as a ubiquitous term (Tan, 2024); all environmental issues linked to this concept in order to step forward to the problems of climate crisis.

NEOM City claims to be a zero-carbon city with the elimination of cars and roads and unnecessary infrastructure and will operate 100% renewable energy. However, when the construction processes of NEOM City considered, it is clear to observed that it spends earth's energy and resources. In the official web page of NEOM City, it is claimed that integration of nature and open spaces will enhance air quality, but the double walls of The Line is worked as a natural barrier that caused a gap between two side of The Line itself.

As Palmini & Cugurullo (2024) stated that juxtaposition between technocentric and ecological perspectives – that is between *smart* and *eco* urbanism in cities - provides a weak foundation for a possible relationship between AI and sustainability in the urban context. However, in NEOM City project, this contradiction is somehow accomplished by the help of the Latourian approaches; by articulating people, cybernetic objects and environment could be a solution for this contradiction.

Neoliberalism: "Open for Business"- Implicit Narrative

"With world-class partners in place and a growing pipeline of investment opportunities across regions and sectors, NEOM is open for business. Strategically located and economically attractive, NEOM provides partners and investors with the opportunity to incubate, develop and deploy scalable solutions to global challenges." (URL5)

After 1980s, with the shift from managerialism to entrepreneurialism (Harvey, 1989), cities began to be seen as economic engines for fostering economic growth and capital accumulation (Aly, 2023). Although the private sectors and investors could be observed as the actors at the web site of the NEOM city, the project is a state-led (Aly, 2023), the main financer is the Saudi Arabian government. However, it is remarkable to consider that new Saudi government is the entrepreneurial state. The government's legacy stems from the capital accumulation, and it is preferred to expose this accumulation via constructing an ideal futuristic city (NEOM City) that run for an economic engine to enhance more capital accumulation.

As Harvey (2005) stated economic and political contradictions of Neoliberalism could be controlled by the financial crisis. There is a direct link between the argument of Harvey and the construction process of the NEOM City; entrepreneurial state of Saudi Arabia is in an effort to rescue the Neoliberalism from the deep financial crisis, which will bring the end of Neoliberalism itself. Therefore, it is possible to find the reason of why the NEOM City project is launched at the date 2021; if it is speculated about the date of the beginning of the NEOM City project, then it should be the end of Neoliberalism for the sake of autocracy.

Conclusion

Spencer (2016) stated that architecture accommodate itself to the present date pragmatics of doing business; means and methods of the market give form to architecture. In the post-political era, neoliberalism—described as the "ideology of no ideology" (Spencer, 2016)—has become the dominant force guiding architectural production. NEOM City, launched by the Saudi Arabian government in 2021 as a symbol of sustainable urban utopia, is deeply embedded in this framework. Despite its ambitious rhetoric of ecological harmony and innovation, NEOM City operates as a pseudo-utopian project that reflects the entanglement of neoliberal agendas with autocratic governance.

Rather than presenting a genuine alternative to the climate crisis, NEOM City exemplifies how sustainability can be instrumentalised as a tool for political legitimacy and economic spectacle. Its immense scale, resource-intensive development, and top-down vision raise essential questions: Can true sustainability emerge from projects rooted in excess? Or is NEOM City merely a performative effort to extend neoliberalism's lifespan under the guise of environmental progress? In this oscillation between utopia and dystopia, NEOM City may reveal less about the future of cities—and more about the contradictions of our present. The final question could be raised at the end; is the project NEOM City created for rescue the Neoliberalism from its own inevitable collapse?

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SUSTAINABILITY CHALLENGES IN URBAN DESIGN AND PLANNING

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THE ROLE OF CULTURAL HERITAGE AT THE INTERSECTION OF CIRCULAR ECONOMY AND RURAL DEVELOPMENT

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The Role of Cultural Heritage at the Intersection of Circular Economy and Rural Development

Abstract: This study explores the pivotal role of cultural heritage in advancing circular economy principles within rural development contexts. Cultural heritage, encompassing tangible assets such as historic buildings, monuments, and landscapes, alongside intangible practices and local knowledge, represents a valuable resource for sustainable rural economies. By integrating heritage preservation with circular economic strategies—such as adaptive reuse, resource efficiency, and sustainable tourism—rural communities can stimulate economic growth while minimizing environmental impacts. The research emphasizes how heritage-led initiatives contribute to local identity, community resilience, and the diversification of income sources, particularly in areas facing depopulation and economic marginalization. Ultimately, the study highlights that leveraging cultural heritage within a circular economy framework not only preserves historical assets but also catalyses sustainable and inclusive rural development.

Keywords: circular economy, heritage, rural development, sustainability

Introduction

In recent years, the concept of sustainability has expanded beyond environmental policies to encompass economic, social, and cultural dimensions. Within this framework, the concepts of circular economy and rural development, when examined in relation to cultural heritage, open up new research perspectives. The circular economy promotes the reuse of resources, the minimization of waste, and more efficient production-consumption cycles, while rural development aims to enhance the socio-economic empowerment of local communities, improve quality of life, and protect natural and cultural assets. In this context cultural heritage not only serves as a central element in rural development policies but also aligns with the principles of reuse, repair, and value creation within circular economy models. This paper aims to discuss the role of cultural heritage at the intersection of circular economy and rural development.

Methods

This study is based on a qualitative literature review that examines recent national and international academic works on circular economy, rural development, and cultural heritage. Within this framework, circular economy principles (Ellen MacArthur Foundation, 2019; Kirchherr, Reike & Hekkert, 2017), rural development policies, and sustainability approaches to heritage preservation are evaluated. Comparative examples from Turkey (Safranbolu, Cumalıkızık, Cappadocia, Şirince, Kars Gravyer) and the world (Rome, Istanbul, Alberobello, Hallstatt, Matera, Douro Valley) are used to illustrate the discussion. The methodology involves

a conceptual, descriptive, and comparative approach, highlighting how cultural heritage contributes to both circular economy practices and rural development goals.

Circular Economy: Principles and Definitions

The circular economy has been developed as an alternative to the linear economy model (take-make-dispose). This model aims to reduce waste in production and consumption while extending the lifecycle of resources (Geissdoerfer et al., 2017). The European Commission (2020) defines the circular economy as a system in which "products, materials, and resources are kept in the economy for as long as possible, while waste generation is minimized." At the literature, circular economy has been discussed particularly in the context of industry, agriculture, and construction, with an emphasis on resource efficiency and sustainability (Demir, 2021). Globally, scholars highlight how circular economy can address climate change, resource scarcity, and urban sustainability (Murray et al., 2017; Kirchherr et al., 2017; Güngör, 2023). In the construction sector, which accounts for a significant portion of waste production as well as material and energy consumption worldwide, the circular economy model has begun to attract attention instead of the widely used "take, make, throw away" (Linear Economy) model (Deniz and Oğuz, 2025; Güleç and Yalçın, 2025) (Figure 1, Figure 2).

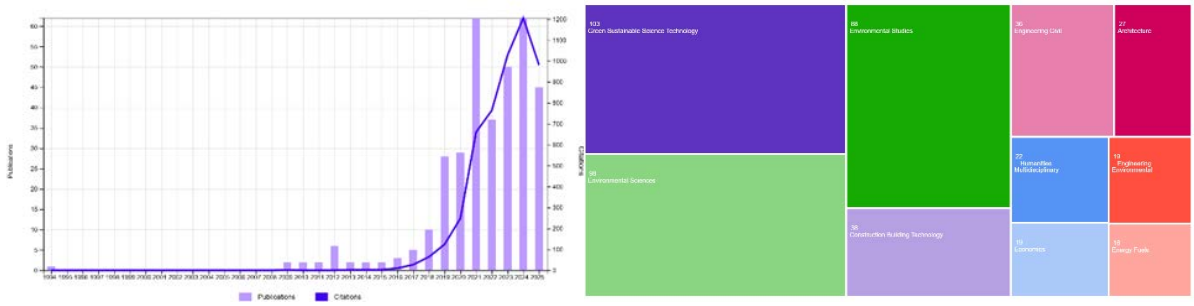

Figure 1. Publications with the keywords circular economy and heritage (WOS source search, keywords: “circular economy” and heritage, 2025).

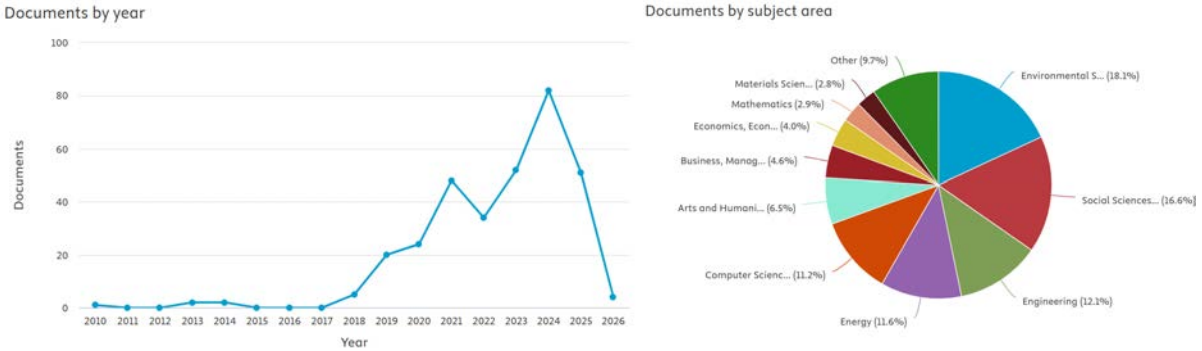

Figure 2. Publications with the keywords circular economy and heritage (SCOPUS search, keywords: “circular economy” and heritage, 2025).

Cultural heritage buildings hold a unique place in the urban landscape. In addition to providing shelter, they also embody the local cultural and historical characteristics that define communities. Therefore, when it comes to heritage buildings, extending their lifespan provides numerous benefits that extend beyond the project to the surrounding area, contributing to economic and social development (Foster, 2020). As a result of the preliminary research conducted with the keywords circular economy and cultural heritage, it is seen that the subject is mostly discussed under the title of adaptive reuse in the listed research articles.

Key principles include:

- Reduce: Preventing unnecessary consumption.
- Reuse: Using existing products and materials repeatedly.
- Recycle: Reintegrating waste into production cycles.
- Repair: Extending product lifecycles through maintenance.
- Recover: Extracting energy and resources from waste.

These principles align closely with cultural heritage practices: restoration, adaptive reuse, and sustainable tourism are directly parallel to circular strategies of reuse and repair (Ahunbay, 2019).

Rural Development and Relationship with SDGs

Rural development is increasingly framed as a multidimensional strategy that integrates economic, social, cultural, and environmental aspects in line with global sustainability agendas. According to the OECD (2016), rural development entails strengthening local economies, improving access to services, and preserving environmental and cultural assets. Beyond agricultural modernization, contemporary approaches emphasize diversification through rural tourism, renewable energy, and cultural heritage valorization (Kara & Yıldız, 2020; Woods, 2011).

The adoption of the United Nations Sustainable Development Goals (SDGs) in 2015 has further positioned rural development as a critical arena for sustainability transitions. SDG 1 (No Poverty) and SDG 2 (Zero Hunger) highlight the role of rural economies in food security and poverty alleviation, while SDG 8 (Decent Work and Economic Growth) underscores the importance of creating local employment opportunities (Sachs et al., 2019). Similarly, SDG 11 (Sustainable Cities and Communities) and SDG 15 (Life on Land) directly call for the protection of rural landscapes, biodiversity, and cultural heritage. As Scoones (2015) argues,

sustainable livelihoods in rural contexts depend on both ecological resilience and social capital, which align closely with these goals.

Cultural heritage emerges as a cross-cutting resource in this framework. By fostering identity and community belonging, heritage strengthens rural resilience and supports SDG 16 (Peace, Justice and Strong Institutions) through inclusive governance of local assets (Bebbington et al., 2018). Moreover, integrating circular economy practices into rural strategies contributes to SDG 12 (Responsible Consumption and Production), particularly by promoting adaptive reuse, low-carbon agriculture, and circular tourism (Rodríguez, Florido, & Jacob, 2020).

In Türkiye, rural development policies have gradually shifted toward acknowledging heritage and tourism as drivers of sustainable growth (Kara & Yıldız, 2020; Deniz & Oğuz, 2025). Local initiatives in Safranbolu, Cumalıkızık, and Kars demonstrate how heritage-based rural economies can simultaneously advance economic diversification, environmental stewardship, and cultural continuity. Thus, rural development linked with SDGs is not merely about modernization but about cultivating integrated strategies where cultural heritage and circular economy principles act as catalysts for long-term sustainability.

Cultural Heritage at the Intersection of Circular Economy and Rural Development

Cultural heritage plays a multifaceted role in the interaction between the circular economy and rural development. Recent studies demonstrate how cultural heritage can integrate these two areas and contribute to sustainable development goals. This section will examine the impacts of cultural heritage on the circular economy and rural development through strategies such as adaptive reuse, restoration and conservation efforts, support for local production and traditional knowledge, development of circular tourism policies, and the promotion of community participation.

Adaptive reuse stands out as a strategy compatible with the principles of a circular economy in the preservation of cultural heritage. Cultural heritage is a resource that makes significant contributions to environmental sustainability and local economic development (Gravagnuolo et al., 2025). While defining World Heritage, UNESCO also mentions many times that cultural heritage is also a resource as a part of development. For instance, the traditional houses of Safranbolu, Turkey, have been transformed into boutique hotels and cafés, creating both economic benefits and heritage preservation (Ahunbay, 2019). Similarly, the

stone dwellings of Matera, Italy, under UNESCO World Heritage status, have been adapted for tourism, contributing significantly to rural development (Gravari-Barbas, 2018).

Restoration and conservation activities ensure the sustainability of cultural diversity while also providing economic benefits. In addition to adaptive reuse, the techniques and material use applied during restoration are also important for the circular economy. Choosing ecological materials, procuring materials from local sources, and paying for labor provide economic and time-consuming benefits. The restoration of historic structures is vital for both circular economy and rural development. Cumalıkızık Village in Bursa, with its Ottoman-era civil architecture, entered the UNESCO list through restoration projects that stimulated tourism (Özkan, 2015). Likewise, Albarracín in Spain has become a cultural tourism hotspot following comprehensive heritage restoration projects (Navarro, 2017).

Traditional crafts and agro-food systems embody the fundamental elements of a circular economy. The circular economy and rural development stages are complemented primarily through the diversity of production areas, particularly through examples such as the location-specific manufacturing of food products. Even within Türkiye, examples can be quite diverse; there are rural areas where traditional production, where olives, olive oil, wine, cheese, tea, bulgur, and other products are cultivated and processed, is at the forefront, and where other tangible and intangible environmental/cultural landscapes are shaped (Manav, 2020). Literature studies have also highlighted the impact of cultural heritage in rural areas on sustainable development and the importance of local production and traditional knowledge for economic development and cultural identity (Min, 2025).

When combined with circular economy principles, traditional production methods in rural development yield sustainable models. Gravyer cheese production in Kars, Turkey, is a prime example of traditional knowledge transmission contributing to local economies (Çakır, 2020). Similarly, the Alsace wine-producing regions of France integrate heritage, local production, and tourism to create economic vitality (Demossier, 2016).

The circular economy, an approach based on the principles of efficient use of resources, waste reduction, and reuse, promotes sustainable development in the tourism sector (Rodríguez, Florido, & Jacob, 2020). This model is critical for preserving cultural heritage and supporting the local economy, especially in rural areas (Neves & Marques, 2022). Cultural heritage elements such as historical buildings, traditional village houses, stonemasonry, and handicrafts in rural areas are considered not only tourist attractions but also assets that preserve the identity and cultural continuity of local communities (Santos & Marques, 2021). The circular tourism

approach aims to preserve these heritage elements and use them in an economically sustainable manner. Furthermore, circular tourism directly contributes to the preservation of cultural values by increasing visitors' interest in local culture and heritage (Sustainable Rural Development Based on Cultural Heritage, 2002). Transforming local crafts and production processes into economic gain through tourism supports cultural continuity and enhances community well-being (Rodríguez et al., 2020). In this context, circular tourism serves as a bridge between the preservation of cultural heritage and the redesign of economic cycles to achieve sustainable development in rural areas (Santos & Marques, 2021). The Cappadocia region in Turkey, with its cave dwellings, integrates heritage into tourism while highlighting environmental sustainability (Timothy & Nyaupane, 2009). The Douro Valley in Portugal, combining wine tourism with landscape conservation, is another example of circular tourism (Marques, 2017).

Community participation is essential for heritage preservation. Şirince Village (İzmir, Turkey) has become a rural development model through civic initiatives, transforming into a popular tourism destination (Gültekin, 2018). The Findhorn Ecovillage in Scotland illustrates how local communities can collectively preserve cultural and natural heritage within a sustainability framework (Seyfang, 2010).

Conclusion

This study explores how cultural heritage can contribute to creating a sustainable future at the intersection of a circular economy and rural development. By integrating heritage conservation into circular practices, local communities not only preserve their cultural identities but also enhance their socioeconomic resilience. Examples of rural heritage sites demonstrate that heritage-focused development has the potential to support the UN Sustainable Development Goals (SDGs), particularly those related to sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and decent work and economic growth (SDG 8) (Duxbury et al., 2021; Feroz et al., 2021).

The integration of cultural heritage into circular economy strategies should be viewed not merely as an economic opportunity but as a transformative approach that redefines the relationship between people, place, and production. As Williams (2023) argues, cultural heritage is a repository of values and practices that can inspire alternative models of resource management, moving from extractivist paradigms toward regenerative cycles. In rural contexts, where heritage often takes tangible forms such as local architecture, agricultural landscapes,

and traditional crafts, circular practices can strengthen local livelihoods while reducing waste and environmental degradation (Lazarevic and Valve, 2017).

At the same time, the challenges are significant. Rural communities often face limited access to financial and technical resources, which limits their capacity to implement circular strategies. Furthermore, the risk of overtourism or overcommercialization of heritage assets raises concerns about sustainability and authenticity (Pereira Roders and van Oers, 2014). Addressing these tensions requires multi-level governance in which local actors, municipalities, and international organizations collaborate on common frameworks that promote circularity while respecting cultural diversity.

Furthermore, new policies and strategies should be developed to ensure the balance between cultural heritage conservation and sustainable development.

Recommended Questions for Future Research:

How can authenticity be preserved in adaptive reuse? How can authenticity and identity be preserved during the reuse of historic buildings?

How can rural development strategies integrate cultural heritage more effectively? How can the role of cultural heritage be enhanced in rural development policies?

What models can be effective for increasing community participation? What approaches should be adopted to encourage local participation in cultural heritage management?

How can economic growth be balanced with overtourism pressures in circular tourism? How can tourism activities be made sustainable in line with circular economy principles?

These questions provide an important foundation for better understanding the role of cultural heritage in circular economy and rural development processes and developing sustainable solutions in these areas.

In conclusion, cultural heritage, the circular economy, and rural development are deeply intertwined areas that, when strategically aligned, can contribute to sustainable futures. However, as the guiding questions demonstrate, this alignment is far from simple. It requires careful negotiation between conservation and innovation, economic imperatives and cultural values, and global sustainability goals and local realities. Ultimately, the future of circular heritage will depend on the capacity of communities, academics, and policymakers to co-create adaptable and inclusive frameworks that respect the past while building resilience for the future.

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BEING ON THE EDGE: SEARCHING THE CONTINUITY OF RURAL CHARACTERISTICS IN THE URBAN PERIPHERY

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Being on the Edge: Searching the Continuity of Rural Characteristics in the Urban Periphery

Abstract: Urban sprawl increasingly threatens peri-urban rural settlements, leading to the loss of agricultural land, ecological integrity, and cultural identity while also weakening urban resilience to climate crisis. Yet these settlements hold strategic importance for sustainable urbanization by offering ecosystem services, food systems, and socio-cultural continuity. This study develops an evaluation framework to analyze the social, economic, and spatial characteristics of rural settlements on the urban fringe revealing how rural–urban linkages can generate mutual benefits. Findings indicate that governance models rooted in bottom-up participation, territorial branding, sustainable food and energy systems, and nature-based spatial strategies strengthen resilience and cohesion. The research highlights the potential of peri-urban rural settlements not as passive recipients of urban pressure but as active contributors to sustainability, offering vital synergies for resilient futures in the context of climate crisis.

Keywords: peri-urban rural settlements; urban sprawl; rural–urban linkages; sustainability; climate resilience

Introduction

Urban sprawl and increasing peri-urban development pose a threat to the rural settlements located on the urban fringe. These settlements are subject to an expanding urban development which brings on the loss of rural settlements, communities and social life, agricultural land and rural landscape. Uncontrolled sprawl also interrupts the economic, social and environmental sustainability of the rural settlements located on the urban fringes. However, the negative effects of urban sprawl are not only on the rural areas and settlements surrounding the city but also on the growing city itself. The loss of peri-urban rural settlements brings on poorer access to nature, clean air, food, ecosystem services for the growing city. This weakening relationship aggravates the effects of climate change. However, peri-urban rural settlements have vital importance for the rapidly developing urban areas both ecologically and socio-economically. Similarly, the urban center, located in an accessible distance, bears great potentials for the socio-economic sustainability of those rural settlements.

Based on these reciprocal potentials, this study aims to highlight the growing importance of rural – urban interactions both for achieving sustainable urbanization within the context of climate crisis and for assuring the continuity of rural landscapes, settlements and communities. Accordingly, the study proposes an evaluation framework to analyse the rural characteristics of settlements located on the urban fringe that will reveal the synergies to be born out of rural – urban interactions, that work positively both for urban and rural areas.

The study focuses on the different rural characteristics of the settlement and its community with the aim of discovering the potentials that will enhance the adaptability of the rural settlement to its emerging context - being on the urban edge.

Literature Review

The rural–urban periphery is conceptualized as a dynamic transitional zone taking place between the outer boundaries of the urban macroform and the rural hinterland. It is characterized by relatively low building and population densities (Santos & Beyond, 2022) and the intermingling of urban and rural land uses (Scott et al., 2013; Hazar, 2017; Santos & Beyond, 2022). Can (2022) further defines the urban fringe as a compressed landscape positioned between urban and rural identities, shaped by sociological, environmental, economic (production cycle), and typo-morphological dimensions.

Many scholars emphasize the adverse impacts of urban sprawl on social, economic, and ecological dimensions within the context of transformations at the rural–urban periphery. Mainly, the expansion of urban land uses into rural areas at the urban fringe leads to a decline in agricultural activities and, particularly, transformation of the rural way of life through property relations (Altundal Öncü, 2024; Karaman et al., 2022). Similarly, Aşıcı et al. (2025) emphasize that the pursuit of cheap land and labour generates pressures on rural areas, accelerating the transformation of the rural fabric. Moreover, with the expansion of the urban fabric, the countryside is adversely affected both physically (through development pressures and the loss of ecological integrity) and socially (through population decline and the erosion of cultural identity) (Karaşah, 2007). Processes such as the loss of young populations in rural settlements, the underutilization of agricultural land leading to a decline in agricultural production, and the erosion of tangible and intangible cultural heritage contribute to the impoverishment of rural communities (URL 1; Özkavaf Şenalp, 2023; TCSKB, 2020).

On the other hand, various studies indicate that residents of rural settlements face not only limited economic opportunities but also inadequate access to social amenities and infrastructure (TCSKB, 2020). Furthermore, many contemporary rural settlements, including those located at the urban fringe, struggle to adapt to rapidly advancing technologies and shifting lifestyles (URL 1; UNDP, 2025).

Rural settlements at the urban periphery, distinguished by both unique challenges and opportunities, play a critical role in 21st century urbanization. Their proximity to cities fosters mutual accessibility—granting rural populations improved access to urban services while allowing urban residents to reach the countryside—thereby creating synergies and co-development potentials that highlight the importance of sustaining them.

Urban sprawl worsens the negativities caused by climate change, intensifying pressures on ecosystems that rural landscapes help to mitigate. As emphasized by Özkavaf Şenalp (2023), the benefits of rural landscapes extend well beyond the communities that inhabit them; at urban, regional, and even global scales, they contribute critically to carbon sequestration, biodiversity conservation, and the protection of water resources. Moreover, these areas represent dynamic and multifunctional landscapes, sustaining historical development, urban identity, biodiversity, production, recreation, and cultural values (Aşıcı et al., 2025; Gündel et al., 2022).

In this respect, ensuring the continuity of the rural requires both the adaptation of rural settlements to changing conditions at the rural–urban fringe and the examination of interactions between the two modes of living (Sakal, 2007).

Urban sprawl has become a defining feature of Türkiye's metropolitan growth, with Ankara serving as a critical example. Driven by migration-fuelled population increases and the demand for residential, functional, and infrastructural areas, the city's uncontrolled expansion along development corridors has placed formerly rural settlements under serious threat of disappearance. Altundal Öncü (2024) shows that Ankara's polycentric urbanization is increasingly extending into nearby rural areas, particularly along the western and south-western corridors. The rising real estate demand in these zones illustrates the mounting transformation pressures on the rural fabric at the city's urban fringe.

The evolving dynamics between rural and urban areas have become a central theme in contemporary planning and policy discourses. Recent studies highlight the shift from a rural–urban dichotomy toward dynamic partnerships and interactions shaped by regional and nature-based policies as well as spatial interpenetration (Artmann et al., 2012).

In this respect, the Rural Vision 2040 document developed by the European Commission and implemented within the European countries investigates the reciprocal relationship between rural and urban settlements. The rural-urban relationship is conceptualized as rural-urban partnerships or linkages, and strategically tested in various projects around Europe (Eurocities, 2022). Similarly, Severin and Morrison (2024) stress the significance of the regional policies in strengthening and reinforcing these linkages to promote cohesion, effective governance, and shared benefits. Artmann et al (2012) highlight that the rural-urban 'partnerships' may operate as a joint functional unit based on shared vision and strategies to yield improved benefits.

Complementing this perspective, Yıldırım and Hazar Kalonya (2021) emphasize that nature-based policies implemented in such rural areas can serve to protect the countryside

against urbanization pressures. Today, it is observed that the traditional dichotomies between rural and urban are diminishing, giving way to intensified mutual interactions; this is also spatially illustrated in the interpenetration of rural and urban forms (Altundal Öncü, 2024).

Methods

This research follows a qualitative and interpretative approach, drawing on a review of national and international literature to reveal the dimensions of rural–urban linkages. Building on this foundation, the study develops a framework to identify the inherent social, economic, and spatial (natural/ecological and built environment) qualities of peri-urban rural settlements, examining the characteristics that should be sustained and that can contribute to urban areas in terms of sustainability and resilience to climate change. In this respect, the investigation specifically addresses social, economic, and spatial aspects (including both the natural/ecological environment and the built environment), thereby allowing for a comprehensive understanding of the complex interactions shaping peri-urban rural settlements.

Findings and Discussion

The investigated literature illustrates that there are mainly two approaches to urban–rural linkages. One emphasizes developmental policies aimed at empowering local rural settlements and their socio-economic conditions, while the other highlights the strengthening of ecological functions in rural areas to mitigate climate change and control urban development, thereby contributing to urban sustainability and resilience.

Joint regional strategies, a special focus on the needs of the rural areas within their local context, creating and developing innovative partnerships, co-operation and governance models, improving accessibility and providing better communication, accepting sustainable models in sectors and ecosystem services are presented as success factors by Artmann et al. (2012), in rural-urban interactions.

When mapped onto the proposed framework, the findings highlight several key dimensions as shown in the following Table 1. In the social dimension, governance models built on bottom-up, community-driven processes and collaborative “quadruple helix” structures enable inclusive decision-making, while identity-based initiatives such as awareness campaigns and territorial branding strengthen local distinctiveness and resilience against urbanization pressures (Severin and Morrison (2024). Similarly, the involvement of Metropolitan scale administrations as well as local municipalities is suggested for better governance (Eurocities,

2022) In the economic dimension, policies emphasize food systems, territorial branding, urban agriculture, and peri-urban environmental quality, supported by small, tangible, low-cost pilots in food supply chains, renewable energy, and water management that demonstrate how rural economies can remain viable while contributing to wider sustainability agendas (Severin and Morrison (2024) The European Green Deal Action plan aims at attracting innovative entrepreneurship and creating new job opportunities, providing access to better quality jobs, enhancing skills and capacities for improved economic development (Eurocities, 2022). From the spatial perspective, the ecological environment emerges as a critical resource through ecosystem services, green infrastructure, and nature-based solutions that support both climate mitigation and adaptation (Yıldırım and Hazar Kalonya (2021). Meanwhile, in the built environment, opportunities lie in tourism and multifunctional land-use strategies that integrate rural assets into broader urban–regional development (Yeşilbağ and Haliloğlu Kahraman, 2025).

Table 1. Policies according to the social, economic, spatial (ecologic & built environment). dimensions.

Policy aspect		Approach	Examples	Reference
Social		**Governance** ● bottom-up, community-driven initiatives. ● Quadruple helix approach: citizens, academia, business, civil society. ● Local partnerships	Milano Metropoli Rurale; Riso&Rane Rural District (Lombardy, Italy) SERÀ 2030 (Valencian Community, Spain). Graz surroundings, Austria	Severin & Morrison, 2024 Artmann et al. 2012
		Identity ● Awareness campaigns and territorial branding ● Attractive spaces, Lively Places	Regional Brand "Lubelskie" (Poland) Rural Vision 2040	Severin & Morrison, 2024 Eurocities 2022
Economic		**Local Rural Development** ● Focus on food systems, territorial branding, urban agriculture, and peri-urban environmental quality. (EU Farm to Fork Strategy) ● small, tangible, low-cost, high-impact pilots (food supply chains, water management, renewable energy)	Milano Metropoli Rurale; Riso&Rane Rural District (Lombardy, Italy) Amsterdam Circular Economy Strategy; Twentse Canteen; Mértola Food Network. Le Pays du Mans, France PURPLE project - Catalunya, Spain	Severin & Morrison, 2024 Artmann et al. 2012
Spatial	Natural/Ecological Environment	**Ecosystem services** ● Provision of ecosystem services, green infrastructure, and nature-based solutions **Transportation** ● Improving the transportation infrastructure, sustainable mobility solutions **Places** ● Open spaces, leisure spaces, recreation green-belt, Attractive spaces, Lively Places	Bursa, Türkiye Ödemiş, İzmir, Türkiye Le Pays du Mans, France Graz surroundings, Austria PURPLE project - Frankfurt, Germany Rural Vision 2040	Taşkan & Atik (2020) Yıldırım, M., & Kalonya, D. H. (2021) Artmann et al. 2012 Eurocities 2022
	Built Environment	**Tourism** ● Focus on the conservation of the local rural landscape and cultural heritage, and transforming it into an economic benefit through tourism activity. ● Focus on sustainable rural tourism and leisure and cultural activities	Cemil Village, Nevşehir, Türkiye Le Pays du Mans	Yeşilbağ & Haliloğlu Kahraman (2025) Eurocities (2022) Artmann et al. 2012

Considering these interrelations, the potentials of the rural are not limited to preserving traditional landscapes or practices but extend to becoming active agents in shaping resilient urban futures—through governance that empowers communities, economies that diversify and innovate, and spatial strategies that protect ecological systems while reimagining the built environment.

Conclusion

This study underscores that peri-urban rural settlements, situated at the urban edge, hold strategic importance for both sustainable urban development and the continuity of rural landscapes, communities, and practices. The analysis demonstrates that while urban sprawl threatens ecological integrity, cultural identity, and rural livelihoods, it simultaneously creates opportunities for rural–urban partnerships that can generate mutual benefits. By framing these settlements not as passive recipients of urban pressure but as active contributors to resilience, sustainability, and climate adaptation, the research highlights their vital role in 21st century urbanization.

The proposed evaluation framework, built on social, economic, ecological, and spatial dimensions, provides a tool to uncover the inherent values of rural settlements and to design policies that reinforce synergies between rural and urban areas. In doing so, it emphasizes the need for integrative governance approaches, context-sensitive policies, and nature-based solutions that safeguard rural qualities while enhancing urban sustainability. Ultimately, sustaining peri-urban rural settlements requires moving beyond the traditional rural–urban dichotomy toward dynamic linkages that support territorial cohesion, ecological balance, and resilient futures for both urban and rural communities.

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INDICATORS AND PARAMETERS OF THE FIVE CAPITALS IN THE SUSTAINABLE LIVELIHOODS FRAMEWORK: A COMPREHENSIVE LITERATURE REVIEW

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Indicators and Parameters of The Five Capitals in the Sustainable Livelihoods Framework: A Comprehensive Literature Review*

Abstract: This study provides a comprehensive literature review by systematically examining indicators and parameters related to five basic types of capital (natural, human, social, financial, and physical) within the framework of sustainable livelihoods as defined by DFID (1999) in the context of national and international literature. The literature review covers studies published between January 2009 and May 2025, with the Web of Science, Scopus, ScienceDirect, and TR Dizin databases examined. The findings show that livelihood studies largely rely on these five basic types of capital, which sometimes limits academic production and prevents context-specific livelihoods from being adequately examined. On the other hand, it has been determined that some studies go beyond this framework by including new types of capital and enriching the analytical framework.

Keywords: sustainability; livelihood framework; capitals; parameters

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Introduction

This study provides a comprehensive literature review by systematically examining indicators and parameters related to five basic types of capital (natural, human, social, financial, and physical) within the framework of sustainable livelihoods, as defined by the UK Department for International Development (DFID) (1999), in the context of national and international literature. In this context, the study contributes to both academic literature and policy makers and practice by identifying parameters and indicators for the protection of livelihoods, the reduction of vulnerabilities, and the balanced strengthening of capital types, as well as by identifying new directions in livelihood studies.

The study highlights that the sustainability of livelihoods can be achieved not only by protecting existing resources, but also by reducing vulnerabilities, increasing resilience, and strengthening different types of capital in a balanced manner. It also emphasizes the importance of studies in the field of sustainability that go beyond the classic five basic types of capital (natural, human, social, financial, and physical) and include new types of capital (cultural, psychological, and institutional capital).

Literature Review

Livelihood resources are defined as the totality of resources, assets, and income that individuals or households use to sustain their lives. The concept of livelihood resources, which is considered complex to define (Quansah et al., 2020), was first used in history to refer to the

basic economic activities of households, particularly in rural areas, with a focus on agriculture and animal husbandry (Scoones, 2009). In this context, livelihood resources have been seen as the totality of economic capacity and production activities that determine the self-sufficiency level and survival strategies of rural households (Ansoms & McKay, 2010). Today, with the increasing importance of non-agricultural income sources, livelihoods have evolved into a multidimensional structure that encompasses not only agricultural production but also activities in different sectors such as trade, industry, and services (Kassegn & Abdinasir, 2023).

The multidimensional nature of livelihoods is shaped not only by economic assets but also by social relationships, cultural values, and political processes. Indeed, livelihoods require a holistic assessment of all the resources and strategies necessary for individuals and communities to sustain their lives, rather than a narrow economic perspective focused solely on material income and resources (Scoones, 2009). In this context, diversifying livelihoods for rural households is critical for mitigating negative impacts and developing alternative income opportunities (Emeru et al., 2022).

The sustainable livelihoods approach aims to protect existing economic, natural, social, and physical assets for the benefit of both present and future generations (Chambers & Conway, 1992). This approach emphasizes that livelihood strategies should focus not only on short-term income generation but also on long-term capacity and asset development. Sustainability requires communities to be resilient in the face of shocks and environmental changes and to conserve rather than consume their resources (DFID, 1999; Ellis, 2000).

Resilience is a fundamental element of the sustainability. Communities' ability to balance external shocks, manage their resources through self-organization, and adapt to change through their learning capacity strengthens sustainability (Sallu et al., 2010). However, natural disasters, climate change, economic crises, and political instability increase vulnerability and lead to the reshaping of livelihood strategies. Climate change directly affects agriculture-based households, while non-agricultural activities and income transfers become important adaptation strategies in this process (Chuong et al., 2024).

Historically, the sustainable livelihoods approach was conceptualized in the 1980s by Chambers' work focusing on rural poverty and the resilience of vulnerable communities, and in the 1990s by Scoones (1998), Bebbington (1999), DFID (1999), and Ellis (1999; 2000) systematized it in development literature. Scoones (1998) based this framework on the idea that livelihoods should be analyzed through the five basic capitals of natural, human, social,

financial, and physical capital. These five basic capitals serve as a reference point for assessing communities' capacity to sustain their livelihoods and for developing strategies.

Ellis (1999) emphasizes that households' livelihood strategies depend not only on access to resources but also on decisions made in environmental, economic, and institutional contexts. Therefore, the sustainable livelihood approach goes beyond listing resources to examine how they are organized, how communities adapt to change, and how different income strategies reduce vulnerability (Ellis, 2000). Today, this approach is widely used by development actors in poverty reduction, food security, resource management, and climate change adaptation strategies (DFID, 1999; Scoones, 1998).

DFID's Sustainable Livelihoods Framework (1999)

The Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (DFID) in 1999, aims to analyze the livelihoods of rural communities in a holistic manner. This approach, based on Carney's (1998) study, addresses poverty not only in terms of income and consumption, but also in terms of capital diversity, life strategies, and environmental vulnerabilities. The SLF focuses on helping individuals and communities develop sustainable systems that can meet both current and future needs by effectively utilizing their existing resources (Chambers & Conway, 1991; DFID, 1999).

1) **Natural Capital:** All natural resources used by households and communities to sustain their livelihoods (agricultural land, forests, pastures, treasury lands), water resources (drinking water, irrigation, fishing), air quality, biological diversity (plant and animal species), and ecosystem services (pollination, water cycle) that households and communities use to sustain their livelihoods (DFID, 1999).
2) **Human Capital:** Reflects the knowledge, skills, health, and labor potential of society and individuals as a source of livelihood. In this context, human capital is one of the most fundamental elements enabling individuals to achieve their life goals (DFID, 1999). Education, as a lifelong skill development process rather than merely a transfer of knowledge, enhances individuals' competitiveness and supports their livelihood strategies; however, rural-urban inequalities limit the development of human capital. Labor refers to individuals' ability to physically participate in the production process, and the willingness of family members to work is considered an important source of human capital (Mahdi et al., 2009).
3) **Social Capital:** Social networks, relationships, and norms enable individuals and communities to sustain their livelihood strategies and develop their resources. This

structure, based on mutual trust, supports the success of livelihood strategies by increasing the sense of trust in society (Moser, 1998). DFID (1999) defines social capital as social networks, community memberships, and support groups.

4) **Financial Capital:** Financial capital can consist of material assets such as cash, credit, savings, and investments that support households' livelihood strategies (DFID, 1999). Income level is a fundamental dimension that determines individuals' quality of life and investments in human capital such as education and health. Savings capacity both preserves current opportunities and provides security for the future. Income diversification reduces economic risks by generating income from different sectors (Gwiriri et al., 2021; Zhang et al., 2024).
5) **Physical Capital:** Tools and assets that enable vital activities, such as irrigation systems, machinery and equipment, and houses used by individuals and communities in production processes and facilitating economic production processes, are defined as elements of physical capital (Ellis, 1999). Housing size reflects the quality of life of households, while durable consumer goods reflect the level of economic development (Chen et al., 2013; Wang et al., 2021; Yu et al., 2024). The use of agricultural technology tools directly determines production efficiency (Khanal et al., 2024; Wu et al., 2022). Transportation vehicles are critical for both daily life and economic activities (Adranyi et al., 2023). Infrastructure and public services are decisive for the sustainability of livelihoods (Baffoe & Matsuda, 2018).

Methods

In this study, research conducted in the national and international literature on five basic types of capital (natural, human, social, financial, and physical) in the context of sustainable livelihoods was examined. Within this scope, thematic analysis was used as it allows for the identification, examination, and detailed reporting of themes in the data in qualitative method (Braun & Clarke, 2006).

The literature review conducted within the scope of the study covers studies published between January 2009 and May 2025. The Web of Science, Scopus, ScienceDirect, and TR Dizin databases were examined during the review process. Keywords were determined in both Turkish and English; concepts such as “geçim kaynakları”, “insan sermayesi”, “parametre” were used in Turkish searches, while concepts such as “livelihood”, “human capital”, and “parameter” were used in English searches. During the search process, different combinations

were created using Boolean operators (AND, OR) (e.g., “human capital” AND “indicators”) to increase the comprehensiveness of the search.

Only articles published in peer-reviewed journals were included in the evaluation. The selection criteria were defined as full-text accessibility, clear definition of parameters in the study, and direct relevance to the study's subject matter. Repeated studies, publications with insufficient data, or those containing only theoretical frameworks were excluded.

The sources obtained were examined in detail, and parameters were identified primarily in the context of five basic types of capital (natural, human, social, financial, and physical). In addition, studies that go beyond this five-type model in the literature and propose additional types of capital or alternative classifications were also identified and analyzed. This approach not only systematically presents the existing framework but also offers an innovative perspective on the field by revealing trends that extend the boundaries of the model.

The process of classifying the parameters was carried out by researchers using thematic analysis; the stages of coding, creating, reviewing, and defining themes were applied with attention. Similar parameters were grouped under specific themes, and new themes beyond the five core capitals were also identified. In this regard, the study provides a comprehensive parameter map in the field of sustainable livelihoods and serves as an important reference point for the development of the existing theoretical framework in the literature.

Findings and Discussion

1. Findings Regarding Natural Capital

The studies examining natural capital in the context of livelihoods in the literature is seen in Table 1.

Table 1. The studies examining natural capital in the context of livelihoods in the literature

Cultivated agricultural land presence / Ownership	(Antwi-Agyei et al., 2013; Bhandari, 2013; Hong et al., 2023; Huang et al., 2017a; Li et al., 2020; Ma et al., 2018; Wu et al., 2022; Yang et al., 2018; Yew et al., 2011; Zhang et al., 2024)
Forest area / Forest land resources	(Baffoe & Matsuda, 2018; Chen et al., 2013; Kiconco et al., 2025; Nkansah-Dwamena, 2021; Yu et al., 2024; Zhang et al., 2024)
Size and quality of agricultural land owned	(Adranyi et al., 2023; Huang et al., 2017a; Khanal et al., 2024; Mumuni & Oladele, 2016; Wu et al., 2022; Yang et al., 2018)
Land use	(Baffoe & Matsuda, 2018; Guo et al., 2019; Hong et al., 2023; Mumuni & Oladele, 2016; Wang et al., 2021)
Access to land	(Gwiriri et al., 2021; Kiconco et al., 2025; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Yang et al., 2018)
Water resources, access to water, and irrigation efficiency	(Baffoe & Matsuda, 2018; Guo et al., 2019; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021)

Table 1 shows that the variable of cultivated agricultural land presence / ownership is the most frequently addressed parameter in natural capital literature.

2. Findings Regarding Human Capital

The studies examining human capital in the context of livelihoods in the literature is seen in Table 2.

Table 2. The studies examining human capital in the context of livelihoods in the literature

Education status / Level	(Adranyi et al., 2023; Antwi-Agyei et al., 2013; Arif et al., 2019; Baffoe & Matsuda, 2018; Bhandari, 2013; Chuong et al., 2024; Guo et al., 2019; Gwiriri et al., 2021; Hong et al., 2023; Huang et al., 2017a; Ibrahim et al., 2017; Khanal et al., 2024; Kiconco et al., 2025; Li et al., 2020; Ma et al., 2018; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Sardar et al., 2020; Wang et al., 2021; Wu et al., 2022; Yew et al., 2011; Yu et al., 2024; Zhang et al., 2024; Zhao & Xu, 2024)
Labor force status / Number	(Baffoe & Matsuda, 2018; Bhandari, 2013; Guo et al., 2019; Gwiriri et al., 2021; Hong et al., 2023; Huang et al., 2017a; Khanal et al., 2024; Li et al., 2020; Ma et al., 2018; Sardar et al., 2020; Wang et al., 2021; Wu et al., 2022; Yang et al., 2018; Yew et al., 2011; Yu et al., 2024; Zhang et al., 2024; Zhao & Xu, 2024)
Health / Insurance status	(Adranyi et al., 2023; Antwi-Agyei et al., 2013; Baffoe & Matsuda, 2018; Chen et al., 2013; Hong et al., 2023; Ibrahim et al., 2017; Khanal et al., 2024; Kiconco et al., 2025; Li et al., 2020; Ma et al., 2018; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Wu et al., 2022; Yu et al., 2024; Zhang et al., 2024; Zhao & Xu, 2024)
Technical support / Skills training	(Baffoe & Matsuda, 2018; Chen et al., 2013; Guo et al., 2019; Hong et al., 2023; Huang et al., 2017a; Ibrahim et al., 2017; Kiconco et al., 2025; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Wu et al., 2022; Yang et al., 2018; Yu et al., 2024; Zhao & Xu, 2024)
Household size	(Arif et al., 2019; Chuong et al., 2024; Guo et al., 2019; Wang et al., 2021; Yew et al., 2011)
Household age	(Bhandari, 2013; Ibrahim et al., 2017; Wang et al., 2021; Yew et al., 2011)

Table 2 shows that the variable of education status / level is the most frequently addressed parameter in human capital literature.

3. Findings Regarding Social Capital

The studies examining social capital in the context of livelihoods in the literature is seen in Table 3.

Table 3. The studies examining social capital in the context of livelihoods in the literature

Social relations / Networks	(Adranyi et al., 2023; Chen et al., 2013; Hong et al., 2023; Kiconco et al., 2025; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Sardar et al., 2020; Wang et al., 2021; Wu et al., 2022; Yang et al., 2018; Yu et al., 2024; Zhang et al., 2024; Zhao & Xu, 2024)
Community / Association / Foundation membership	(Antwi-Agyei et al., 2013; Baffoe & Matsuda, 2018; Chen et al., 2013; Ibrahim et al., 2017; Ma et al., 2018; Mumuni & Oladele, 2016; Yew et al., 2011; Zhang et al., 2024)
Gift expenditures	(Huang et al., 2017b; Wang et al., 2021; Yu et al., 2024; Zhang et al., 2024)
Leadership in the family / Family ties / Number of relatives	(Baffoe & Matsuda, 2018; Guo et al., 2019; Hong et al., 2023; Zhang et al., 2024)
Organization participation	(Chuong et al., 2024; Gwiriri et al., 2021; Hong et al., 2023)

Table 3 shows that the variable of social relations / networks is the most frequently addressed parameter in social capital literature.

4. Findings Regarding Financial Capital

The studies examining financial capital in the context of livelihoods in the literature is seen in Table 4.

Table 4. The studies examining financial capital in the context of livelihoods in the literature

Loans / Financial assistance	(Antwi-Agyei et al., 2013; Baffoe & Matsuda, 2018; Gwiriri et al., 2021; Hong et al., 2023; Khanal et al., 2024; Kiconco et al., 2025; Ma et al., 2018; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Sardar et al., 2020; Wu et al., 2022; Yew et al., 2011; Yu et al., 2024; Zhao & Xu, 2024)
Household income per capita / Cash income	(Arif et al., 2019; Chen et al., 2013; Guo et al., 2019; Hong et al., 2023; Huang et al., 2017b; Ibrahim et al., 2017; Nkansah-Dwamena, 2021; Wu et al., 2022; Zhang et al., 2024; Zhao & Xu, 2024)
Savings	(Baffoe & Matsuda, 2018; Chuong et al., 2024; Huang et al., 2017b; Ibrahim et al., 2017; Khanal et al., 2024; Kiconco et al., 2025; Ma et al., 2018; Mumuni & Oladele, 2016; Nkansah-Dwamena, 2021; Wang et al., 2021; Yang et al., 2018)
Income diversity	(Gwiriri et al., 2021; Mumuni & Oladele, 2016; Zhang et al., 2024)
Remittances received	(Antwi-Agyei et al., 2013; Baffoe & Matsuda, 2018; Kiconco et al., 2025)
Agricultural income	(Adranyi et al., 2023; Gwiriri et al., 2021)
Borrowed money	(Mumuni & Oladele, 2016; Ma et al., 2018)

Table 4 shows that the variable of loans / financial assistance is the most frequently addressed parameter in financial capital literature.

5. Findings Regarding Physical Capital

The studies examining physical capital in the context of livelihoods in the literature is seen in Table 5.

Table 5. The studies examining physical capital in the context of livelihoods in the literature

Housing area per capita / Home ownership	(Adranyi et al., 2023; Arif et al., 2019; Guo et al., 2019; Hong et al., 2023; Huang et al., 2017a; Kiconco et al., 2025; Ma et al., 2018; Mumuni & Oladele, 2016; Wu et al., 2022; Yew et al., 2011; Yu et al., 2024; Zhao & Xu, 2024)
Physical asset index of household	(Chen et al., 2013; Chuong et al., 2024; Guo et al., 2019; Khanal et al., 2024; Li et al., 2020; Wang et al., 2021; Yew et al., 2011; Zhao & Xu, 2024)
Value of durable consumer goods	(Chen et al., 2013; Huang et al., 2017a; Ma et al., 2018; Wang et al., 2021; Yang et al., 2018; Yu et al., 2024; Zhang et al., 2024)
Availability / Ownership of agricultural technology tools	(Hong et al., 2023; Khanal et al., 2024; Kiconco et al., 2025; Mumuni & Oladele, 2016; Sardar et al., 2020; Wu et al., 2022; Yang et al., 2018)
Availability / Condition of infrastructure and public services	(Arif et al., 2019; Baffoe & Matsuda, 2018; Kiconco et al., 2025; Nkansah-Dwamena, 2021; Wu et al., 2022; Zhao & Xu, 2024)
Number of transportation vehicles	(Adranyi et al., 2023; Ibrahim et al., 2017; Ma et al., 2018; Nkansah-Dwamena, 2021; Zhang et al., 2024)
Number of communication assets	(Adranyi et al., 2023; Antwi-Agyei et al., 2013; Ma et al., 2018; Mumuni & Oladele, 2016; Yang et al., 2018)
Number of livestock	(Ma et al., 2018; Sardar et al., 2020; Zhang et al., 2024)
Availability of market	(Arif et al., 2019; Baffoe & Matsuda, 2018; Mumuni & Oladele, 2016)
Proximity to urban center / Distance from town	(Bhandari, 2013; Ibrahim et al., 2017; Sardar et al., 2020)

Table 5 shows that the variable of housing area per capita / home ownership is the most frequently addressed parameter in physical capital literature.

Conclusion

As a result of the literature review conducted within the framework of sustainable livelihoods, it was found that studies largely relied on five types of capital (natural, human, social, financial, and physical), which sometimes limited academic production and prevented context-specific livelihoods from being sufficiently examined. However, it was also determined that some studies go beyond this framework by including new types of capital, thereby enriching the analytical framework.

This study reveals that the sustainable livelihoods approach plays a critical role in understanding the social, economic, and cultural development processes of communities through different types of capital. However, the five types of capital frequently used in the literature are not always sufficient to explain the diversity of livelihoods of households and

communities. As a result of the findings obtained within the scope of the study, it has been observed that cultural, psychological and institutional capitals have begun to be considered as an innovative trend that broadens the scope of the approach, in addition to these five basic capital dimensions.

In the literature, cultural capital is used to measure individuals' and communities' mastery of traditional knowledge, norms, and beliefs, as well as their level of familiarity with the traditions and customs of society (Kiconco et al., 2025; Yang et al., 2018; Zhao & Xu, 2024). Psychological capital focuses on analyzing changes in individuals' psychological states and their effects on various areas of life. In this context, desires and expectations represent individuals' motivation to set goals and achieve them, while self-confidence and self-efficacy reflect a person's belief in their own abilities and capacity to successfully complete tasks (Ma et al., 2018; Li et al., 2020). Finally, institutional capital is discussed in the literature for its role in strengthening communities' governance capacity, including benefit sharing, and effective participation in successful policy-making processes (Kiconco et al., 2025).

In conclusion, new dimensions such as cultural, psychological and institutional capital offer a framework that enhances the sustainability of communities, strengthens social cohesion, and expands opportunity capacity. This approach goes beyond viewing development solely as an economic phenomenon, supporting sustainability through its social and cultural dimensions. The five basic capital frameworks frequently applied in the literature are being expanded in various studies by incorporating these new types of capital, enabling the development of a more comprehensive and holistic approach.

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CARING FOR THE EMERGENCY CITY

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Caring for the Emergency City

Abstract: This PhD research explores public spaces as a caring tool for communities to face the trauma in post-earthquake scenarios in Central Italy and Türkiye. Adopting a social perspective and an interdisciplinary approach, traumatic effects are considered elements of life inequality for temporary settlements inhabitants that are not adequately addressed by architects.
Based on empirical analysis of their facilities, Turkish container settlements in Pazarcık visited following the 2023 earthquake and the 2016 Italian temporary villages in the Marche Region are compared and presented here, keeping in mind differences in density and context while stressing similarities in human perception and behaviour.
Meant for the Italian regulatory framework, thanks to a direct collaboration with the Civil Protection Department, the study identifies community well-being strategies with solutions from the empirical and theoretical overview that can be replicated in similar scenarios, and a possible reference for more equal urban spaces.

Keywords: post-emergency; temporary settlements; public space; design criteria; well-being

Introduction

This contribution, part of a wider PhD research programme at the University of Florence, investigates the social power of architecture in temporary post-earthquake settlements, focusing on both risks and opportunities. Two case studies are analysed: a Turkish container city in Pazarcık (Kahramanmaraş Province) and a post-2016 seismic settlement in the Marche Region, Italy.

Architect Shigeru Ban's reflections on temporality illustrate the adopted perspective: even temporary architecture can acquire permanence through care and empathy. This highlights the need for architects to consider not only physical protection but also emotional and social dimensions in post-emergency contexts. Trauma leads to a loss of both place and identity, and recovery requires community reconstruction (Gordon, 2004). Public spaces are therefore interpreted as catalysts for interaction and tools for supporting trauma healing (Camiz, 2018; Van der Kolk, 2014).

The transitional post-emergency phase is crucial to ensure resilient futures for affected populations (Alberti et al., 2021). Studying fragile settlements can provide time-sensitive answers for more sustainable and inclusive urban forms.

Literature Review

The long-term effects of the temporary phase on social systems and on built and natural environments make it urgent to implement innovative policies to design provisional settlements that foster both resilience and sustainability in a wider sense: in such high-risk areas, communities must be resilient to live in sustainable places. Deliberately moving away from the

functional logic that has dominated both in Italy and abroad, the healing process proposed in this research is innovatively supported through the creation of communal spaces that nurture a sense of collectivity, connected to social sustainability[1].

In recent years, innovation in emergency design focused primarily on housing and similar shelter solutions (Verducci, 2020; Bologna & Terpolilli, 2005). Certainly, protection from the external environment is essential, just as it was when humans first turned to architecture. However, there is another kind of necessary shelter: despite the passing of centuries, the need to feel part of a broader circle — accepted, included, safe — remains fundamental and common to humans in most societies (Ruzzon, 2022).

This research instead focuses on a constant element across all settlements, regardless of the kind of emergency housing structures: public space, the connective tissue that conveys local identity and offers opportunities for encounters and sharing (Gehl, 1971). Studies on shock handling and the experiences of psychologists who supported the population of studied Italian cases showed that, once settled in temporary housing, people start to express again the need to feel part of something bigger, such as a community, making this the best time for it to heal before reconstruction (Carpenzano & Balducci, 2020). Community is both a form of shelter and an empowering element, one of the first that must be restored and reinforced, after disasters that tear the social fabric (Mela, 2017), and public space is where communal life is best expressed.

Once the final goal is clarified, the main research question can then be summarized as follows: which requirements must public space possess in temporary post-emergency contexts to foster interaction among its inhabitants and enhance their emotional well-being?

Answering this and related questions necessarily involves how design choices can influence human behaviour, and consequently, how the quality of the built environment can affect – positively or negatively - well-being (Pallasmaa, 2014; Chiesi, 2010; Setola, 2023). This part of the research explores the complexity and intrinsic ineffability of the temporality of spaces, and more specifically, in post-emergency contexts, highlighting the epistemological and methodological challenges related to their interpretation.

To get general possible assumptions as answers and proposed actions, the research looks closely at specific case studies in Italy, Japan, and Türkiye. The national regulatory frameworks are an essential part of the literature review. The empirical analysis in Italy and Türkiye offers

[1] For this aspect, an implementation of this PhD research project won the 2021 New European Bauhaus Prize for the “Reinvented places to meet and share” category.

the chance for direct comparison and reflections between the two countries' provisional sheltering management presented in this contribution.

An earthquake hit eastern Türkiye on February 6th, 2023, five days before the Union of Chambers of Turkish Engineers and Architects UCTEA published the Temporary Settlement Areas Guide. With concise graphics, it directs container city planners to ensure accessibility, safety, infrastructural connections and systems, adequate area location choice and size to ensure the continuation of private and social lives and access to public services in a safe environment: "If the necessary precautions in the establishment of temporary shelters are ignored […]. This could lead to further trauma, loss of life, and property." It also requests the settlements to be structured hierarchically from the single unit to cluster (16 units) up to neighbourhood (16 clusters, max 2500 people), each one named/numbered. The street networks follow a similar layering based on their width, from 2 m between units to a maximum of 30 m for the fire emergency lane.

Referring to Turkish zoning plans, similar to the Italian *Piano Regolatore Generale* (City General Development Plan), this guide reports that they can often be missing in towns and cities, as it happens that in many Italian centres there is a lack of *Piano di Emergenza Comunale* (Municipality Emergency Plan) that the Italian Civil Protection Department (DPC) instead prescribes.

In 2015, Turkey's Disaster and Emergency Management Authority (AFAD) issued the Directive on the Establishment, Administration, and Operation of Temporary Shelter Centers that emphasizes the importance of creating environments that support the physical, psychological, and social well-being of displaced individuals, promoting the local provision of essential services, infrastructure, and resources. It encourages the creation of communal spaces within shelter centres, namely indoor spaces, but also integrated with outdoor furniture, often donated. Here, residents can gather, share information, and engage in social activities, fostering a sense of community and another type of shelter. With special attention for children and women, AFAD encourages the collaboration of support networks (local communities, NGOs, volunteers) and the integration of mental health professionals within the temporary centres, with the same attitude as the Italian DPC management.

In Italy, the identification of area location and the features for semi-permanent temporary settlements are indicated by DPC in the Guidelines for the Preparation of Civil Protection Plans at Various Territorial Levels and in the Operative Manual for Municipality Emergency Plan, although these are outside the sanctioning regime: a risk identified in this

research. More detailed and technical directions are in the Framework Agreement concerning the construction of settlements with Emergency Housing Solutions S.A.E. (*Accordo Quadro)*, on behalf of the DPC in 2023[2]. With this tool, a government contracting authority[3] and one or more economic operators detail the tenders for a given period (4 years) regarding envisaged S.A.E. prices and quantities. Its technical annexes specify many Requirement Classes (UNI 8290-2:1983) : security, environmental well-being, usability, dismountability, handling, integrability, management implementation and placement, furnishings, and accessories. The research identifies the Framework Agreement as the main directive tool that, for Italy, can be integrated with this work's outputs.

Methods

The research adopts a holistic, mixed-methods approach that integrates qualitative and quantitative tools, enriched by contributions from multiple disciplines. The goal is to understand how public spaces can support trauma recovery by fostering social interaction and emotional connection. The methodological framework includes:

- Regulatory and institutional analysis: review of national and international guidelines and directives relevant to temporary settlements.
- Field observations: direct inspections in Italian and Turkish temporary cities to document layouts, facilities, and patterns of use.
- Semi-structured interviews: conversations with experts and stakeholders to capture perceptions, experiences, and critical issues.
- Case study comparison: cross-analysis of settlements in Italy, Türkiye, and Japan to identify transferable practices.

Special attention was given to the link between emotions, perception of space, and collective behaviour, drawing from neuroscience and architectural theory. Collaborations with the Italian Civil Protection Department and Özyeğin University in Istanbul provided institutional support and facilitated access to field sites.

[2] Third edition. First published in 2013, without applications. The second edition issued in 2014 is compared with the 2023 one in the PhD research.

[3] *Consip* is the national purchasing centre owned by the Italian Economy and Finance Ministry.

This integrated approach enabled the collection of diverse and complementary data, ensuring a multidimensional perspective on temporary settlements and their potential to promote community well-being.

Findings and Discussion

Empirical evidence from interviews and field visits confirms that communities affected by earthquakes experience fear, uncertainty, and isolation, which can accelerate processes of depopulation or social fragmentation. International comparisons, particularly between Italy and Türkiye, highlight both shared vulnerabilities and divergent approaches to temporary settlement planning. The following table summarises the key differences and similarities:

Aspect	Pazarcık container cities	Camerino S.A.E. settlements
Planning framework	AFAD (2015) Directive; UCTEA (2023) Guide with clear hierarchy (unit → cluster → neighbourhood).	Civil Protection Guidelines (non-binding); Framework Agreement for S.A.E. (2023).
Settlement duration	~3 years planned.	~5 years planned (still in use).
Density & scale	High density, 200+ containers, hierarchical structure.	Lower density, dispersed small villages.
Mandatory facilities	Medical centre, playground, kindergarten, women's centre, prayer space, psychological support desk.	Not mandatory; often absent.
Public/communal spaces	Playgrounds, cafés, outdoor furniture (gazebos, picnic tables) consistently provided.	Lack of cafés/shops; weak informal meeting places.
Community life impact	Facilities foster interaction and continuity of daily life.	Social life fragmented; loss of urban centre as psychological/social reference.
Challenges	Managing high density, inclusion of refugees, political/administrative centralisation.	Monotony of settlements, difficulty orienting, ongoing depopulation.

The comparison shows that Turkish settlements benefit from stronger regulations requiring communal facilities, which help maintain daily routines and social interaction. In contrast, Italian settlements reveal weaknesses linked to the absence of informal meeting spaces, contributing to the erosion of social ties and the loss of a shared urban centre. Both cases demonstrate that public spaces are essential to sustain community identity and emotional recovery, but their design and integration into settlement planning vary significantly.

These findings reinforce the central research claim: without attention to collective spaces, temporary housing risks becoming socially unsustainable. The Turkish approach illustrates the benefits of mandatory communal infrastructure, while the Italian case underlines the risks of neglecting such provisions. This evidence informs the proposal for a performance-based framework for post-emergency settlements, where inclusivity, adaptability, and proximity become crucial requirements.

Figure 1. Temporary settlement “Area S.A.E. Cortine centro e Cortine est”, Camerino (MC), Italy, 2023.

Figure 2. Bayrampaşa Container city, Pazarcik, Kahramanmaraş, Turkey, 2023. Source: İbrahim Yilmazcan, Pazarcik Municipality.

Proposal and conclusion

In addition to the general objective, as summarized in the main research question, two intermediate results were achieved. The definition of dimensions and characteristics for public spaces in temporary settlements was based on multidisciplinary scientific references and/or empirical observations. The sources, presented in connection with each specific proposed requirement and specification, constitute an intermediate outcome of this research and may serve as a reference point for an approach that can be considered in other design contexts as well.

Other intermediate outputs come from a problem-setting phase, which led to the development of a resource system, organized into eight thematic areas of intervention: urban planning, regulatory, operational, social, professional, academic, environmental, and technological production and construction.

The proposed solutions include strategic actions accompanied by operational, procedural, and/or design examples, as well as bibliographic references to field-tested experiments, all derived from a careful review and selection process. This system of resolutive hypotheses is an organised collection of actions that can be selected according to four criteria, i.e., purposes: cost-effectiveness, speed, need for intervention, and social impact. Combining them using a weighted matrix generates a best-spoken strategy[4]. The selection system is the first product of this research meant for the Italian DPC or other design stakeholders, as the main identified recipients of the research products are national government emergency management departments and municipal bodies located in seismic risk areas.

Among the eight application areas, the operational one was explored to deliver a final product: the integration of proximity[5], inclusivity, and adaptability requirements into the Technical Sheet for the Usability Functional Class of the DPC Framework Agreement based on UNI standards 10838:1999, 8290-2:1983, and 8289-1:1981 for a proper performance-based framework.

Inclusivity's specifications emphasize safety, flexibility of public space, and its recognizability, with the same interaction opportunities for all. Adaptability focuses on building distances, pedestrian routes dimensioning, parking and rest areas location, equipment and

[4] The integration of at least two criteria into the matrix is envisaged.

[5] In Europe, the concept of proximity is linked to the EU Green Deal, the New European Bauhaus, the UN 2030 Urban Agenda and EU goals (Mecca, 2023).

furniture provision and storage, and outdoor environment comfort. Proximity requires a main public space, suggesting its positioning and essential services, and housing orientation.

The final goal is to provide a tool via public tenders for post-emergency contractors and designers with features and dimensioning of public open and enclosed spaces to encourage sociality, as part of a larger system of strategic actions. Such strategies can prevent damage to social systems even in other fragile contexts if shared as a user-friendly tool for public administrations, designers, and citizens.

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COMPLEX SYSTEMS FOR SUSTAINABILITY AND REPRESENTATION OF INFRASTRUCTURE AND TRANSPORT. FROM PHOTOGRAMMETRIC SURVEY TO 3D MODELLING.

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Complex Systems for Sustainability and Representation of Infrastructure and Transport. From Photogrammetric Survey To 3D Modelling

Abstract: The research presents the results of the study of the railway line from Tirana to Pogradec, Albania. The aim of the research is to learn about the railway line and its architectural elements in order to graphically document the state of affairs through the established tools of the discipline of drawing, with archival research, surveys and digital modelling to promote the sustainability of the sites. The stations of Tirana, Durres, Kavaje, Rroghozine, Pequin, Elbasan, Libazhed Perrenjas, Lin and Guri kuq - Pogradec were analysed, a route that starts from the capital Tirana and runs along the coast to Durres, then returns inland to the border with Macedonia.
The study was conducted on the basis of archival documents preserved at the Central Archives in Tirana. Finally, the virtual representation of the stations was tested through digital modelling. A further difficulty was represented by the textualisation of the stations, since, no longer in use, they are in a state of total abandonment and structural decay. The result is a graphic documentation through 3D modelling of the architectural and structural elements of the Albanian railway, a tangible sign of the enormous abandoned heritage, built in the 1920s and currently subject to vandalism and deterioration caused by the passage of time.

Keywords: sustainability, photogrammetric survey, model, railway, Albania

Introduction

The contribution proposes the study of the route of the railway line from Tirana to Pogradec, in Albania, and the architectural elements serving the rail route. Currently, no longer in use, it constitutes an element of considerable interest for architectural drawing, as there are numerous artefacts such as stations, shelters, bridges, tunnels, and viaducts, which have never been documented until now.

The research aims to get to know the railway route and its architectural elements in order to graphically document the state of affairs through the consolidated tools of the discipline of Drawing, or rather with archive research, survey and digital modelling.

The Tirana - Pogradec railway is one of the two Albanian railway tracks (the second track was built in a north-south direction to connect the coal mines on the border with Montenegro and the settlements) and was the only transport route between the sea and the hinterland near Macedonia. Currently only used for the Tirana-Durrës route with only one daily convoy, it is in a state of total abandonment.

The study was carried out from archival documents kept at the Central Archives in Tirana. The first phase of the research involved the cataloguing of materials and the construction of a chronological timeline of the cities' evolution. This was followed by the identification, at first through existing cartography and then on the field, of the architectural elements that aroused interest in order to subject them to architectural survey actions. The scarce archival sources

revealed a total lack of knowledge of the structures, and with this work, the intention was to build a database of the current state of the stations. The stations of Tirana, Durrës, Kavaje, Rroghozine, Pequin, Elbasan, Libazhed Perrenjas, Lin and Guri kuq - Pogradec were analysed, or rather a route that starts from the capital Tirana and moves along the sea to Durrës and back inland to the border with Macedonia. A route characterised by a diversification of the territory consisting of plains along the coast, hills and wide valleys before reaching the mountain range in front of Lake Ohrid.

Finally, the virtual representation of the stations was experimented with digital modelling actions. The architectural elements were modelled and preparatory representation phases were carried out, from construction of the bare model to its insertion into the landscape. A further difficulty was the textualisation of the stations since they are no longer used and their structures are in a state of total abandonment and decay.

Literature Review

The In order to illustrate the railway route graphically, it is particularly interesting to analyse the layout of the urban centres crossed by the railway line and the historical and architectural features along the route.

The cities analysed correspond to the railway stops, with the exception of the terminus in Pogradec, where the station is located a short distance from the city centre. The cities of Tirana, Durres, Kavaje, Rroghozine, Pequin, Elbasan, Libazhed Perrenjas, Lin and Pogradec were therefore analysed, starting with a large-scale planimetric identification. The analysis then focused on historical maps, where available, with a re-proposal of the state of the city and the position of the railway station over the years. It can be seen that the station, initially located on the outskirts of the city, was absorbed by the urban centre as it expanded into the countryside and became a hub for the city itself. The surrounding buildings were affected, and the railway line itself underwent geometric changes as a result of the terrain.

For the city of Tirana, the station, now destroyed, is located to the north, at the opposite end of Boulevard Zog I, which connects Scanderbeg Square with the avenue of the Ministries. It is now a central location, but in the past it was on the outskirts of the city and therefore a means of transport for people living in buildings far from the centre.

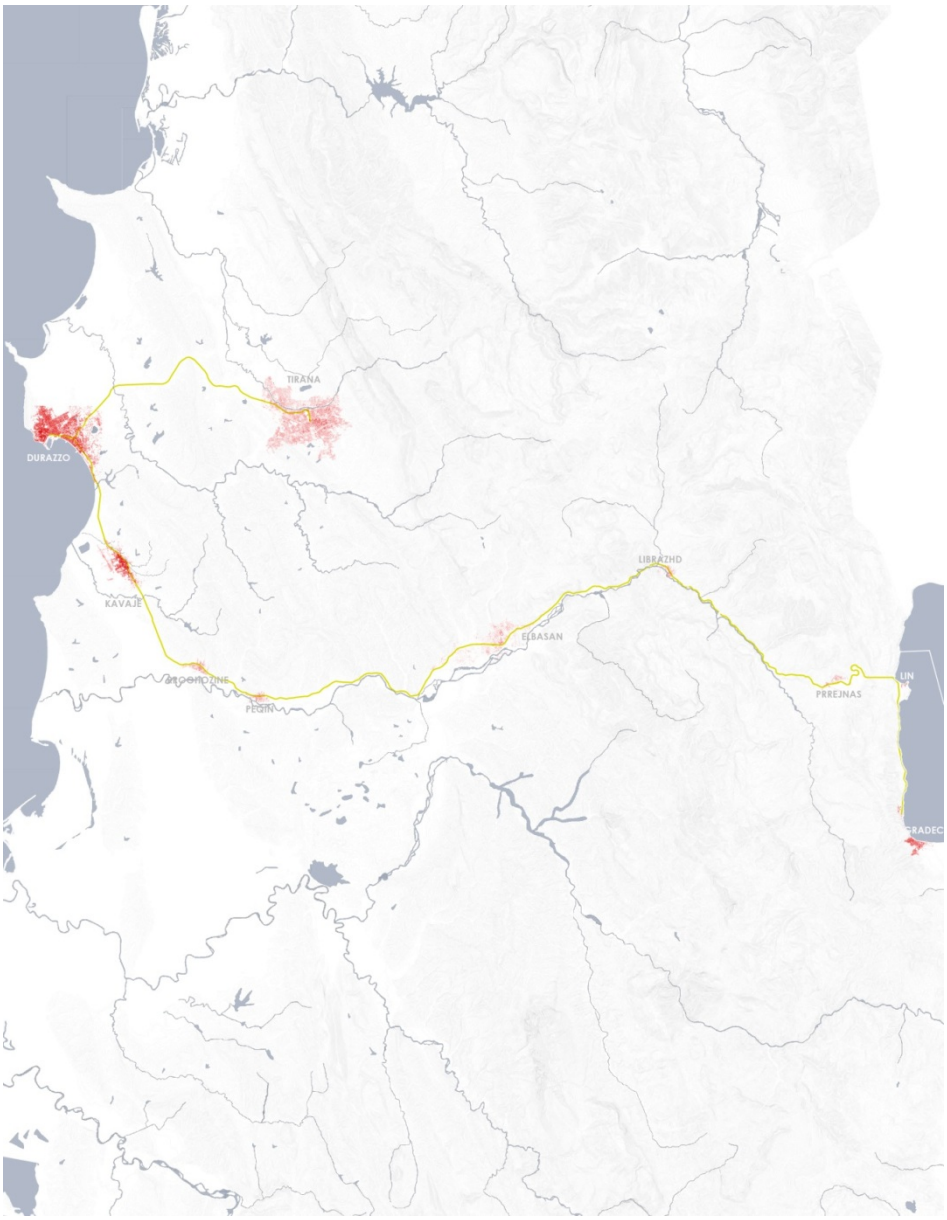

Figure 1. Planimetric representation of the railway line and identification of the towns crossed by the railway from Tirana to Pogradec.

The city of Durres is characterised by a series of Hippodamian grid roads that converge towards the port. The station is located on the eastern edge of the city, towards the sea. It is a place of commercial exchange between the port, which constitutes Albania's external link with the West, and the hinterland, which is served by the next section of railway.

The city of Kavaje is the first inhabited centre in the eastern direction of the railway line. It is bordered on the eastern edge by the railway line and has a station in the southern area at the end of the central axis.

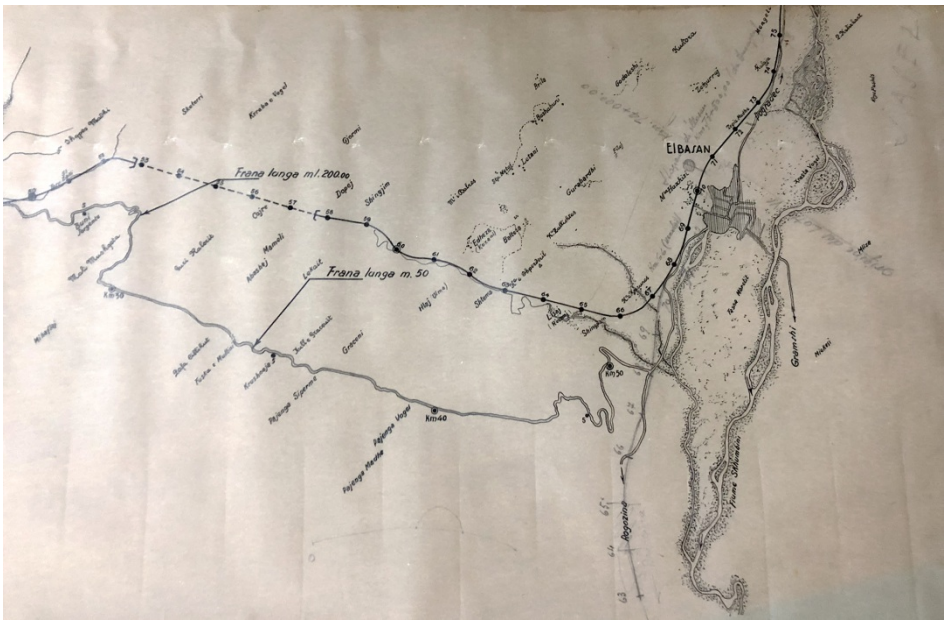

Figure 2. Archival graphic documentation of the Tirana-Pogradec railway line. Excerpt from the section near the city of Elbasan. (Source: Central Archives of Tirana)

The city of Rroghozhine is both a crossing point and an interchange hub. In fact, a secondary route heads south towards the mining area for the extraction of iron and coal. The route crosses the southern part of the city, which is characterised by a compact urban centre and a series of buildings for the exchange of goods.

The city of Peqin is bordered to the north by the railway line and has a station located north-west of the town centre. Historical records show that it has always been a centre of transit and feudal rule. The small castle, of great historical interest, bears witness to its architectural significance.

The city of Elbasan, located along the Via Egnatia route, with its fortified system that represented the meeting point between the Albanian and Macedonian communities, has a railway station to the south-west.

The city of Librazhd is located on the slopes of the mountainous stretch that separates the Elbasan plain from the city of Korca. The urban layout is spread out along the only source of water in the valley, and the railway line divides the city transversally. There are no connections between the road network and the railway, and the station is located to the north-west. The town of Perrejnas marks a change of direction in the journey across the mountains. From this town, the route begins its descent towards Lake Ohrid and the Macedonian border. The railway line runs outside the town centre, with a small country station.

The town of Lin stands on a promontory jutting out into Lake Ohrid on the border with Macedonia. The town centre is some distance from the railway line and is connected to the station by a dirt track.

The town of Pogradec is the terminus of the railway line. The station does not reach the town centre but ends to the north of the town near the lake. This is a strategic location for sending goods to neighbouring countries and avoiding the unnecessary expense of building an additional section of railway to the town itself.

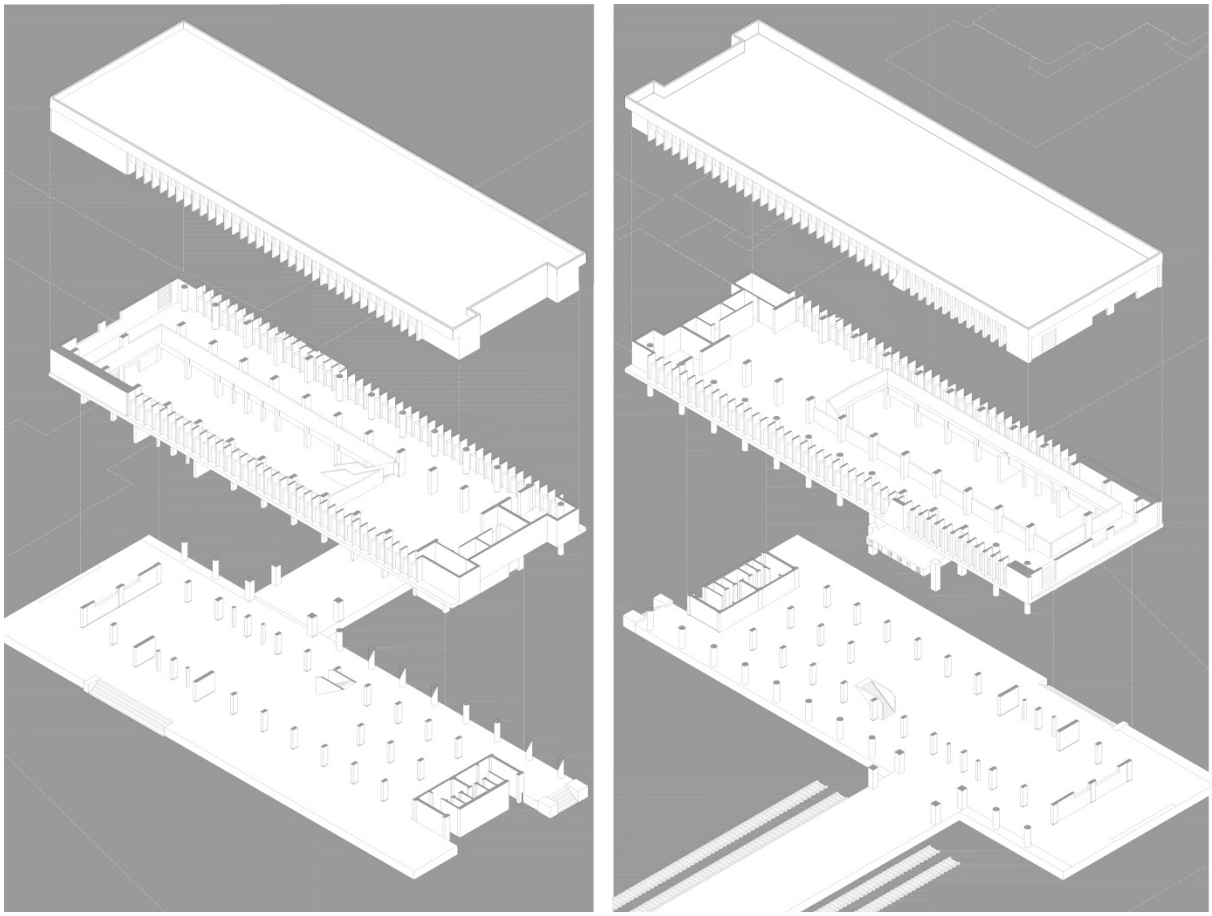

Figure 3. Durres railway station. South-facing axonometric projection of the survey, showing the supporting structure and flow system.

Methods and analysis of architectures

The study conducted on the railway stations of the Tirana-Pogradec line aims to graphically illustrate the architectural artefacts through plans, sections and elevations and with axonometrics and exploded views. This representation technique is used to compare the few archival documents with the actual surveys carried out on-site.

For architectural surveying, the indirect method was preferred, with the aid of laser scanners and the photogrammetric technique supported by a digital camera and a small four-powered drone. For the laser scanner surveys, the laser of the company Faro M was used in order to create point clouds for the subsequent graphic restitution. The active sensors were then referred to following a precise pipeline of indications necessary to achieve the survey. From the surveys conducted, models were derived that meet the requirement of fidelity to the railway architecture. In order to carry out the activities, preliminary steps were planned prior to the acquisition of the gripping plan. In addition to traditional acquisition techniques, the planned pipeline also included the programming of range maps and surface reflectance characterisation. This activity was necessary for the classification of the colour present in the surfaces and the management of the same among the problems that emerged from the sunlight and reflection of reinforced concrete and surfaces subject to degradation.

In addition to laser scanning, the DJI quadriplegic drone mini allowed both external flight for linear surfaces and internal flight for the documentation of inaccessible spaces. As is well known, photogrammetry, like topography, extracts metric information from the evaluation of fixed elements on the scene of the image taken by the operator for research purposes.
Following the survey campaign, the processing of the collected data was carried out. Very important was the alignment of the images using digital software. For error control, the overlap was calculated to the extent of 60 per cent between one image and another with a symmetrical view from two vertices towards the same point of capture.

The editing phase, on the other hand, was developed by marking and eliminating typological errors related to image acquisition and the subsequent point cloud alignment processes. Subsequently, although to a lesser extent, manual intervention was necessary to close the gaps in the less exposed or overexposed surfaces due to the photographic shot taken against the light. The faces of the railway stations, at the contact points determined by sharp-edged corners, had small gaps caused by software instability. These gaps after an initial automatic generation of the closing surfaces required manual intervention to create the model.

The results achieved demonstrate how the technologies enable the documentation of a large number of architectures within a wide spatial context such as the railway section from Tirana to Pogradec.

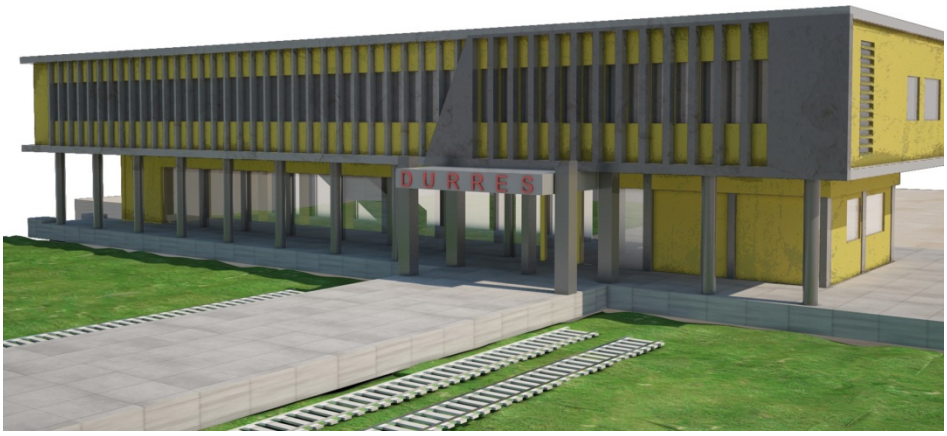

Figure 4. Durres railway station. Digital reconstruction of the current state based on the survey model.

Figure 5. Preejnas railway station. Model of the current state and condition of deterioration of the building.

Conclusion

The analysis for the understanding of the different elements of the railway line from Tirana to Pogradec is constrained by strategies of communication and virtual use of spaces, as well as the technological development used for documentation and data representation purposes. In the planning of the survey phases, solutions were planned in order to achieve a reliable result in the subsequent 3D modelling phases. These activities culminated in the realisation of a textured digital model capable of recomposing the formal and geometric characteristics of railway structures such as stations, stops, bridges and tunnels.

Figure 6. Pogradec railway station. 3D representation of the current state of the premises.

The activities involved the creation of digital models, the study of compositional and colourimetric geometries, the creation of patterns for the analysis of materials, and the possibility of creating remotely usable images.

The texture mapping phase was realised using the information gathered during the photographic survey campaign. The digital software reported the data collected in support of certain colour points identified on the photographic samples on a 3D basis. The surfaces used as samples for the digital reconstruction of the railway tracks were identified based on the pixel quality and the overall colour match of the surface under investigation.

The attempt to model the elements that make up the Albanian railway is part of the idea of making the various pieces of information accessible, through the use of multimedia systems capable of integrating new communication strategies, imposing the definition of operational programmes for the development of "intelligent" digital databases that can provide the basis for more aware management tools and activate processes for the reuse of the railway heritage, which is today in a state of complete abandonment.

The 3D geometries were created by sampling 20 to 30 images, mainly orthogonal to the vertical surfaces and with drone shots for the construction of models on a territorial scale.

Established methodologies were used, as textures were mapped both based on surfaces and vertices to which a sample colour was assigned. For colour mapping on the digital model, certain corrective measures were required, such as the possibility of combining colours and geometries, the possibility of varying the resolution, technical-operational compatibility, and the visual and perceptual impact of the stations in the landscape. The technique used, therefore, is based on the principle of planar projection of the surface with the colour matrix. The

projection was carried out parallel to the architectural element with software reporting the geometries of the 3D model.

In order to promote a digital database obtained from the integration of range-based and image- based instrumentation, for each of the railway elements and architectures present along the route, a three-dimensional model was prepared, structured according to its capacity to respond to a multiplicity of purposes related to knowledge, re-use and communication.

The contribution aimed to illustrate the territorial characteristics of the towns and cities crossed by the railway line, namely Tirana, Durres, Kavaje, Rroghozine, Pequin, Elbasan, Libazhed Perrenjas, Lin and Guri kuq – Pogradec. This route starts in the Albanian capital, moves towards the sea at Durres, and then heads inland to the border with Macedonia. It is characterised by a diverse landscape consisting of plains along the coast, hills and wide valleys, before reaching the mountain range opposite Lake Ohrid. The graphic documentation through 3D modelling represented, for the architectural and structural elements of the Albanian railway, a tangible sign of the immense abandoned heritage, built in the 1920 and currently subject to vandalism and deterioration due to the passage of time. This activity is intended as a tool for knowledge and enhancement for the environmental sustainability of the territories in order to restore the railway line and allow citizens and tourists to avoid polluting the Albanian landscape.

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ECOLOGICAL ISSUES IN CIRCULAR CITIES TRANSFORMATION

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Ecological Issues in Circular Cities Transformation

Abstract: Environmental rebalancing interventions in urban contexts, structured with a view to both functional and structural enhancement, are a complex process that requires rethinking places, considering each constituent element as an integral part of the wider ecosystem.
This ecosystemic approach necessarily involves working with a view to enhancing the environment, paying close attention to possible interference between human activity and natural aspects. Based on these premises, below are some ecological considerations that can guide the structuring of rebalancing interventions aimed at activating adaptation processes for conservation and preservation purposes.
An important contribution can be made by cities' transition from a linear to a circular model. The adoption of circular practices within cities has a significant impact on ecological-environmental sustainability. National and international examples demonstrate that adopting a circular approach generates sustainable and resilient urban environments. In this way, the territory is no longer simply a "context" but becomes an "agent" that supports the triggering of urban circularity processes (Lucertini, 2021).

Keywords: ecological-environmental design, urban ecosystem, mesosystem approach, circular city.

Introduction

The identification of ecological and environmental strategies to improve the conditions of our urban habitat currently affects both local and large-scale policies. The challenge is precisely this: can urban contexts become capable of ecological and environmental self-regulation to ensure the control of such complex transformations? To answer this question, we must consider that currently, cities are ecosystems that consume resources, generate emissions, and produce a significant amount of waste. Furthermore, the growth of urban populations worldwide means that cities are increasingly responsible for global resource depletion and climate change. Operating according to circular logic based on processes that focus on reducing, reusing, and recycling can generate circular resource flows, support natural cycles, and enable cities to renew themselves. These processes, working together, form the basis of the circular city approach and reduce the impact of the urban population on the global ecosystem. They also contribute to the creation of healthier local ecosystems in which the urban population can live (Williams, 2021).

Based on these premises, below are some ecological considerations that can guide the structuring of rebalancing interventions aimed at activating transformation processes for the circular transformation purpose.

These interventions operate according to mitigation and adaptation logic and allow for the conservation and redevelopment of natural resources in the area and the connection between ecological and environmental values for the overall enhancement of the built environment. Indeed, it has long been believed that to improve the resilience of habitats and urban systems,

a significant contribution can be made by developing projects for the transformation and management of human settlements inspired by the functioning of natural and ecological processes (Mcharg Ian L., 2013).

Literature Review: Perceptive Urban Patterns

The first cultural reference, speaking of urban spatial patterns, remains today Joseph Rykwert's "idea of a town", strictly connected to the spiritual idea of places, looking back to Roman tradition, and confirming that a symbolic structure is behind each town's foundation (Rykwert, 1976). This reference lets us ask ourselves if there could be today a theoretical framework that increases iconic perceptive attitudes, making people, on one side, feel deeply isolated with an internal focus in each public open space and, on the other side, connecting each space with the others towards many osmotic surrounding areas. By combining different perceptive attitudes in urban patterns, the designer could create a dimension of otherness in comparison to daily life in a sheltered space that allows for the possibility of feeling renewed in the relationship between routine moments and extraordinary moments that leave one astonished and suspended.

Variability in urban patterns, made of alternative design strategies of contrasting and osmotic layouts, creates variable emotional perceptions of spaces. A continuously alternate interrelation between natural elements and constructions into variable urban patterns implies a kind of multiple perception which encourages people's recognizability of personal experiences in a way which is more than simply functional. The objective is to promote a design process capable of redesigning the relationship between man and the environment with respect to the characteristics of places and their dynamic rules. Flexible and unpredictable dimensions, in a framework like the one that has been prefigured but in fact already in place, do not deny in any case the need to anchor itself to a basic stability offered again by a local dimension of project, production, life.

Once this direction is identified, the perspective is deeply bound to indirect ways of perceiving our dimension in an open space, and we must move beyond the paradigm of mere vision. Pallasmaa made us understand very well how, with all the senses, there is a profound perception that constitutes the exchange between internal and external, connected with people's wellness and their personal conditions, which is essential to acquiring knowledge of physical environments and remembering them (Pallasmaa, 1996).

Over time, the town's overall open space design has come to be recognised as a primary indicator of urban recognizability. In particular, public gardens from the early era of urbanisation constituted an essential reference, like a common heritage, in view of strategies for dispersing urban pressure. If we still lived in a condition very similar to that of early urbanisation time, as a first thing, we would simply advocate a kind of traditional urban projects with opening channels and lines of union between vegetation areas and built context, to improve wellbeing, while emphasising collective identity recognizability. However, more complex patterns are to be implemented today, with a connection to new needs. Today, design is not only an act of creation but foremost an act of understanding – a respectful conversation with the town and people's conditions. It's about creating spaces that resonate with their natural and cultural contexts, where everything is a response to the rhythms of the environment and the community. In this careful balance, we see not just a maintenance of identity but an evolution of it, as design becomes a catalyst for nurturing places that are alive with relevance and meaning, enriching both the spaces and those who inhabit them.

The intersecting features of distinct layers in an urban collective space must first and foremost produce a human-centred setting that promotes our interdependence with ourselves and the places we visit daily. As a result, we might understand it as an interchange space moving through several routes in which urban ecosystem design serves as a vivid communication tool, connecting people to their firsthand experience of the concept of “nature”.

Methodology: approach to the mesosystem concept

In order to hypothesise strategies that operate with a view to the circular transformation of urban contexts, it is useful to start by examining the difficult relationship between the needs of the human world and those of nature. The urban environment differs from the natural environment due to the massive presence of the human species, which largely influences its structure and functioning, to such an extent that we are led to consider it something completely artificial.

Over time, the relationship between humans and nature has undergone many changes, often oscillating between harmony and conflict, but in most cases, humans have altered the characteristics of nature to adapt it to their needs.

When delving into assessments of the interrelationships between anthropogenic and natural phenomena to provide tools and methods for rebalancing, it can be helpful to view the territory as a true ecosystem (Adler & Tanner, 2013; Aitkenhead-Peterson & Volder, 2010).

This ecosystem, however, differs significantly from the natural one. Cities, while they may resemble a natural ecosystem because they are composed of multiple components, are not living organisms with beating hearts, bones, muscles, and nerves, and they do not have a simple metabolism that provides materials and energy to the different parts of the body (Zhang, 2023).

Starting from the consideration that the natural world constitutes a perfect ecosystem, the same cannot be said for the urban world, i.e., the world in which humans interact with various biotic and abiotic components.

The urban world can be considered a transitional ecosystem, as human activity prevents it from achieving a state of stability. In fact, "*cities are a key nexus of the relationship between people and nature and are huge centres of demand for ecosystem services and also generate extremely large environmental impact"* (Elmqvist, 2015).

The urban ecosystem, characterised by highly complex relationships between physical and biological components, is composed of different types of biotopes: artificial, semi-natural, and semi-natural.

An urban ecosystem can be understood as a superorganism with various metabolic processes that cause significant problems, such as land cover changes, increased energy imported, and the carbon source effect of cities. All of this raises numerous questions about the sustainability and carrying capacity of the urban ecosystem (Kapoor et al., 2020).

Precisely because of all the characteristics described above, it is clear why the urban ecosystem cannot be considered completely autonomous. It can only achieve a certain "balance" through interaction with other ecosystems. This has led to the proposal to structure the urban ecosystem as a set of artificial and natural microsystems, which interconnect to form a "mesosystem" to achieve intermediate states of equilibrium.

These considerations are based on the transposition to the urban environment of the theory of ecological systems, formulated by Urie Bronfenbrenner with the aim of promoting understanding of the dynamic interrelationships between the various personal and environmental factors of human development (Bronfenbrenner, 1981).

Transposition consists of structuring the "mesosystem" as an interconnection between microsystems, including at the level of urban environment development. To implement this proposal and structure the "mesosystem" appropriately, a crucial role is played by the areas of interconnection between artificial and natural microsystems, which must constitute a genuine network of connections supporting the ecological infrastructure (Perschke et al., 2023) as a

functional element in biodiversity management (Keitaro, 2021) aimed at conserving, restoring, and connecting natural and semi-natural habitats.

The proposed approach is to consider the system of interconnection zones as a network for connecting, integrating, recomposing, and protecting human intervention, enhancing the ecological and environmental qualities of the territory by providing it with appropriate and sustainable services. It is a connecting element in that the network can interconnect services and built/natural spaces through optimisation processes, both in terms of the built environment and the natural environment and ecological context in which it is located, and which helps to change. Element of integration, in that the network can enhance the environmental performance of anthropic intervention, making it more productive in terms of relationships between individuals and more sustainable in terms of relationships with nature and natural phenomena. Elements of recompositing, because the network can contribute to the recovery of interventions carried out with land use choices that have occurred over time, without comprehensive and unified references. Finally, protective elements, such as network logic, can help reduce the risk of accidents or environmental pollution.

To appropriately structure the transformation and rebalancing of artificial microsystems in an eco-oriented manner, with a view to making them compatible with natural systems, particular attention is paid to the contribution deriving from the use of strategies that employ the principles of nature as a model of operation.

It is also very important to customise the transformation intervention by identifying, on a case-by-case basis, the necessary actions that are always oriented towards the application of systems that operate using natural resources (Catalano et al., 2021; Brears, 2020) and their operating principles, stimulating the intrinsic potential inherent in these resources that have not been developed due to massive anthropisation.

The codes and protocols for the design of such interventions cannot be defined or proposed in the abstract, but must be structured in relation to the particular circumstances and types of contexts and must not ignore the uniqueness and irreproducibility of the characteristics of the natural environment, since each place is subject to physical and biological transformation processes that are not found elsewhere, except for their fundamental characteristics.

Considering these considerations, the circular transformation of cities (Langergraber & Atanasova, 2023) can make a valuable contribution to improving the efficiency of natural resources, reducing environmental impacts, and generally increasing the resilience of the built

environment. In this regard, the city should not be understood as a "context," but as an "agent" that fuels the triggering of urban circularity processes (Lucertini, 2021).

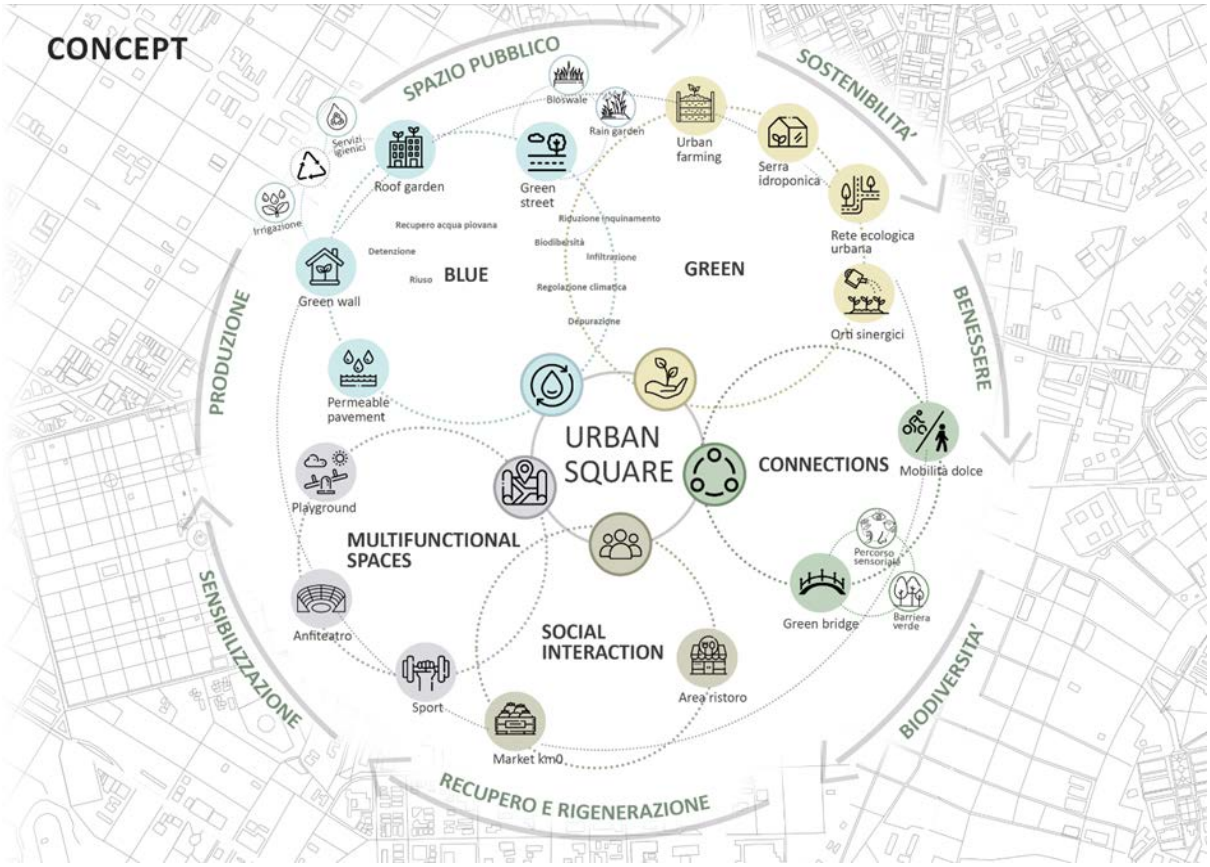

Figure 1. A concept of an urban square structured according to the logic of a "mesosystem approach" (F. Cerbone, 2024).

Findings and Discussion: circularity as a driver of urban change

The systemic logic proposed as an action approach for urban transformations aims to address ecological issues, starting with the conservation and rehabilitation of the natural resources within the intervention contexts. Sharing the idea of "*A city can be visualised as an ecosystem due to the interconnected parts that work together"* (European Investment Bank, 2023), it becomes strategic to think in a way that enhances its potential in terms of circularity. To realise this perspective, it is necessary to create an ecosystem in which collaboration, knowledge and information sharing are enhanced through the promotion of, for example, training and awareness-raising activities addressed to the stakeholders involved in the different project phases and in relation to their specific roles. The creation of such an ecosystem may have greater possibilities to activate circular mechanisms, aimed, for example, at improving the

capacity to collect, sort and recycle construction and demolition waste, bringing benefits with respect to the supply chain linked to the recovery and recycling of products, materials and resources in an increasingly rational and systemic way (European Investment Bank, 2023).

As part of a circular approach, in fact, not only the reduction of land consumption and carbon emissions are confirmed as objectives to be pursued, but everything related to the internal life cycle of buildings and the overall efficiency of resources in the building sector, which are, in a general sense, "*one of the keys to the change towards a circular model of cities* (...) *responsible for most of their consumption and more than 75% of the energy produced worldwide*" (Zucca, 2022).

The system of development based on the supply-consumption-waste-to-disposal relationship has created complex ecological and environmental imbalances that are difficult to manage and require not only action according to reduction approaches but, above all, the regeneration of the urban ecosystem in which buildings must be considered as interrelated objects within a larger, more complex ecosystem. The well-established concepts related to the principles of sustainable design are being interpreted in increasingly innovative ways by resorting to approaches that focus not only on environmental protection but also on regenerative design and the circular economy (Sousa, 2021).

In the building process, durability, adaptability, and waste reduction are considered the main challenges facing construction, principles which are interrelated to both planning and the life extension of buildings (Charef, 2024). In fact, the reuse and recycling of components and materials in the building sector allow for circularity processes and, at the same time, feed the value chain (Giglio et al., 2021).

The actions and recommendations promoted in the European context for the productive sector highlight, among other things, the strategic role that the renovation of existing assets takes on as a field of experimentation and application to identify practices that aim at an efficient use of both energy and material resources (Giorgi et al., 2019). The integration of the most innovative principles concerning the circular transition into architectural design implies *"the management of integrated knowledge systems, expanding its approach in terms of pluralism, the interaction between disciplinary specializations, recognition of contributions avoiding cultural hegemonies or instrumental subalternity"* (Losasso, 2021).

Conclusion

This paper, sharing the idea that the city should not be understood as a "context," but as an "agent" that fuels the triggering of urban circularity processes, suggests some ecological considerations that can guide the structuring of rebalancing interventions aimed at activating transformation processes for the circular transformation purpose. These interventions, based on the activation of processes that use the principles of nature as a model for sustainable management, aim to configure the city as a fabric in which there is no boundary between the artificial and natural environment and in which each process is controlled so that its impact and consequently the irreversible degradation induced is as minimal as possible in relation to the constraints of the process itself.

The advantages of using these interventions are numerous, and those related to improving environmental resilience and ecological conditions to preserve biodiversity are particularly highlighted.

Finally, this paper contributes to the discussion on ecological issues with a special lens on the circular transformation of the built environment, where the relationship between people and nature can be examined in terms of both ecosystem services and environmental impacts.

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SUSTAINABILITY IN PERCEPTION, EXPERIENCE, AND BEHAVIOUR

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OBSERVATION-BASED EXPERIENCE OF DELFT: FROM OBJECT(HOOD) INTERFACES TO FAMILIARITY AND CULTURAL SUSTAINABILITY

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Observation-Based Experience of Delft: From Object(hood) Interfaces to Familiarity and Cultural Sustainability

Abstract: This study is based on an observation-based experience carried out in the city of Delft within the context of cultural sustainability. The experience was conducted through walking, and its research focus was framed by the theory of objecthood. Four groups of objects—wooden doors, stained glass windows, iron railings, and Delft ceramics—were addressed as interface objects through their aesthetic, emotional, and representational meanings within objecthood theory. These object groups were analysed through the integration of heuristic strategy and morphological reading in relation to cultural sustainability. Interface objects were also evaluated regarding concepts such as object scale, viewing position, human-scale relation, observer's position, and temporal engagement. The study states that in the Delft experience, these interface objects act as carriers of cultural memory and serve as sources for cultural sustainability. Object(hood) interfaces referred to the values such as belonging, domesticity, home and place attachment and emphasized feeling of familiarity.

Keywords: cultural sustainability; observation-based experience; objecthood

Introduction

Cultural sustainability depends on the emergence, valorization, and preservation of a city's local production, on the formation of a unique language through its urban, architectural, and everyday objects, and on the perception and continuity of the aesthetic codes of this language (Memmott & Keys, 2015). Craft production, locally specific material types, and the safeguarding of historical or place-based meanings and values not only ensure cultural sustainability but also construct the identity and memory of the city (Sethi, 2023; Mahira, Soemardiono & Santoso, 2023).

This study addresses the context of cultural sustainability by focusing on the emotional engagement established with the city of Delft through an observation-based experience and on the interface objects that represent the city. Highlighting that emotions are not only biological but also cultural in nature, this study situates the formation of emotions within the interaction of the human with surrounding objects, space, and environment (Büscher & Kristensen, 2023). This interaction differentiates architectural or everyday objects in terms of their capacity to represent urban identity, framed through the concept of objecthood. Objecthood emerges as the condition by which an object distinguishes itself beyond mere physical existence, carrying aesthetic, emotional, and representational meanings (Fried, 1967). In line with the topic of transcendence of an object's physical context, Orlikowski (2010), within the socio-material context, approaches the objects not as fixed and rigid entities, but rather as possessing a fluid nature that is shaped through real-life interactions and relationships. While Pickering (1995) argues that human and material elements exist as independent agents but interact together to

create an effect, Latour (2005), eliminates this distinction and approaches the subject from a more relational point of view, arguing that everything exists through mutual interaction. Beyond this ontological distinction, the socio-material perspective posits that objects possess functions that exceed their mere physical existence, and that these functions are mutually constructed in relation to the social context (Orlikowski, 2010; Pickering, 1995; Latour, 2005). Similar to this viewpoint, Michael Fried (1967) relates the quality of objecthood to the necessity of a viewer's presence and a theatrical experience situated in real time and space. Thus, objecthood is concealed within the temporal and physical relationship it establishes with the viewer.

Within the framework of the Delft experience, the shaping of the concept of objecthood takes place through an impression-based, single-day experience in which the researchers act as viewers. In this experience, the objects that acquire the quality of objecthood are those that captured the researchers' aesthetic attention, evoked emotional associations, carried cultural meanings, interacted with the body at eye level or within the line of sight, and gained presence by inviting the viewer's gaze within that particular time span. These objects—wooden doors, stained glass, iron railings, and Delft ceramics—were perceived by the viewer not merely as architectural fragments or everyday items but as objects that generate meaning for Delft and communicate on behalf of the city. In other words, what rendered these objects meaningful and endowed them with objecthood was the presence and gaze of the researchers as viewers, along with the time specifically devoted to these objects throughout the experience. This study regards these objects as carriers and transmitters of cultural memory. Through observing these objects that reference traditional and local modes of production, the researchers' personal experience intersected with collective and cultural memory.

This research is a qualitative study that, through an observation-based urban walk in Delft, examines the emotional and representational effects of urban, architectural and design objects as revealed by heuristics and morphological analyses. Accordingly, the study first explores the relationship between the formal characteristics of these objects and their intuitive-emotional reflections. Secondly, it analyzes how the presence of these objects is experienced within the interaction of body, time, and space, and how this contributes to cultural memory within the framework of cultural sustainability.

Literature Review

After social, economic, and environmental dimensions, cultural sustainability is defined as a new dimension of sustainability (Hawkes, 2001). With this definition being adopted by international organizations such as United Cities and Local Governments (UCLG), culture began to be recognized not merely as a tool serving the other three dimensions (environment, economy, society), but also as a domain with intrinsic purposes and values of its own. In the literature, discussions on cultural sustainability are largely conducted through the concept of culture itself (Memmott & Keys, 2015; Meireis, 2018; Kagal, 2018).

Looking at classical theories of culture, we see that Cassirer (1944) approaches culture not as a rigid and uniform construct, but as a dynamic and multifaceted relationship; he seeks culture not only in the physical world but also within emotions and abstract connections. Williams (1989) conceptualizes these relationships through everyday life, defining culture as a whole of shared meanings, while Geertz (1973) describes this meaning as an ensemble of interactions shaped by the interpretations of the observer. In this sense, culture is understood not as a fixed entity, but as a web of symbols that people continuously interpret, either intuitively or consciously (Meireis, 2018). Accordingly, cultural sustainability concerns not so much the continuity of the physical, but rather the transmission of shared meanings, emotions, and cultural memory. Kagal (2018), with his concept of the ‘complexity of aesthetics’, draws attention to the multi-layered nature of cultural sustainability, which is constructed not through objective, knowledge-based strategies but through sensory, emotional, and experiential means. Within this layered structure, architectural and everyday objects in urban life transcend their functional roles and contribute to the sustainability of culture through the aesthetic and emotional meanings they carry.

Methods

This study is framed as a qualitative method grounded in observation and lived experience as a way of walking (Ingold & Vergunst, 2008). The research method is based on an unstructured, spontaneous walk through the urban fabric of Delft, conducted over a single day for approximately seven hours, covering both morning and afternoon. This walk constitutes an observation-based experience in which the researchers adopted the position of observers. Here, the term ‘observation’ is used to express the multi-dimensional nature of the experience as intuitive, sensory, and aesthetic (Pink, 2009). Although the study conducted through

photographic documentation; observation is developed beyond merely visual mode (Atkinson et al., 2007) by integrating emotional and heuristic dimensions to the readings.

For Pink (2009) the experience is understood through subjective, aesthetic, and emotional interactions with the materiality of urban space. Such an experience embraces phenomenological perspectives on perception. This is not an event related to physics or biology or originating from the organs, but rather is such an experience the continual re-creation and re-animation of the world at every moment (Merleau-Ponty, 1962, p. 240). This experience also refers to the vitality of materials, integration of observation and description, formation the ground through light, sound and emotional experiences (Ingold, 2011). This study is grounded in observation, and a lived experience with its subsequent emotional reflections concerning to the place (Seamon, 2013). These multi-layered engagements are analyzed within the conceptual framework of objecthood, allowing the researchers to interpret the affective qualities of urban form beyond representational methods. The research design consists of three phases (Table 1).

Phase 1: Observation-Based Experience

On May 12, 2025, the researchers intuitively walked through the city center of Delft without a predetermined route or focal points. During this period, a large number of photographs were taken based on spontaneous visual attraction (Figure 1).

Figure 1. Some of the photos taken on Delft Map.

The day was sunny and bright, typical of spring. The experience was enriched by the tactile texture of the city's natural brick surfaces, the human scale of the built environment, and the reflections created by water and canals—elements which together evoked emotional responses. The walk included two short coffee breaks and one lunch. These observations formed the foundation for later analysis.

Phase 2: Evaluation of Observation Day

Following the walk, the researchers conducted a reflective brainstorming session to assess the visual and emotional impressions left by the experience. Objects that had formed memorable aesthetic and emotional connections during the experience were identified as emotional interface objects. Notably, the objects remembered most vividly were those perceived at eye level and within human scale. While the city offered rich visual variety, the researchers' recollections and impressions coalesced around four primary object groups: wooden doors, iron railings, stained glass windows, and Delft ceramics. These were recognized as emotionally charged interface objects that left lasting impressions.

Phase 3: Analysis of Interface Objects

This stage integrates heuristic strategy with morphological analysis. While some approaches consider heuristic strategies to be inadequate and unreliable in terms of logic and probability rules (Tversky & Kahneman, 1974), some researchers (Prietula & Simon, 1989) argue that everyday interactions often exceed human cognitive capacity, making fully rational decision-making practically impossible. In parallel with this view, naturalistic approaches (Klein, 2008) emphasize that the real world is not comparable to the isolated environment of a laboratory; instead, it is filled with uncertainty and complexity. Therefore, they suggest that coping with this complexity is only possible through heuristic strategies. Within this framework, heuristics are not seen as simple shortcuts, but rather as cognitive tools that develop through experience over time and enable individuals to make fast and effective decisions (Albar & Jetter, 2009). The term ‘morphological analysis’, on the other hand, refers to the study of structural relationships within the specific field in which it is employed (Alvarez and Ritchey, 2015). The intuitive responses of the researchers are not separated from formal analysis but are combined and presented as a unified interpretation. The morphological content of the objects—their form, composition, and surface articulation—is considered as a trigger for emotional and cognitive responses.

The final phase involves synthesizing heuristic strategy and morphological readings through objecthood, and cultural sustainability, to evaluate how these objects function within

the urban scale. While the intuitive dimension remains subjective, it is treated as a critical trigger for analysis.

Table 1. Research design.

Basic phases	One day observation experience-evaluation of observation day-analysis of interface objects
1.One day observation experience	
Research approach	Observation, experience
Researchers	Two observers walking together
Date of experience	12.05.2025
Duration	One day-7 hours-10.00-17.00
Weather	Sunny spring
Feature of experience	One day walk taking photos
Collection of data	329 photographs
2.Evaluation of observation day	
Theoretical frame	Objecthood, cultural sustainability
Brainstorming & discussion	Interface objects: doors, stained glass, iron railings, Delft ceramics
Reduction of Data 1	Grouping of photos on interface objects
3.Analysis of interface objects	
Theoretical frame	Heuristic strategy, morphological analysis
Heuristic strategy	Subjective-affective-emotional-aesthetic responses
Morphological reading	Recurring formal elements shaping observers' emotional engagements: Form, proportion, pattern, light-shadow, variation, repetition
Form of data	Photo collages

Findings and Discussion

Doors

Although these are exterior doors, they are positioned at eye level and are of narrow, modest dimensions, aligned flush with the sidewalk and the building façade, thus forming a subtle threshold. Their size and placement at eye level evoke a sense of intimacy and familiarity. They serve as delicate boundaries between exterior and interior spaces. With their saturated hues—ranging from red, blue, purple, green, to navy—some in glossy finishes, others in matte, they become the most prominent and distinguishing symmetrical vertical elements of the buildings. This generates a feeling of belonging, turning the doors into identity markers. Most doors are carefully outfitted with aligned mail slots, doorbells, and knockers, which we interpret as a reflection of the value placed on domestic space and locality, extending right to the doorway. Nearly all doors feature a transom window above them that allows light to enter, fostering a dialogue between interior and exterior spaces. They are often accentuated by white framing that creates a striking contrast. We perceive these doors, with their geometric order, as

proportional, symmetrical, and balanced, conveying a profound and stable sense of place. Their semi-transparent panels and accessories invite entry into the domestic realm, stirring curiosity about the interior and a desire to engage. The fact that these doors are positioned directly at sidewalk level, so openly accessible, and mostly made of wood, suggests that this is a safe place.

Stained Glass Windows

The stained glass panels are positioned as fixed transoms above doors or windows, typically in rectangular or square forms. Through the play of light, they elevate the act of passage, emphasizing the interior as a more sacred and transcendent space. They render the home and domesticity more intimate and special, reinforcing the notion of the interior as a journey into one's inner world. The glass, often in shades of yellow, red, and blue, generally appears muted and leaning toward grey, which suggests that these stained glass pieces have been there for many years, standing as representatives of a long tradition. The various patterns in these stained glass windows are largely non-directional; sometimes they feature horizontal or vertical bands, while at other times an abstract geometric arrangement is interrupted by a floral motif placed at the center or framed by differentiated motifs along the periphery. The designs combine modern geometries with occasional floral or semi-abstract figures. Through these frequently encountered, variant forms of stained glass—which appear both modern and traditional, and clearly exhibit the hand of craftsmanship—we observe a living cultural continuity.

Iron Railings

Around the canals of Delft, one frequently encounters iron railings that enclose these waterways with a functional and understated approach, reinforcing the repeated canal vistas. These railings are composed of vertical posts—each formed by a single upright bollard—and two horizontal pipe profiles connecting them. Executed with remarkable simplicity, they wrap around the canals in a uniform manner. The posts rise along the vertical axis with a symmetrical, slightly rotational profile. A slender, rounded shaft in the middle is capped by more block-like, prismatic masses at the top and bottom, strengthening the sense of verticality. The robust base underscores their stability. Because the horizontal pipes are positioned at about elbow height, they naturally invite leaning or resting upon. The rotational form and white-painted surface encourage touch, rendering them inviting objects. The white cast iron creates a vivid contrast

with the surrounding brickwork and the color of the water, reflecting light and generating a sense of freshness and vitality. The gentle curves along the shafts, along with the subtle narrowing and widening of the form, recall classical column profiles, referencing tradition. The bases and upper block forms feature grooves or beveled edges, while the stacked elements and the carefully designed transition details at their joints highlight a deliberate articulation. The horizontal pipes linking the posts are also pragmatically used for parking and securing bicycles. The wide spacing of these simple, repeating horizontal bands reveals how accustomed the local culture is to living alongside water. Throughout the experience, these railings invited us to come closer, pause, and gaze at the canal scenery. Their repetitive, column-like traditional forms foster a sense of familiarity and belonging. The fact that they are made of iron further suggests a local, customary materiality.

Delft Ceramics

Delft ceramics appear in various forms such as vases, semi-abstract human and animal figures, and decorative plates. Created with blue floral motifs on white backgrounds, these ceramics reflect both a traditional and a modern sense of domesticity. The flower patterns, botanical scrolls, and Dutch landscapes that adorn them continue a long-standing decorative tradition. These designs and colors evoke feelings of lightness, calm, and freshness. Among Delft ceramics, tulipiere vases with rounded organic bodies and multiple openings on their surfaces stand out as primary objects. By turning the display of flowers indoors into a kind of celebration, these vases elevate the sense of domestic life. Some of these vases feature bases that emphasize verticality, while others lack bases and, through the arrangement of their openings, produce a more horizontal effect. The relationship between the mouths and the body of the vase allows the openings to be perceived almost as limbs. Typically, one mouth is broader and centrally positioned, surrounded by an average of five narrower openings. While some of these openings taper inward, most are designed to flare outward. These vases not only highlight traditional ceramic craftsmanship but also showcase uniqueness of form and the distinctive ‘Delft blue’ color. Furthermore, these fertile, original, and haptic forms, which symbolize domesticity, emphasize tulip cultivation and ceramic production as part of Dutch heritage. With their organic shapes and patterns, these objects evoke familiarity, domesticity and intimacy in a warm, elegant, creative, and original manner, while simultaneously generating a sense of tranquillity, lightness, and clarity that invites one to approach and examine them closely.

Table 2. Analysis of interface objects: heuristics reflections and morphologic attributes.

Interface objects	Heuristic reflections	Morphological attributes	Interpretations to cultural sustainability
Wooden doors	Inviting through colours, bells, plants, mail slots; personalization and access cues; curiosity for inside; identity markers	Focal point with contrast frame; geometric divisions and symmetry; decorative and functional inserts; geometric orders and patterns; gridial compositions with indentations; insertion of glass and iron; insertion of floral motifs	Valuing entrance to home; colourful thresholds; symbols of identity; symbolism of door; the dialogue between inside and outside; valuing everyday life; valuing belonging and home
Stained Glasses	Emphasis on transitions with light filters; spirituality of inside; interior space with symbolic meaning	Coloured glass fragments; geometric patterns and composition; insertion of central or periferical floral motifs; insertion of figures, elevation of doors and windows	Valuing stained glass craft, symbolic elevation of domesticity; valuing intimacy of interior and domestic space

Iron railings	Invitation for pause, and canal vistas; modest framing of homely landscapes	Repetitive iron posts; classical column-like posts; vertical forms and horizontal bars; surrounding lines; open ironwork	Valuing ironwork; functional bars for bicycles; gentle framing of canal vistas; framing water; pastoral associations; homely landscapes
Delft ceramics	Emphasize domesticity tradition and domestic things; elevate tulips and tulipiere; and original product typology of local identity	Haptic and glazed rounded organic abstract forms as tulipiere; organic forms with pattern like parts as vases; semi abstract figures as figurines; floral motifs; blue motifs on white background	Valuing cultural preservation of tulipiere; domestic elevation with ornamentation; symbol of Dutch heritage; Delft Blue

Basis of Observation

The elements such as scales, positions, and temporal engagement—in relevance of body, object, space, and time—form the basis of observation (Table 3). The scale-dependent relationship established with the object and the position of the observer form the basis of this observation-based experience. When the head is raised to look at a stained glass window, a sense of respect also arises. When standing directly in front of a door and the doorknob is within reach, you become curious about what is inside and feel the urge to reach out and press the bell. When holding a ceramic vase with both hands, you lean toward it, draw closer, and become silent. One may approach the iron railings around the canal in parallel and stand beside them. By grasping them with your hands and looking straight ahead toward the end of the canal, you may begin to dream. The interactions with these objects encountered during the walk—the scale of the object, its relation to eye level, the posture of the observer's body, and the duration of

the engagement—become the measures of the emotional responses that emerge. With these measures, the objecthood of the objects is discussed.

Table 3. Basis of observation: scales, positions, and temporal engagement.

Interface objects	Object scale	Viewing position	Human scale relation	Observer's position	Temporal engagement
Wooden doors	Medium & vertical	Eye level	Full body height, accessible from front	Observed frontally	Momentary but recurrent engagement, bells/plants cause micro-pauses
Stained glasses	Medium & non-directional	Above eye level	Above head level, no direct touch	Observed as head tilted upward from a distance	Brief but careful engagement, upward gazes cause micro-pauses
Iron railings	Large & horizontal	Below eye level	Elbow to hand height, approachable, touchable, and stood besides	Moving along side	Stationary engagement, pausing, leaning as lingering
Delft ceramics	Small & haptic	Below eye level	Hand-level, and close range	Observed closely looking downward, grasping object, with examination of ornaments	Stationary engagement, Pausing as close-intimate examination

Conclusion

The analysis of these four groups of objects has shown that they derived from simple gridial arrangements, framing systems in horizontal and vertical relations, or organic forms characterized by simplicity, modesty, human scale, balance, and proportion; and that by incorporating floral motifs, figures, or functional elements into their structures, they emerged as highly balanced, recurring aesthetic codes at urban, architectural, and object scales, thereby contributing to cultural sustainability. Morphological readings of the objects—such as simple geometric layouts and organic haptic forms with floral or figurative insertions—referred to modesty, safety and familiarity (de Vries et al., 2010; Kinoshita, 2002). They all created the heuristic reflections to the domesticity and home.

In this study, the group of objects—wooden doors, stained glass windows, iron railings, and Delft ceramics—to transcend their functional roles and carry aesthetic, emotional, and representational meanings was examined through a two-stage analysis. Within the framework of the concept of objecthood, these objects were revealed to function as emotional interfaces between people and the city of Delft. Through these objects, the primary feeling evoked in the

researchers was a sense of being at home (Norberg-Schulz, 1980; Heidegger, 1971). Delft, with its elegant vistas, also inspired hope and a longing for home (Berleant, 1997; Relph, 1976; Seamon, 2013). Doors strengthened the sense of place and highlighted the connection between home and identity. Stained glass elevated interior spaces and sanctified the inner world, while ceramics emphasized domesticity with feelings of warmth and intimacy. The city of Delft, through its walkability (Gehl, 2010, p.119), human-scale proportions and careful attention to place, cultivated this sense of being at home. These four interface objects, through their references to home, domesticity, belonging, and identity—or their power to represent these within the framework of objecthood—construct the cultural sustainability of Delft via the 'feeling of familiarity', materialized in both modern and traditional ways through four sustainable craft materials: wood, glass, iron, and ceramics.

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BEYOND THE CLASS HOURS: INTERIOR ARCHITECTURE STUDENTS' USE OF FACULTY SPACES IN THEIR LEISURE TIME

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Beyond the Class Hours: Interior Architecture Students' Use of Faculty Spaces in Their Leisure-Time

Abstract: Educational buildings are not only limited to educational activities but also serve as environments for interaction and socialization. This study investigates the potential of social sustainability of the Faculty of Architecture building at Çankaya University by examining how its educational and social spaces are used outside formal class hours. The data mainly focused on the visiting frequency and the length of stay of 46 undergraduate interior architecture students. The results illustrated that among the educational spaces, studios were the only spaces with frequent visits and long visit durations. Among the social spaces, the cafeteria was the most frequently used social place on a daily basis. Therefore, as spaces other than these two are almost never used, it can be argued that the facilities within the faculty are insufficient in terms of social sustainability. These findings underline the importance of rethinking existing spaces to enhance social sustainability.

Keywords: social sustainability; higher education environments; educational spaces; social spaces; space utilization

Introduction

Sustainability has been one of the most discussed topics of the past century, but the social dimension still requires further research. In particular, the theme of social sustainability has been relatively under-explored in higher education indoor spaces. Faculty buildings not only host educational activities but also structure students' daily social lives, shape their sense of belonging, and influence their well-being and culture of collaboration (Matthews et al., 2011; Strayhorn, 2018). Educational and adjacent social environments are often used spaces beyond class hours, where students exchange ideas, develop projects, learn from their peers, and engage in creative exchange. Therefore, the importance of social and educational needs in educational buildings may contribute to achieving socially sustainable environments.

This study examines a newly designed faculty building at Çankaya University in Ankara, Türkiye, home to architecture-based departments, to evaluate its capacity to foster socially sustainable student environments. We treat the frequency and manner of students' leisure-time use of educational and social spaces as a proxy for social sustainability: when spaces enable gathering, lingering, and interaction, social sustainability is strengthened. However, it remains unclear whether students perceive educational spaces such as studios as suitable for social use outside scheduled hours, or whether they compensate for potential shortcomings elsewhere. Focusing primarily on undergraduate students, we employ a user-centered survey to capture usage tendencies across two interior space groups, educational and social, including visiting frequency, the time spent. Accordingly, the study seeks to clarify how students use these spaces, why they choose them, and to what extent the building meets their social needs beyond class hours.

Literature Review

The social dimension of university environments is increasingly recognized as important as the educational dimension (Strange & Banning, 2001; Temple, 2008). Social sustainability in faculty buildings can be read through opportunities for students to gather, spend time, and interact (Matthews et al., 2011). Studies on informal learning and third places indicate that flexible, welcoming, and accessible semi-public interiors invite peer interaction, whereas studios, while effective for focused creation, often limit social use through time rules and ergonomic constraints (Lee, 2022; Salih et al., 2024). The term “third place” was first used by Oldenburg & Brissett (1982) to describe a public space where people can socialize in spaces such as a library, coffee shop, restaurant, etc. Oldenburg (1997) asserts that third places enhance people's quality of life by offering areas for relaxation, social interaction, emotional release, and escape from everyday life. Therefore, creating and utilizing third places on university campuses, among the most important places in students' lives, is crucial for meeting their social needs.

When semi-public third places are absent or insufficient, students often repurpose educational spaces such as studios and classrooms as de facto third places. Therefore, faculty interiors do more than host classes; they shape students' daily social life by supporting informal learning, peer support, and identity formation (Matthews et al., 2011; Strange & Banning, 2001; Temple, 2008). In design education, studio environments are central and often used after hours, and these extended practices sustain creativity and success (Boyer & Mitgang, 1996). Psychologically supportive studios and campuses are also associated with better learning experiences and outcomes in architecture, interior architecture, and urban planning (Boyer & Mitgang, 1996; DiasBroens et al., 2024). Therefore, examining social sustainability in educational interiors, especially in design schools, addresses a core condition of student learning beyond scheduled class time.

When evaluating social sustainability through behaviors, focusing on visit frequency and length of stay provides a baseline for how socially a space is being utilized. Higher visit frequency indicates that places are preferred more (Webb et al., 2008), while longer stays point to comfort and social support (LeGrow et al., 2023; Min & Lee, 2020). Thus, visit frequency and length of stay serve as concise behavioral traces for comparing the social sustainability of educational and semi-public spaces.

Methods

This study examines social sustainability in the context of higher education environments by focusing on how students use and engage with faculty interiors during their leisure time. Accordingly, a user-centered survey was conducted at a single site, the Faculty of Architecture building at Çankaya University in Ankara, Turkey.

The Faculty of Architecture building is a six-story structure, extending from the basement level (-1) to the fourth floor. Except for the basement, the floors share a similar layout: a main corridor connects studios, lecture halls, personal computer (PC) laboratories, elevators, and staircases, while a secondary corridor leads to academic and administrative offices. The basement hosts a cafeteria and lecture halls shared with the Law Faculty. In addition, the building includes an indoor tiered seating space between the first and second floors, and an outdoor tiered seating space between the ground and first floors.

For the study, the building's spaces were grouped into two categories: educational and social (Table 1). Educational spaces include studios, lecture halls, computer laboratories, and classrooms, which are primarily designed for formal instruction but also available for use outside class hours. Studios are equipped with standard drawing tables and stools, lecture halls and PC laboratories are furnished with chairs and fixed desks, and classrooms feature chairs with folding writing tablets. Except for the PC laboratories, all educational areas are accessible only during working hours (between 09:00 and 17:00) and are locked outside this time range.

However, certain studios are available for student use outside class hours upon reservation. PC laboratories are accessible only when classes are being held.

Table 1. Categories of spaces in the Faculty of Architecture building

Educational Spaces	Social Spaces
Studios	Outdoor spots at building entrances
Classrooms	Corridors
Lecture Halls	Cafeteria
Computer Laboratories	Outdoor seating area with fixed stools
	Outdoor tiered seating
	Indoor tiered seating

Social spaces, on the other hand, were grouped into two: indoor and outdoor. Indoor social spaces consist of corridors and a tiered space. Corridors varied across floors: some included no seating at all, while others offered single chairs placed side by side. Outdoor social spaces included building entrances with one or two seating units, as well as the common area with fixed stools located between the entrances of the Law Faculty and the Faculty of Architecture. While the cafeteria serves only during working hours, all the remaining areas are always accessible.

The instrument for the main study was designed to capture students' demographics, using tendencies for educational and social spaces. Demographic items recorded class year, gender, and age. For using tendencies, respondents reported how frequently they visit the spaces, and how much time they typically spend at each visit. For the frequency of visiting spaces, the answer options are listed as "never", "rarely (1– 2 times a month)", "sometimes (1–2 times a week)", "often (3–4 times a week)", and "very often (almost every day)". Options for the time spent at each visit are listed as "never", "less than 15 minutes, 15 minutes – 1 hour", "1–3 hours", "more than 3 hours".

The participants consisted of 46 undergraduate interior architecture students across all four class years, including 11 males and 35 females (M=23, SD=1.94, range 20-28). Participation was restricted to volunteer individuals aged 18 or older who approved an informed consent statement that appeared at the beginning of the survey. The participants were recruited through a snowball sampling method. The questionnaire was initially distributed to a small group of students, who then shared the link with their peers. The questionnaire was prepared through Google Forms, and the data collection was administered in the summer term from 18 to 25 August 2025. We examined the frequencies of visiting time and the time spent at each visit, using Jamovi (version 2.6.26.0).

Findings and Discussion

Educational Spaces

The data related to visiting frequency showed that, at least once a week, students use studios (71.7%), classrooms (26.1%), lecture halls (15.2%), and PC laboratories (2.2%) in their leisure time (Figure 1). They reported that, apart from studios, none of them visited educational spaces almost daily. Moreover, more than half of the students reported never using classrooms (58.7%), lecture halls (67.4%), and especially PC laboratories (91.3%).

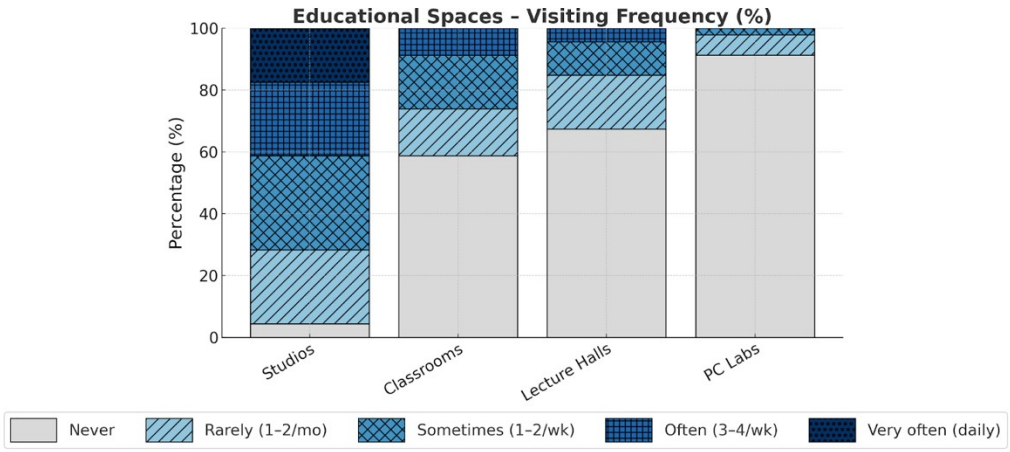

Figure 1. Visiting frequency of educational spaces during students' leisure time.

The time spent at each visit revealed that studios (28.3%) were the only educational spaces where students spent more than three hours at each visit (Figure 2). When we grouped the options into three categories: no visit, short visit (less than an hour), and long visit (more than an hour), a majority of students stayed in studios for long visits (54.4%) as well as for short visits (41.3%). On the other hand, students preferred short visits in classrooms and lecture halls instead of long visits.

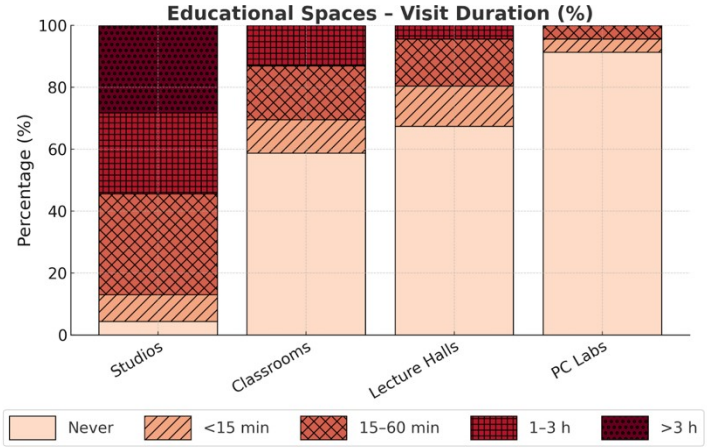

Figure 2. Visit duration of educational spaces during students' leisure time.

When visiting frequency and duration are considered together, students perceive studios as the most suitable educational spaces for both working and socializing (Salama & Wilkinson, 2007). In contrast, classrooms and lecture halls do not provide the same level of usability beyond teaching hours. The fact that computer laboratories are locked outside of class hours results in a low use rate. Besides, the design-oriented workload of architecture-related departments might explain why studios were the educational spaces most frequently visited and occupied for the longest periods. Students are likely to rely on the large tables in studios to carry out design-based drawings and projects that require activities such as drawing, cutting, and pasting (Scupelli & Hanington, 2016).

Social Spaces

When we merged the week-based options related to visiting frequency, the cafeteria (95.7%) was the most frequently visited space, among the social spaces, followed by corridors (76.1%), outdoor spots near the entrances (69.6%), outdoor stools (67.4%), and the outdoor tiered seating area (63.1%) (Figure 3). The indoor tiered seating area was the least preferred, with only 23.9% of the students. On the other hand, daily use patterns highlight that 58.7% of students visit the cafeteria daily. This trend is considerably higher than for any other social space. Analysis of no visits demonstrated that the indoor tiered seating area (41.3%) was the most unvisited social space, nearly twice that of the second, the outdoor tiered seating area (21.7%).

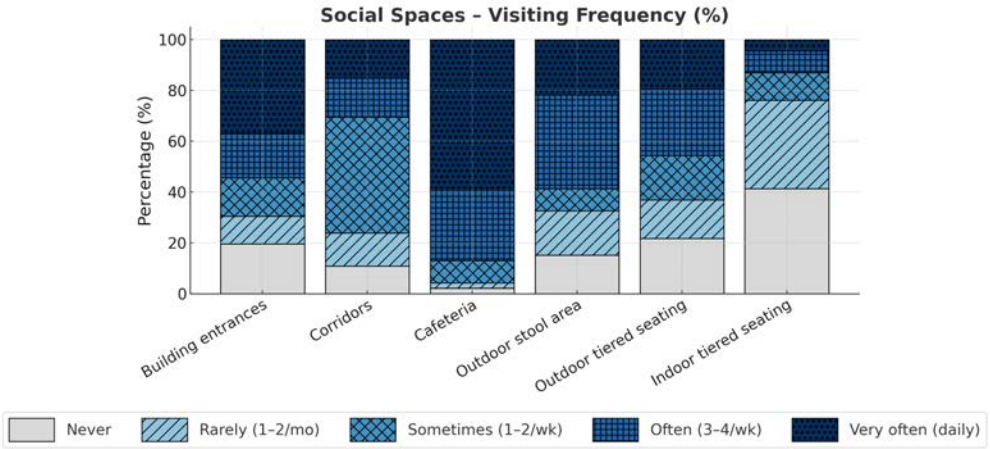

Figure 3. Visiting frequency of social spaces during students' leisure time.

Regarding visiting durations, the cafeteria (56.5%) was the primary social space where students spent more than one hour (Figure 4). However, in all other social spaces, at least half of the students reported visits shorter than one hour.

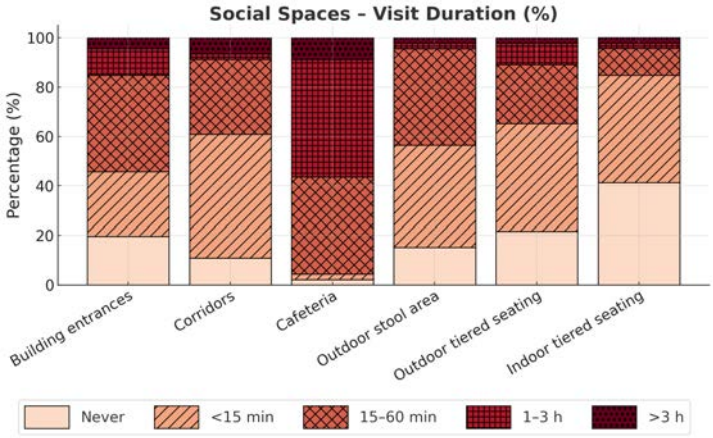

Figure 4. Visit duration of social spaces during students' leisure time.

From the results, we may suggest that the cafeteria dominates as the central social environment, while the other social areas remain secondary, serving primarily as short-stay places (Bahha, 2025). The low use of outdoor and indoor tiered seating might indicate that their design intentions do not align with students' needs. Our observations reveal that the scores given to the spaces might be related to seating arrangements. For example, students might have preferred using the cafeteria most, as it featured a face-to-face seating arrangement that contributed to social interaction (Sommer, 1969). On the contrary, the inadequacy of seating and working areas, as well as side-by-side seating layout, may discourage social interaction (Mehrabian & Diamond, 1971), and this might explain students' low ratings for the remaining social spaces, such as corridors and tiered seating areas.

Conclusion

This study examined how educational buildings that accommodate architecture-based departments contribute to social sustainability by focusing on students' leisure-time use of spaces. Findings revealed that studios were the only educational areas to support frequent and long visits, reflecting their key role for students in design-oriented tasks. Among social spaces, the cafeteria dominated daily use, probably due to seating arrangements that facilitated face-toface interaction. These results contribute to the limited literature on social sustainability in

campus buildings, focusing on students' leisure time use. Further research may reveal an expanded knowledge about students' motivations, purposes of use, and sense of attachment. Such insights would provide a deeper understanding of how educational interiors can foster socially sustainable learning environments beyond class hours.

Acknowledgments

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URBAN IDENTITY, PLACE ATTACHMENT, AND SOCIAL SUSTAINABILITY: THE CASE OF HASANPAŞA NEIGHBORHOOD

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Urban Identity, Place Attachment, and Social Sustainability: The Case of Hasanpaşa Neighborhood

Abstract: This study explores the interconnections between urban identity, place attachment, and social sustainability through the case of Hasanpaşa Neighborhood in Kadıköy, Istanbul. Historically shaped by recreational, agricultural, and industrial activities around Kurbağalıdere, Hasanpaşa has undergone significant spatial transformation, resulting in weakened ecological ties, loss of collective memory, and erosion of residents' sense of belonging. Drawing on a qualitative methodology that combines literature review, field observations, and spatial analyses, the research examines how urban identity and place attachment are disrupted by industrialization and urbanization. The study argues that re-establishing social and ecological connections in public spaces can revitalize collective memory and reinforce urban identity. The restoration of the Hasanpaşa Gasworks as a cultural facility illustrates the potential of adaptive reuse in strengthening social sustainability. Ultimately, the study proposes that redesigning Kurbağalıdere as an accessible, multifunctional ecological corridor can foster belonging, resilience, and shared urban identity while reconnecting the neighborhood with its cultural and natural heritage.

Keywords: urban identity, place attachment, social sustainability, Hasanpaşa.

Introduction

Social sustainability refers to the sustainability of cities in environmental and economic terms, and with elements such as social bonds, justice, belonging, and quality of life. Urban identity and place attachment stand out as the fundamental components of this process. Place attachment encompasses individuals' emotional, cultural, and social ties, while urban identity reflects their collective materialization.

In this context, the study's primary purpose is to conceptualize social sustainability, urban identity, and place attachment through urban public spaces and discuss their relationships through a case study. More specifically, the study examines how spatial transformations in Hasanpaşa Neighborhood affect collective memory and residents' sense of belonging, aiming to propose spatial strategies that can strengthen social sustainability and support the reconstruction of urban identity, particularly through the revitalization of Kurbağalıdere and the adaptive reuse of the Hasanpaşa Gasworks. This approach can also be evaluated as an effort to redefine and preserve urban identity's fundamental values.

In Turkey, although there are academic studies on urban identity, place attachment, and social sustainability, examining these concepts with the concrete transformation processes in urban public spaces is limited. The literature highlights a lack of sufficient studies, particularly at the neighborhood scale in Istanbul, that address ecological and cultural values together from the perspective of social sustainability. To address this gap, this study examines Hasanpaşa as an exemplary neighborhood.

Hasanpaşa was selected due to its historically layered structure and the spatial experiences that reveal the transformation of urban identity. The recreational, agricultural, and industrial activities that once developed around the Kurbağalıdere River shaped the lifestyle and collective memory of the residents; however, processes of industrialization and urbanization have weakened these ties. Accordingly, the research questions have been formulated as follows:

- How can the concepts of urban identity, place attachment, and social sustainability be associated in the Hasanpaşa?
- How has the spatial transformation around the Kurbağalıdere affected the residents' sense of place attachment and belonging?
- Regarding social sustainability, which design, and planning strategies can strengthen the place identity in and around the Kurbağalıdere?

Method

In the study, the concepts of social sustainability, urban identity, and place attachment are first addressed, and the relationships between these concepts are explained to establish the theoretical framework of the research. Subsequently, these relationships are examined through the analysis of the Hasanpaşa Neighborhood. In this analysis, which is structured based on the qualitative research method, the data collection techniques employed are literature review (articles, theses, and reports), field observation (February 3 – March 6, 2025), and spatial analyses (IMM maps, Kadıköy Municipality website, Beyoğlu Archive, Google Earth-Maps).

The methodological framework was designed in alignment with the study's aim of proposing spatial strategies. Each method was selected to provide insights for the research questions presented above. The literature review established the conceptual basis for analyzing social sustainability, urban identity, and place attachment. Field observations documented the underuse of public spaces and the weakening of residents' everyday connection with Kurbağalıdere, while spatial analyses revealed physical transformations and fragmentation in the neighborhood. These combined findings not only describe the current situation but also provide the empirical ground for developing the spatial strategies.

Theoretical Framework

The Latin-origin concept of *genius loci* was first used by the Romans. In the 1980s, Norberg-Schulz explored this concept in his work *Genius Loci: Towards a Phenomenology of*

Architecture, examining the identity of places, human experiences, and their relationships with space. The concept of *genius loci* (the spirit of a place) is significant in this context, suggesting that the identity of a place is shaped through the meaningful relationships that individuals establish with nature and space. Lynch (1960), in his work *The Image of the City*, identified five fundamental elements — paths, edges, districts, nodes, and landmarks — that ensure the legibility and memorability of cities, emphasizing their decisive role in shaping collective urban identity.

The formation of urban identity also entails the concept of "place attachment" which involves establishing emotional and social bonds of residents to a specific space. Williams and Stewart (1998) define place attachment as the sum of meanings, symbols, values, satisfaction, loyalty, and emotions that individuals or communities associate with a particular space. This definition reveals that the relationship between the resident and the place gains depth in physical, emotional, cultural, and social dimensions. When a resident can express themselves in a space, their relationship with that space is strengthened; this relationship reinforces both individual belonging and collective identity.

Urban identity is directly related to place attachment at individual and collective levels. This relationship strengthens both individual belonging and social identity. However, as Manzo and Perkins (2006) point out, place attachment does not always produce positive outcomes; excessive attachment can lead to negative situations such as spatial conflicts or resistance to innovations.

Understanding the relationship between social sustainability, urban identity, and place attachment (Figure 1) is critical for evaluating the social impacts of spatial planning and design. Social sustainability encompasses environmental protection and economic development goals and elements such as justice, equity, belonging, social cohesion, and quality of life (Oktay, 2009). Developing a sense of place attachment increases individuals' motivation to protect, improve, and maintain social values in their living environment.

Figure 1. Concept map illustrating the relationship of the city with other contexts. (created by authors).

Public spaces are the areas where urban identity and place attachment are most visibly manifested. In the form defined by Habermas (1994), the public space consists of spatial arrangements open to all citizens to exchange ideas and social interaction. Squares, parks, waterfront areas, and pedestrian axes directly contribute to strengthening social sustainability as carriers of urban identity. Squares, which are defined as voids that provide breathing space for cities, can be designed as areas where social awareness and resilience emerge and a vibrant and enjoyable urban life takes place. As Erzen (2021) notes in his book *Urban Life*, parks, campuses, cafés, and public spaces are physical components that bring together social sustainability, identity, and place attachment in the city. These open spaces gain meaning through the residents' relationship with the place and, over time, transform into elements that sustain social sustainability.

Case Study: Hasanpaşa

Within the scope of this study, the concepts of urban identity, place attachment, and social sustainability were addressed at a theoretical level, and these relationships were discussed in a spatial context specifically for Hasanpaşa, which is in the Kadıköy district of Istanbul (Figure 2). The transformation process the area has undergone from past to present demonstrates how the bond between residents and space has weakened; this situation makes the problems arising in terms of social sustainability more visible. Therefore, Hasanpaşa is considered a qualified case area that should be examined regarding the reconstruction of urban identity and the strengthening of place attachment.

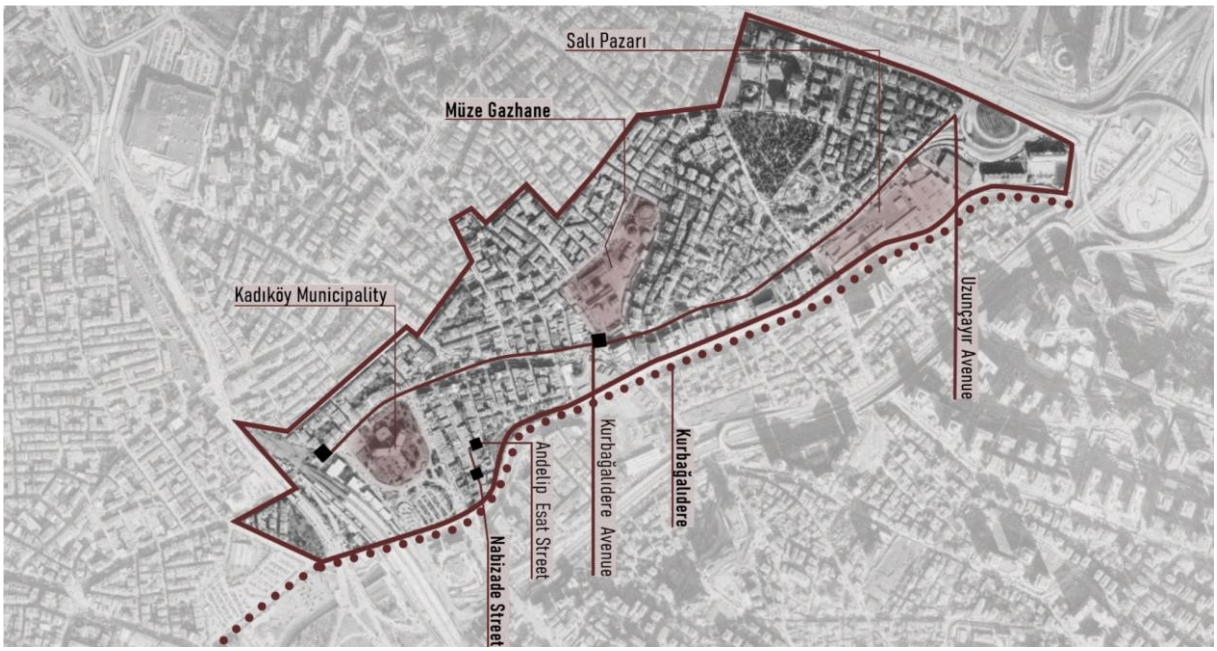

Figure 2. Hasanpaşa at 1/1000 scale (Base map: Google Earth, 11 February 2025, edited by authors).

Hasanpaşa: From Past to Present

Hasanpaşa (Figure 2) is one of the oldest settlements of Kadıköy and possesses an important settlement fabric that shapes Kadıköy's urban identity in historical, cultural, and sociological dimensions (Önen, 2007). The neighborhood was formed through recreational and agricultural activities developed around Kurbağalıdere; over time, these relationships became fundamental elements determining the residents' lifestyle and social interaction patterns. The relationship established with the area was not limited to a physical interaction but also contributed to forming a sensory, emotional, and cultural memory.

However, this historical continuity was interrupted by the process of industrialization. Consequently, the strong bond between the local population and the natural environment weakened over time and was severed mainly (Öncü, 1997). This situation caused ecological destruction and led to the erasure of social memory and the transformation of urban identity. The residents ' attachment to place has been damaged by the rapid destruction of the spirit of place and spatial memory (Relph, 1976; Norberg-Schulz, 1980). Familiarity with the physical environment, shared collective memory, and cultural assets have been, in a sense, exploited.While many residences have not survived, some were registered and restored. The location of the mentioned registered buildings includes structures starting from the boundaries

of Nabizade Street, which lies north of Kurbağalıdere, and continuing along Kurbağalıdere Street (Figure 2). The forgetting and succumbing to the industry of such important spaces that constitute the "spirit of place" (Norberg-Schulz, 1980) have undermined the residents' attachment and belonging to the place.

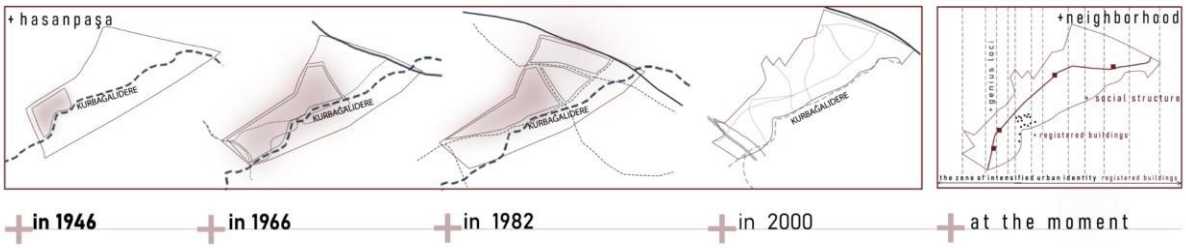

Figure 3. Maps illustrating the transformation of Kurbağalıdere's interaction with the neighborhood.

Indeed, as emphasized by Williams and Stewart (1998), place attachment is constructed through the meanings, values, and emotions individuals attribute to a particular space. The severing of this bond leads to a weakening of belonging at the individual level and the erosion of collective urban identity. The settlements in the area gradually developed around the stream to meet agricultural needs (Figure 3). This, in turn, led to the formation of collective memory between the stream and the residents. As new needs emerged, the neighborhood transformed along with new axes.

With the improved transportation, urban opportunities increased, and the migration rate to the area rose proportionally. With migration, the city developed in the industrial sector, increasing employment opportunities. Along with industrialization, a gasworks was established in the city to meet its energy needs. The gaswork established in Hasanpaşa, while contributing to the city's development on one hand, on the other hand caused a weakening of residents' attachment to the space and to Kurbağalıdere, which forms a fundamental part of the city's natural fabric (Mazbaşı Berktay, 2012). This weakened relationship between Kurbağalıdere and the residents significantly undermined the city's original fabric, sense of place attachment, and spatial memory of the past (Figure 4).

Figure 4. Collage illustrating the urban memory of Kurbağalıdere.

As the ecological corridor—comprising recreational and public spaces that sustain urban integrity, cultivate a culture of shared use, and maintain internal continuity—weakens and its social use is curtailed, the result is not only physical fragmentation but also an erosion of residents' sense of belonging. Such disruption weakens urban identity and reduces residents' sense of security and ownership. Because residents find it difficult to attach to spaces where they do not feel safe, cannot easily access, or struggle to make sense of, directly affecting their quality of life.

Recalling Memory and Traces

The reactivation of the ecological corridor around Kurbağalıdere and ensuring its meaningful interaction with the residents can enable the integration of values carrying traces of the past with contemporary needs. Such spatial and emotional reconnection is not limited to a physical restoration; it will also contribute to forming a new social memory and strengthening residents' sense of attachment to the place.

As expressed in Norberg-Schulz's (1980) concept of "genius loci," the identity of a place is shaped by meaningful relationships established with its natural, cultural, and historical characteristics. In this context, new forms of interaction established with Kurbağalıdere will allow the transformed urban identity of Hasanpaşa to reintegrate with the natural environment, offering significant opportunities in terms of social sustainability. Thus, the interaction between the city's open spaces and different user groups will revive its memory, creating a basis for an identity compatible with its historical and cultural roots. Strengthening urban

identity in this way will enhance residents' attachment to public space while reinforcing their psychological sense of security regarding the space.

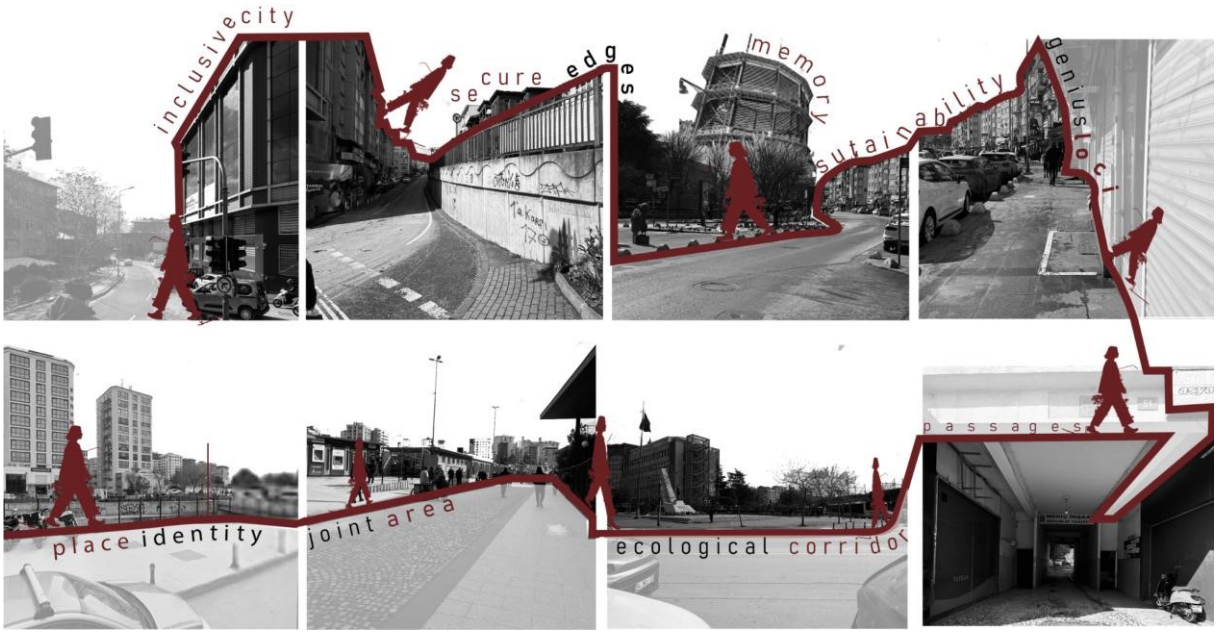

Figure 5. Collage illustrating the relationship between the city's edges and its residents.

Field observations also revealed that the potential of the city has been neglected. As residents' interactions with this area were observed (Figure 5), it was found that open spaces were largely unused, and that residents felt, and even acted, as strangers to the place. The social and ecological connections once embodied by Kurbağalıdere have gradually receded from residents' everyday lives. In particular, the function of Hasanpaşa as a transitional zone around

Kurbağalıdere has led to a loss of the area's depth of meaning and altered its connection with memory. However, attachment, trust, and awareness of shared use lie at the core of social sustainability. In the case of Hasanpaşa, the inadequacy of spatial arrangements has hindered the development of these fundamental elements. As expressed in Lynch's (1960) concept of "urban continuity," when the dialogue between residents and space weakens, continuity is disrupted, and the space loses its capacity to generate meaning. In this context, the Hasanpaşa Gasworks example constitutes an important reference for re-establishing this continuity.

Built during the Industrial Revolution to meet the gas needs of the area, the Gasworks gradually lost its function and became an abandoned structure, facing erasure from urban memory. However, with the restoration and reactivation process that began in 2014, the

Gasworks was reintroduced to the residents as a museum and community center (Müze Gazhane); this transformation reconstructed the place's position within collective memory. The

Gasworks example demonstrates that a physical structure can carry not only functional but also symbolic value, and that it can become a spatial representation of social memory.

Figure 6. Storyboard illustrating the proposed ecological corridor for Kurbağalıdere.

Similarly, the rehabilitation and landscaping works to be carried out around Kurbağalıdere, transforming the area into an accessible, safe, and multifunctional "public space," can contribute to revitalizing the city's lost memory. Within the scope of these works, it is crucial to integrate residents into the process and to establish a designer–resident network (Figure 6). The active participation of residents in the design process accelerates the sense of attachment and trust toward public spaces, thereby positively contributing to the development of urban identity. Public space is open to all citizens, providing opportunities to form public opinion within the city (Habermas, 1994). In this context, offering such opportunities to the users of Kurbağalıdere also enables the continuity of the city.

Water gives identity to cities; due to changing living conditions (industrialization, migration, population growth, etc.), the city begins to shape water with identity elements derived from artificial and human-made environments (Önen, 2007). The water resource, which transforms along with the city, also changes proportionally in relation to the connection it establishes with the residents. Therefore, rehabilitation works necessary for reviving the stream's collective memory are crucial. In this way, the ecosystem along the stream will be revitalized, supporting biodiversity and improving water quality. Furthermore, by opening

Kurbağalıdere —an element that holds a significant place in the formation of Hasanpaşa's urban identity—to the public, the city's memory will be substantially revitalized, and a sense of shared use will be established.

Reconstructing the lost collective memory in Hasanpaşa will be possible through new spatial configurations that establish connections with the past. As expressed in Nora's (1984) concept of "sites of memory", certain places can transform into symbolic spaces that carry the collective memory of society. Integrating the collective usage potential that Kurbağalıdere offered in the past with today's social needs can create a physical, cultural, and social continuity.

Just as in the transformation of the Gasworks, restoring Kurbağalıdere for the residents will strengthen their sense of belonging, contributing to a safe, shared, and sustainable urban life.

Conclusion

This study examined the concepts of social sustainability, urban identity, and place attachment through the case of Hasanpaşa, investigating the effects of spatial transformation on collective memory and belonging. The Hasanpaşa example demonstrates that cities are shaped not only by physical but also by emotional and cultural connections. Kurbağalıdere, historically a natural focal point, has gradually lost its ecological and social bonds; this disconnection has weakened the relationship between residents and their environment. However, as demonstrated by the Müze Gazhane example, such spaces can be revitalized through appropriate interventions, restoring collective memory and supporting social sustainability. In this context, redesigning the area surrounding Kurbağalıdere should be approached as a physical improvement and a social restoration process. Such an approach will contribute to reconstructing an urban identity that simultaneously connects with the past and fosters a sense of belonging and trust toward the future.

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SUSTAINABLE PLAYGROUNDS: AFFORDANCE-BASED APPROACHES TO DESIGN AND PLAY ENGAGEMENT

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Sustainable Playgrounds: Affordance-Based Approaches to Design and Play Engagement

Abstract: This paper argues that sustainability in playground design must go beyond material efficiency to encompass the capacity of play to remain meaningful over time. Drawing on the "Affordance Theory" (Gibson, 1979), play theories, and Csikszentmihalyi's (1990) concept of flow, the study develops a framework for *sustainable play*. This paper emphasizes how spatial affordances such as exploration, social interaction, risk-taking, and multi-functionality can sustain participation in children's environments. Findings highlight that adaptable and open-ended affordances foster long-term engagement in play, also support ecological, social, and economic sustainability. The paper concludes by framing playgrounds as play infrastructures that support both child development and a sustainable urban future.

Keywords: sustainability; affordances; playground design; play engagement; urban design

Introduction

The design of children's playgrounds is an increasingly important topic in current discussions on sustainable urban design. Although sustainability is often associated with ecological measures such as using durable materials, improving energy efficiency and increasing recyclability, these strategies alone do not guarantee that play opportunities will remain engaging over time. A playground built with recycled materials may appear environmentally responsible, but if children quickly lose interest, its developmental, social and economic sustainability is questionable.

In cities, playgrounds function as rare environments where children can experience autonomy, creativity, and social interaction outside of school or home (Hughes, 2011). However, many remain standardised, mono-functional and rule-bound, thereby limiting developmental opportunities and necessitating costly renewal (Moore & Cosco, 2007). As emphasised in United Nations Sustainable Development Goal 11, urban environments must provide inclusive, safe and resilient spaces (United Nations, 2015). Nevertheless, child-centred play environments are frequently overlooked in such discussions, which tend to prioritise infrastructure or energy systems.

This paper argues that playgrounds can only be considered sustainable if they encourage play sustainability. To address this, it introduces a conceptual approach that integrates affordance theory, play theories, and flow psychology. This approach emphasises spatial-functional affordances, such as exploration, social interaction, risk-taking and multi-functionality, which encourage participation, inclusivity, and resilience. By connecting

theoretical insights with historical developments, the paper redefines playgrounds as essential infrastructures of play for sustainable cities.

Literature Review

An interdisciplinary approach is needed for the concept of sustainable play requires. Insights from ecological psychology, developmental play theories, and motivational psychology. This section reviews the key theoretical approaches that provide the basis for the proposed framework. First, it examines affordance theory and its application to children's environments. Then, it considers how classic play theories explain the developmental and cultural value of play. Finally, it integrates psychological perspectives such as flow and self-determination to explain how environments sustain engagement over time.

Affordance Theory and Play

James Gibson (1979) introduced the concept of affordances. He defined affordances as the possible actions offered by the environment in relation to an individual's abilities. According to Gibson affordances are relational, they emerge through interaction between the environment and the individual, rather than existing in either alone. This ecological perspective is particularly pertinent to children's play, where abilities, motivations, and environments are in a constant state of mutual shaping one another.

Following on Gibson's work, Heft (1988) proposed functional categories such as 'climbable', 'jumpable', and 'hideable'. The categorization shift the focus from adult-defined classifications (e.g. 'slide' or 'swing') towards children's experiential understanding of space. Kylä (2004) expanded this framework by differentiating between potential and actualised affordances by emphasising that opportunities only become meaningful when children can access them independently. Independent mobility, therefore, plays a crucial role, though it is often limited in urban environments.

Aldo van Eyck's post-war playgrounds in Amsterdam represented their principles even before any of these theories were formally outlined. He designed over 700 small playgrounds between 1947 and 1978. Each playground used simple elements such as sandpits, stepping stones, and climbing domes. These play elements could be interpreted in multiple ways by children. His work showed that minimal forms could instead stimulate discovery, cooperation, and creativity. In this sense, Van Eyck's approach anticipated ecological psychology, showing how affordances could be designed to invite interpretation and sustain engagement.

Nicholson's (1971) Theory of Loose Parts further reinforced this perspective. He argued that the richness of play environments depends on the variety of manipulative elements they contain. Loose parts, such as sand, sticks, crates, and recycled materials, are open-ended by nature, offering many possibilities for construction, role-play, and experimentation. Significantly, loose parts promote sustainability as they utilise natural or recycled materials, thereby broadening play opportunities while minimising ecological impact.

The developmental role of risky play was underlined by Sandseter (2009), who showed that opportunities for managed risk can stimulate excitement, mastery and resilience. Similarly, Brussoni et al. (2015) demonstrated that risk-taking during play encourages long-term participation and well-being in children. Also, emphasize the importance of taking on risky opportunities for sustained engagement.

These studies show that affordances are not permanent components of equipment. Instead, they are considered as dynamic opportunities shaped by accessibility, context, and social interaction.

Play Theories

Classic play theories demonstrate the importance of affordances. Huizinga (1955) described play as a voluntary cultural activity defined by freedom within boundaries, and he highlighted how environments help set the conditions for play. Four categories were identified by Caillois (1961): agon (competition), alea (chance), mimicry (role-playing) and ilinx (vertigo). Each of these categories requires specific environmental support. Climbing walls, for instance, can encourage agon through competition, while spinning devices can embody ilinx by providing experiences of dizziness and exhilaration.

Vygotsky (1978) emphasised play as a 'zone of proximal development', in which symbolic and social activities extend children's abilities beyond their current level. Sutton-Smith (1997) later emphasised that risk, uncertainty and ambiguity are essential for play's developmental value. Gray (2013) described play as a natural context for autonomy and social negotiation, reinforcing its intrinsic motivational qualities. Lester and Russell (2010) further linked the child's right to play to well-being, underscoring that intrinsic motivation is central to sustained participation. Together, these perspectives highlight that environments are active participants in shaping the forms, meanings, and developmental potential of play. Linked with affordance theory, they suggest that the actual value of a playground lies less in fixed objects than in the variety of play forms its affordances make possible.

Flow and Engagement

Csikszentmihalyi's (1990) concept of 'flow' explains how environments can encourage deep engagement. Flow occurs when the level of difficulty matches the individual's skill level. The flow creates a sense of involvement and an intrinsic motivation. Affordances support flow by adapting to children's abilities and levels. For instance, a climbing dome may offer a simple ascent for beginners and a balancing challenge for more experienced children. Loose parts enhance this adaptability, enabling children to create their own levels of challenge (Hyvönen, 2008). Flow emerges when environments provide layered, adjustable affordances relating to agility, mimicry or ilinx. Vygotsky's notion of proximal development is similar, showing that engagement is sustained when challenges are stretching but not overwhelming for children.

Recent studies have connected flow to Self-Determination Theory (Deci & Ryan, 2000), which identifies autonomy, competence, and relatedness as core needs. Amholt et al. (2022) show that playgrounds which support choice, challenge, and social connection enhance children's well-being. Fredricks, Blumenfeld, and Paris (2004) emphasized that emotional and cognitive engagement depend on the richness of opportunities. They highlighted that such opportunities link play affordances to sustained motivation. Prins (2022) illustrated how inclusive play spaces support social sustainability. He showed that their design fosters cooperation and dialogue. Therefore, affordance-rich, flow-supporting environments meet psychological needs and reinforce developmental value and sustainability.

Methods

This paper adopts a conceptual methodology that combines literature synthesis with comparative case analysis. Ecological psychology (e.g., Gibson, 1979; Heft, 1988; Kyttä, 2004), developmental psychology (e.g., Vygotsky, 1978; Sutton-Smith, 1997), and sustainable design (e.g., Moore & Cosco, 2007; Guy & Moore, 2005) published between 1950 and 2025 were systematically reviewed. Selection criteria focused on studies explicitly addressing affordance theory, game theories, or sustainability in the context of playgrounds.

The analysis followed a thematic approach and identified four recurring affordance categories: exploration, social interaction, risk-taking, and multi-functionality. To strengthen the theoretical synthesis, case studies were selected to demonstrate how these affordances manifest in practice.

The selection was based on three criteria. The first one is the significance in academic and design literature, second one is geographical and cultural diversity, the last one explicit

inclusion of sustainability in the play. These case examples include both historical precursors and contemporary community- and ecology-focused playgrounds.

This integrated methodology aims not only to produce empirical generalizations but also to establish a conceptual framework for *sustainable play*. The analysis, which combines theoretical literature with practice-based examples, demonstrates how affordance theory, play theories, and flow psychology intersect with sustainability principles. This approach provides a basis for rethinking play spaces as play infrastructures that adapt to children's developing abilities in alignment with ecological and social goals.

Findings and Discussion

Thematic analysis has identified four fundamental spatial-functional affordances that support play engagement and sustainability. These are categorized as exploration, social interaction, risk-taking, and multi-functionality. These categories are interrelated and emphasize that affordances go beyond physical equipment to create developmental, social, ecological, and economic value.

Exploration opportunities support children's curiosity and sense of discovery. As Heft (1988) pointed out in his study, features found in natural topography, vegetation, and natural paths invite activities ranging from climbing to hiding. When these natural elements are renewed over time, they keep play experiences renewed, reduce the need for constant new installations, and connect children's exploration directly to principles of ecological sustainability. Exploration provides strong motivational value by offering autonomy and novelty, both of which are key drivers of intrinsic engagement (Deci & Ryan, 2000; Gray, 2013). Hyvönen (2008) showed that when children can adapt their challenges to their abilities, affordances in play sustain flow. In this sense, natural exploration settings connect with ecological sustainability and continuously renew children's motivation to engage.

Social affordances emphasise the importance of environments in encouraging cooperation, group play and multigenerational interaction. Kylä (2004) demonstrated that realised affordances depend on accessibility and children's freedom to use spaces together. Community-oriented playgrounds show how design can encourage collaboration, as children work together to build and shared features like modular seating or shaded areas invite gathering and conversation (Prins, 2022). These social affordances strengthen inclusivity and foster a sense of community, making them an important part of social sustainability. From a motivational perspective, play that encourages social bonding sustains participation by

fulfilling children's psychological need to belong (Deci & Ryan, 2000; Amholt et al., 2022). Also Lester and Russell (2010) in their study emphasized that children's right to play is fundamentally linked to the well-being and intrinsic motivation. Similarly, Gray (2013) stated that play is a natural setting in which autonomy and social negotiation skills are developed, thereby maintaining children's attention constantly. By encouraging shared experiences (Fredricks, Blumenfeld & Paris, 2004), social opportunities ensure that play areas remain engaging and inviting over time.

Risk-taking opportunities are crucial for developing competence, allowing children to test their limits, build resilience, and gain confidence through challenges. Sutton-Smith (1997) argued that risk is integral to the developmental value of play. Climbing structures, balancing elements, and loose parts present challenges that foster resilience and develop problem-solving skills. Play environments that incorporate managed risk—such as climbing heights, balancing challenges, or reconfigurable loose parts—enable children to test limits safely. Such affordances enhance competence and resilience while extending developmental and functional sustainability. Also, they maintain motivation by keeping children in the “flow” where their abilities match the challenges of the play (Csikszentmihalyi, 1990; Hyvönen, 2008). While Sandseter (2009) emphasizes that risky play creates excitement and mastery, Brussoni and colleagues (2015) have shown that it promotes resilience and long-term participation in outdoor activities. Whitebread and Basilio (2013) have found that challenging play increases self-control and motivation. All of these studies demonstrate that controlled risk is not only functional but also a motivational source that ensures the sustainability of the play.

Multi-functionality integrates the above categories by affording multiple uses from a single element. Platforms, ridges, or modular structures can afford climbing, sliding, sitting, or gathering, thereby maximizing ecological efficiency (Guy & Moore, 2005). This principle can be observed in urban-scale playgrounds where modular and cultural elements afford diverse forms of play across generations. Aldo van Eyck’s Amsterdam playgrounds also demonstrated how minimal structures could support exploration, cooperation, and risk simultaneously, showing that multifunctional design sustains relevance across time while reducing redundancy. In terms of motivation, multifunctionality prevents boredom by constantly presenting new challenges and interpretations (Mainemelis & Ronson, 2006). Csikszentmihalyi (1990) stated that 'flow' emerges when environments enable layered engagement, and Fredricks and colleagues (2004) emphasised that various play opportunities support emotional and cognitive engagement. By meeting their changing and evolving needs, such as autonomy, competence,

and relatedness (Deci & Ryan, 2000; Amholt et al., 2022), multifunctional designs ensure long-term play sustainability. They achieve this by enabling children to maintain their motivation which keeps children coming back to play.

Across these categories, loose parts represent a transversal affordance. As Nicholson (1971) argued, environments containing manipulable elements offer the widest range of creative play. Loose parts allow for constant reconfiguration and support flow, creativity, collaboration and sustainability, while reducing ecological impact. They form the cornerstone of sustainable play environments by bringing together elements such as exploration, social play, risk-taking, and multi-functionality. Loose parts sustain children's motivation by encouraging improvisation, redesign and creation (Hyvönen, 2008). Gray (2013) defines this type of open-ended play as the foundation of intrinsic motivation, and Mainemelis and Ronson (2006) link playful improvisation to creativity and sustained engagement. Loose parts support autonomy, competence and relatedness simultaneously (Deci & Ryan, 2000; Amholt et al., 2022), and uniquely combine motivation with sustainability, making play meaningful over time.

In summary, the findings indicate that affordances align with sustainability when they:

- Extend developmental relevance by adapting to children's evolving skills (Heft, 1988; Hyvönen, 2008).
- Reduce ecological costs through natural or recycled materials (Nicholson, 1971).
- Strengthen social bonds via cooperation and participation (Kyttä, 2004; Prins, 2022).
- Lower economic costs through modularity and reuse (Guy & Moore, 2005).

Together, these insights reframe playgrounds not as collections of fixed equipment, but as infrastructures of play, where adaptability, inclusivity, and ecological responsibility converge to support sustainable urban futures.

Conclusion

This paper has argued that playground sustainability must be understood not only in ecological or material terms but also in its ability to sustain play itself. By integrating affordance theory, play theories, and flow psychology with sustainable design principles, it developed a framework of *sustainable play*. This approach reframes playgrounds as infrastructures of play that remain relevant across developmental stages, cultural contexts, and generations.

The review of literature and comparative analysis showed that four categories of affordances—exploration, social interaction, risk-taking, and multi-functionality—together with loose parts as a transversal element, offer pathways to inclusive, adaptable, and

ecologically responsible play. Historically, Van Eyck's open-ended playgrounds demonstrated how minimal design could sustain engagement, while more recent approaches continue this trajectory by inviting children into open-ended interaction with their environments.

Theoretically, the framework contributes by linking affordance theory with developmental psychology, particularly Self-Determination Theory, to show how autonomy, competence, and relatedness are supported through affordance-rich environments. Practically, it offers municipalities and designers strategies such as modularity, natural integration, community participation, and flexible materials that reduce costs while enhancing inclusivity and resilience.

Future research should extend this framework by evaluating how children in different cultural contexts perceive and actualize affordances in sustainable play environments. By treating playgrounds as infrastructures of sustainable urban life, cities can align child development with ecological and social resilience, ensuring that play remains a durable, inclusive, and vital component of future communities.

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SUSTAINABLE MORPHOLOGICAL TRANSFORMATION IN A UNESCO WORLD HERITAGE SITE: A SPACE SYNTAX STUDY OF BURSA KHANS DISTRICT

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Sustainable Morphological Transformation in a UNESCO World Heritage Site: A Space Syntax Study of Bursa Khans District

Abstract: This paper examines the morphological transformation of the Bursa Khans District, a UNESCO World Heritage Site, following the 2020 urban design competition. Employing the space syntax method, axial maps for 2020 and 2025 were generated and analyzed using DepthmapX software to calculate syntactic indicators of global integration, local integration, connectivity, and intelligibility. The results reveal measurable improvements: global integration increased from 1.33 to 1.54, local integration from 1.73 to 1.86, connectivity from 3.61 to 4.02, and intelligibility from 0.40 to 0.48. These values were derived through comparative axial line analysis of the street network, reflecting the spatial impacts of design interventions. The findings indicate that the district has become more permeable, accessible, and legible. Beyond numerical analysis, the study interprets these syntactic values through a sustainability framework, linking integration to spatial sustainability, local accessibility to community-centric vitality, connectivity to economic resilience, and intelligibility to cultural continuity. In doing so, the paper contributes to debates on sustainable heritage management, demonstrating how morphological interventions can reinforce the spatial, social, and cultural sustainability of historic city centers.

Keywords: bursa khans district; urban morphology; cultural heritage; sustainability; UNESCO

Introduction

Historic urban centers are widely recognized as carriers of cultural heritage and socio-spatial identity (UNESCO, 2015). Within the framework of the Outstanding Universal Value (OUV), UNESCO World Heritage Sites are protected not only for their architectural or aesthetic qualities but also for their spatial integrity, social functionality, and cultural continuity (Jokilehto et al., 2008). Accordingly, historic urban cores are regarded as living cultural landscapes, simultaneously preserving traces of the past while accommodating contemporary urban life.

The Bursa Historical Bazaar and Khans District, inscribed on the UNESCO World Heritage List in 2014, represents a unique urban ensemble composed of Ottoman-era inns (*han*) and bazaars. As the commercial and social heart of Bursa since the early Ottoman period, the district played a vital role in textile production, silk trade, and civic life. Beyond its economic role, it became embedded in the collective memory of the city as a focal point of cultural heritage and everyday life. However, beginning in the 1980s, changing consumption habits and the rise of new lifestyles reduced the vitality of historic commercial centers. As Vural Arslan (2015) highlights, although revitalization initiatives were introduced, many lacked holistic and integrated approaches that address the physical, social, and economic sustainability of such heritage areas. This fragmented planning has often resulted in overlapping or conflicting interventions, underscoring the need for strategic and comprehensive management models.

In 2020, the "Bursa Historical Bazaar and Khans District – Çarşıbaşı Urban Design Project Competition" was launched by the Bursa Metropolitan Municipality to revitalize the district and enhance its spatial quality and sustainability. The competition aimed to reorganize open spaces, strengthen pedestrian accessibility, and redefine the spatial relationship between historic structures and the surrounding urban fabric (Bursa Metropolitan Municipality, 2020). These interventions have led to a morphological transformation that can be observed between 2020 and 2025.

This study applies the space syntax method, a widely used morphological analysis tool in heritage studies (Hillier & Hanson, 1984). Through axial map analysis, it evaluates changes in global integration, local integration, connectivity, and intelligibility. These syntactic measures are interpreted not only as indicators of morphological change but also as proxies for sustainable cultural heritage management, linking spatial configuration to social, economic, and cultural dimensions of sustainability (Gümüş et al., 2022).

The objectives of this research are threefold. First, it aims to evaluate the morphological changes that occurred in the Bursa Historical Bazaar and Khans District between 2020 and 2025. Second, it seeks to analyze how these changes influenced spatial legibility, accessibility, and socio-economic vitality. Finally, it interprets the findings within the framework of UNESCO's sustainable heritage management principles, thereby establishing meaningful links between syntactic indicators and the various dimensions of sustainability.

Literature Review

Understanding the relationship between urban morphology and sustainability is crucial for evaluating the transformation of heritage sites. Morphological studies, often operationalized through **space syntax**, demonstrate how spatial configuration shapes accessibility, legibility, and conservation outcomes. For instance, studies in Erzurum's historic core revealed a duality between tourist-oriented global integration and resident-oriented local integration, suggesting that heritage areas serve both global and local users (Turgut, 2022). Similarly, analyses in Konuralp underscored the relevance of spatial configuration in developing sustainable conservation strategies (Özkaraca & Halaç, 2021), while research in Cairo's Al-Darb Al-Ahmar and Dubai's Al-Fahidi emphasized how morphological connectivity supports adaptive reuse and cultural resilience (Ibrahim et al., 2025).

At the same time, urban morphology has increasingly been linked with sustainability objectives. Van Nes (2021) highlighted compactness and integration as essential features of

spatially sustainable environments, while Zaleckis et al. (2022) demonstrated that façade interventions in Kaunas altered spatial legibility and cultural sustainability. Liu et al. (2022) argued that visual integrity in Prague's heritage core is vital for maintaining cultural identity, confirming that sustainability involves not only architectural preservation but also the **spatial logic** that underpins cultural continuity and urban resilience.

This connection has also been formally recognized by UNESCO. The *Policy Document on World Heritage and Sustainable Development* (2015) stresses that World Heritage properties should balance environmental sustainability, inclusive social development, and economic viability while fostering resilience and cultural continuity. In the Turkish context, Öksüz Kuşçuoğlu and Taş (2017) emphasized the necessity of integrating community participation, economic viability, and environmental adaptation into conservation strategies. Along similar lines, Gümüş et al. (2022) demonstrated in Istanbul's Historic Peninsula that syntactic measures such as integration and intelligibility can serve as proxies for spatial quality, linking quantitative spatial analysis with qualitative user experience.

Collectively, these studies provide a strong conceptual basis for linking morphological transformation with sustainability, particularly in UNESCO World Heritage Sites where cultural, social, and environmental dimensions must be harmonized. This dual perspective—morphological analysis through space syntax and sustainability-oriented heritage management—forms the analytical framework adopted in this study.

Methods

The research area is the Bursa Khans District, a UNESCO World Heritage Site located in the historic center of Bursa, Turkey. The district consists of a dense concentration of Ottoman-era commercial structures such as bazaars and *hans*, which collectively represent a unique cultural and spatial heritage. Following the 2020 Çarşıbaşı Urban Design Project Competition, several spatial interventions were introduced, including the reorganization of pedestrian routes, enhancement of open spaces, and improvement of the relationship between historic buildings and the surrounding urban fabric. These interventions provide the basis for a comparative morphological study between 2020 (pre-intervention) and 2025 (post-intervention). As illustrated in **Figure 1**, aerial photographs from 2020 and 2025 depict the spatial extent of the study area and its transformation context.

Figure 1. Aerial photographs of the Bursa Khans District from 2020 and 2025 (from Google Earth)

The overall methodological framework is summarized in **Figure 2**, which illustrates the link between space syntax measures and sustainability indicators. The study employed axial map analysis within the **space syntax framework** (Hillier & Hanson, 1984). Two datasets were prepared: the first represents the 2020 street network prior to the competition interventions, derived from cadastral maps and aerial photographs (Google Earth, 2020), while the second reflects the 2025 post-intervention configuration, prepared using official project documents and aerial imagery (Google Earth, 2025). Both datasets were digitized and processed in **DepthmapX software**, which calculates key syntactic measures of spatial configuration. The analysis focused on four indicators: global integration (Rn), local integration (R3), connectivity, and intelligibility.

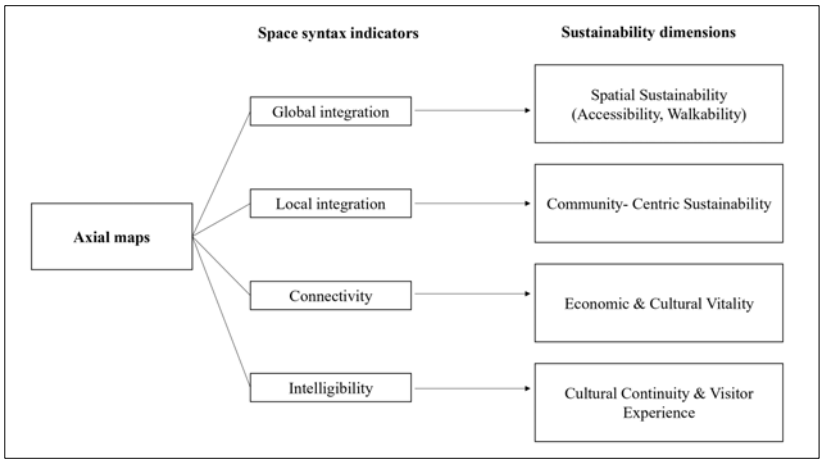

Figure 2. Methodological framework linking space syntax analysis with heritage sustainability.

Finally, the interpretation of results was carried out within a heritage sustainability framework. Quantitative syntactic measures were linked to sustainability dimensions: **global integration** was associated with spatial sustainability, reflecting system-wide

accessibility, compactness, and walkability; **local integration** was connected to community-centric sustainability, highlighting everyday accessibility, resident use, and social interaction**; connectivity** was interpreted as an indicator of economic and cultural vitality, pointing to permeability, visibility of businesses, and the vibrancy of heritage cores; **intelligibility** was related to cultural continuity and visitor experience, improving orientation, legibility, and the reinforcement of cultural identity.

By combining quantitative syntactic analysis with qualitative interpretation within UNESCO's sustainability principles, the method ensures that morphological changes are not only measured but also contextualized in terms of cultural heritage management.

Findings and Discussion

The comparative space syntax analysis of the Bursa Khans District revealed measurable improvements in spatial configuration between 2020 and 2025. As shown in **Table 1**, global integration increased from **1.33** to **1.54**, indicating higher system-wide accessibility, while local integration rose from **1.73** to **1.86**, reflecting stronger neighborhood-scale pedestrian access. **Connectivity** also improved, from **3.61** to **4.02**, suggesting enhanced permeability of the urban fabric. Finally, **intelligibility** climbed from **0.40** to **0.48**, demonstrating a more legible and navigable district overall. These shifts are spatially evident in the **axial maps (Figure 3)**, where integration and connectivity concentrate more coherently along primary pedestrian corridors and their feeders after the interventions.

Table 1. Comparative space syntax values for Bursa Khans District (2020–2025).

Year/ values	***Global Integration***	***Local Integration***	***Connectivity***	***Intelligibility***
2020	1.33183	1.73722	3.61165	0.403745
2025	1.54264	1.86915	4.02151	0.489223

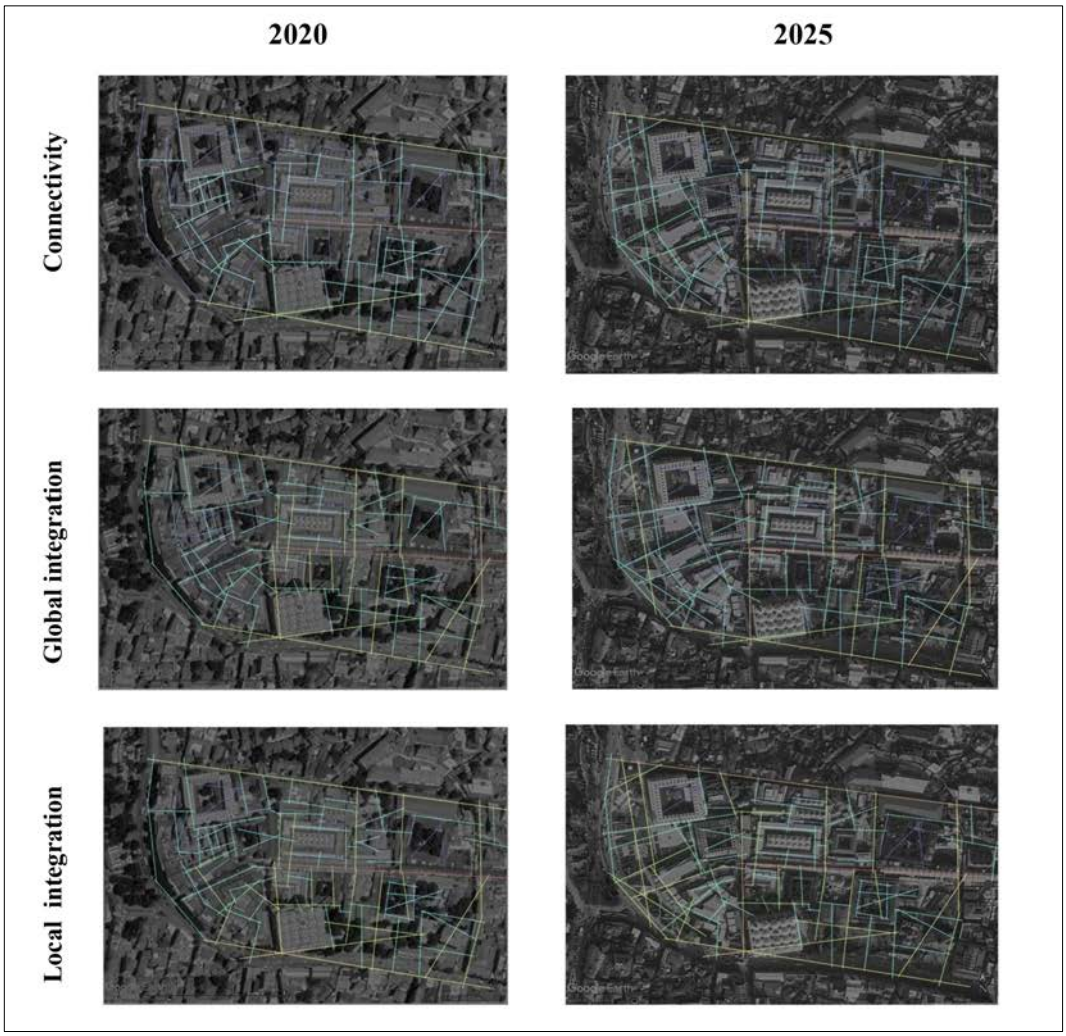

Figure 3. Axial map of Bursa Khans District, 2020 – 2025

As shown in Figure 4, the intelligibility scatterplots demonstrate the consolidation of the district's spatial logic, with the post-intervention distribution clustering more tightly around the regression line and extending upward, thus indicating a stronger correlation between local and global integration. This improvement enhances wayfinding and reduces cognitive effort for visitors, ensures clearer and more continuous paths for residents, and increases through-movement and visibility for merchants. Conceptually, the intensified correlation aligns with sustainability arguments linking spatial legibility to walkability, compactness, and low-carbon mobility (van Nes, 2021), as well as with UNESCO's emphasis on community participation and inclusive access in heritage areas (UNESCO, 2015). It also resonates with findings that morphological legibility shapes cultural perception (Zaleckis et al., 2022), and while it appears to contrast with cases where declining intelligibility coincided with reduced vitality (Turgut, 2022), both confirm the same spatial principle: vitality is directly related to intelligibility. Taken

together with the integration and connectivity gains summarized in Table 1 and illustrated in Figure 3, the strengthened intelligibility shown in Figure 4 indicates that post-2020 interventions reinforced a coherent, multi-scalar spatial structure that supports walkability, everyday use, cultural continuity, and socio-economic vibrancy in the historic core.

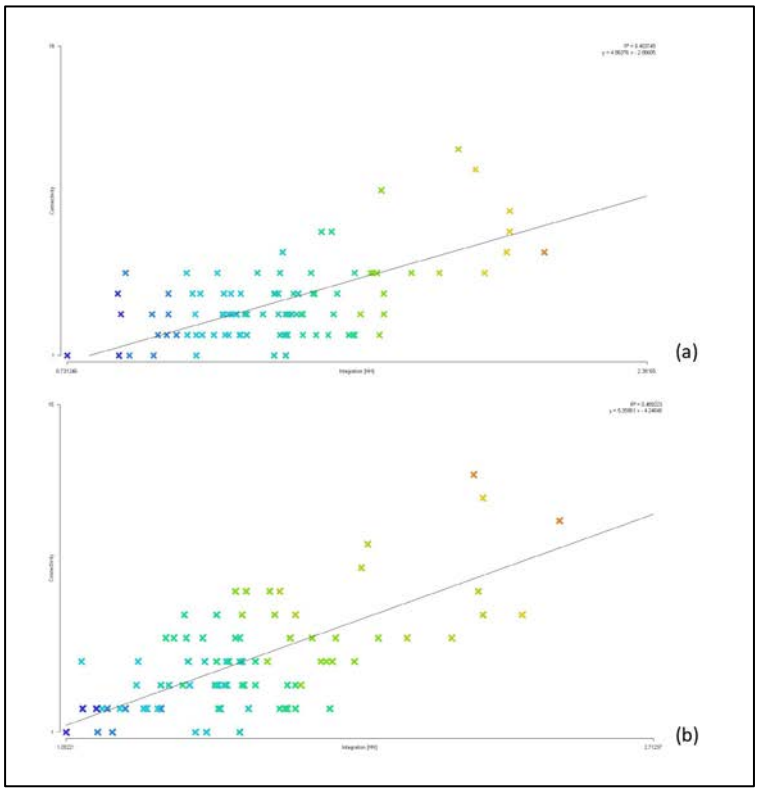

Figure 4. Intelligibility graphs of Bursa Khans District, (a)-2020, (b)-2025

These findings also correspond with broader international experiences in heritage management. In Cairo's Al-Darb Al-Ahmar district, for example, morphological improvements enhanced the permeability of urban space and sustained craft-based economies (Ibrahim et al., 2025). In Konuralp, syntactic analysis highlighted how connectivity informs conservation strategies (Özkaraca & Halaç, 2021), while in Rosetta, integration and connectivity were found to be critical for UNESCO heritage nomination and long-term management (Eldiasty et al., 2021). Similarly, in Kaunas, façade interventions influenced both spatial legibility and cultural perception (Zaleckis et al., 2022), and in Istanbul's Historic Peninsula, syntactic measures were directly associated with sociability and accessibility (Gümüş et al., 2022). this study demonstrates that the Bursa case provides strong evidence that morphological transformation and syntactic indicators can serve as reliable measures for assessing sustainability.

Conclusion

Overall, the findings confirm that the interventions implemented after the 2020 competition enhanced the morphological structure of Bursa Khans District, producing positive outcomes across spatial, social, economic, and cultural dimensions. Rather than isolating conservation from everyday urban life, the interventions created a more integrated and living heritage core, where accessibility, community use, economic viability, and cultural legibility coexist. This case demonstrates that morphological transformation is not at odds with conservation; when carefully designed, it can actively strengthen sustainable heritage management. In this sense, space syntax provides a robust, evidence-based framework for linking morphology with sustainability, offering valuable insights for UNESCO World Heritage Sites worldwide. The Bursa study thus underlines that conservation policies should not only safeguard architectural authenticity but also ensure that spatial configurations remain accessible, inclusive, and adaptive to contemporary needs.

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PERCEPTION, EMOTION, AND BEHAVIOR IN IN-BETWEEN SPACES: A NEUROARCHITECTURAL APPROACH TO CLIMATE NEUTRALITY

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Perception, Emotion, and Behavior in In-Between Spaces: A Neuroarchitectural Approach to Climate Neutrality

Abstract: The paper investigates how architectural and spatial design can influence perception, cognition, and emotion, thereby shaping sustainable behavior. The study examines how in-between spaces—transitional, and often overlooked environments, such as courtyards, atria, plazas, pocket parks, and pedestrian streets—can act as catalysts of pro-environmental action. Drawing on advances in neuroscience, environmental psychology, and environmental technological design, a conceptual framework links spatial features, multisensory perception, neural activation, affective states, and behavioral outcomes. In-between spaces are shown to function as cognitive and emotional interfaces that enhance social interaction, biophilic engagement, and behavioral nudging toward practices such as active mobility, recycling, resource sharing, and reduced energy use. The paper argues that sustainability should be understood not only as a technical or ecological objective, but as a lived and perceptual phenomenon embedded in everyday spatial experience. Ultimately, in-between spaces emerge as strategic thresholds for fostering resilience, well-being, and climate-conscious urban life.

Keywords: in-between spaces; sustainability; neuroarchitecture; climate neutrality; behavioral nudge

Introduction

In-between spaces occupy a strategic role in the transition of cities toward climate neutrality. Often conceptualized as liminal voids, absences, or thresholds between built forms (Piccinno & Lega, 2013), they constitute fertile grounds for experimentation with sustainable urban futures (Rahmann & Jonas, 2011; Tucci, 2018). Despite their frequent neglect, these spaces mediate everyday life, influence microclimatic regulation and foster social and spatial connectivity. Through environmental technological design, they can enhance environmental quality, regulate urban dynamics, improve safety and usability, and, in advanced scenarios, promote circular resource management (Tucci et al., 2021).

Evidence from suburban regeneration projects shows that attention to public and shared spaces generates systemic improvements at the district scale (Tucci et al., 2021). Such outcomes highlight the significance of relationships between buildings and common spaces, advancing health, well-being, and social equity. Emerging models such as decentralized energy systems (Bögel et al., 2021) and the "15-minute city" (Moreno et al., 2021) reinforce the role of proximity and functional diversity in shaping sustainable lifestyles.

Urban form conditions both bioclimatic performance and residents' behaviors, which are mediated by sensory perception and emotional engagement. For example, integrating cycle paths, pedestrian corridors, and local services increase walkability and equitable mobility options, accommodating diverse needs across age and health profiles (Lee & Buchner, 2008; Gehl, 2011; Weng et al., 2019).

Certification systems such as LEED and BREEAM focus on environmental metrics, while TODS emphasizes mobility, and WELL prioritizes user well-being. In parallel, neighbourhood-scale frameworks, such as Green and Thriving Neighbourhoods (C40 & Arup, 2021), advance climate-neutral urban design.

In this context, in-between spaces emerge as connective infrastructures mediating interactions among users, functions, and technologies, thereby contributing to systemic decarbonization strategies and enhancing urban resilience (Angelucci, 2023; Andaloro et al., 2022). Their adaptability, combined with responsive technologies and flexible architectural forms, allows them to actively interact with changing environmental conditions.

Designing accessible and inclusive public spaces can support active mobility, counter sedentary lifestyles, and foster public health goals (WHO, 2017). Moreover, embodied practices such as Tai Chi Chuan and Yoga—known to modulate prefrontal and limbic activation, reduce stress, and enhance interoceptive awareness (Tang et al., 2015; Fox et al., 2016)—illustrate how spatial and bodily perception can reinforce emotional regulation and prosocial orientations. Incorporating opportunities for such practices into in-between spaces may further strengthen their restorative and pro-sustainability impact.

This contribution aims to investigate how in-between spaces can be strategically designed to foster sustainability not only as a technical performance but as a lived and perceived experience. Through a combination of theoretical grounding, case study analysis, and design strategies, integrating neuroarchitecture and environmental psychology features, the paper seeks to demonstrate how in-between spaces can act as active agents of behavioral change, supporting decarbonization, resilience, and social well-being in urban environments.

Spatial perception and behavioral nudging

From the environmental psychology perspective, space functions as a medium that affords action, physical environments can communicate possibilities for behavior (Gibson, 1979). In terms of sustainability, spaces may be designed to afford pro-environmental actions such as walking or recycling. Thus behavioral nudging—the use of subtle cues that guide decision-making without constraining freedom of choice—has emerged as a central strategy for promoting sustainable practices (Thaler & Sunstein, 2008).

Architectural and urban design interventions can make sustainable choices more intuitive, effortless, and socially desirable. Examples include the placement of an inviting, naturally lit staircase in a central lobby to promote active mobility, or the positioning of recycling bins in highly visible courtyards and plazas to encourage proper waste separation.

Similarly, shaded walkways, tree-lined seating areas, and public water-refill stations can encourage walking, lingering outdoors, and reducing single-use plastics. These interventions rely on perceptual salience and affective responses: environments that are attractive, comfortable, or socially engaging shape cognitive appraisal and increase the likelihood of sustainable habits.

From a neuroarchitectural perspective, transitional spaces can be chosen not only to accommodate but to actively foster pro-environmental behavior. Neuroarchitecture emphasizes that the brain response to build environments is neither neutral nor passive. Spatial qualities—form, materiality, lighting, and acoustics—elicit measurable neural activity that influences mood, attention, stress, and behavior. Key brain regions involved include the prefrontal cortex (executive function, decision-making), the insula (interoceptive and emotional awareness), and the limbic system (emotion and memory regulation) (Coburn et al., 2020; Edelstein & Macagno, 2012). Research also demonstrates that environmental features such as daylight, greenery, openness, and coherent visual patterns reliably activate positive affect and cognitive engagement (Kaplan & Kaplan, 1989).

To conceptualize these processes in relation to sustainability, a five-stage framework can be proposed. First, Spatial Features of in-between spaces—configuration, materials, natural light, vegetation, acoustic quality—establish the physical affordances of place (Higuera-Trujillo et al., 2021; Han et al., 2025). These features shape Multisensory Perception, where visual, acoustic, thermal, tactile, and olfactory stimuli are integrated into a holistic spatial experience (Djerbbara et al., 2022). The Neural Activation is triggered, engaging regions linked to attention (prefrontal cortex), interoception (insula), emotional salience (amygdala), and contextual memory (hippocampus) (Vecchiato et al., 2015). This activation produces an Affective State characterized by comfort, safety, social connection, or aesthetic pleasure, which are critical for psychological well-being (Gehl, 2011; Qu & Ma, 2024). Finally, these affective states manifest as Behavioral Outcomes, expressed in social interaction, cooperation, and sustainable actions such as recycling, energy conservation, active mobility, or resource management (Han et al., 2025).

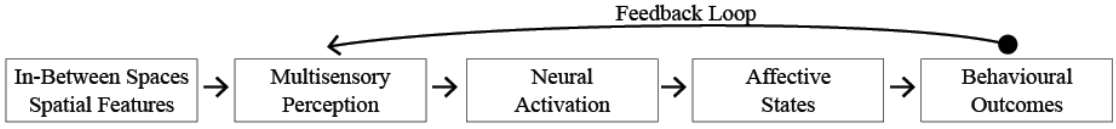

Figure 1. The five-stage process that exemplify the connection between spatial features and behavioral outcomes.

This model highlights that sustainability is not merely the result of design decisions or policies but is also perceived, felt, and enacted through everyday encounters with space. The design of in-between spaces thus extends beyond aesthetics and functionality, relying instead on empirically supported pathways linking spatial features to perception, neural activation, affect and behavior. Evaluation of these dynamics may combine subjective measures (e.g., surveys on comfort and perception) with objective indicators (e.g., behavioral patterns, space utilization), offering an evidence-based framework for shaping resilient and sustainable urban communities.

Defining In-between spaces

In social geography, the "betweenness of space" refers to the quality of places as contexts in which human action unfolds, positioned at the boundary between objective and subjective realities, framing in-between spaces as mediators between dual poles—Being and Staying—emphasizing their role as thresholds of experience (Entrikin, 1991).

Because of their transitional character, in-between spaces are particularly fitted to behavioral nudging: interrupting routine movement and providing moments of pause and sensory reflection, they create opportunities for intentional, sustainable action that may not arise in more static environments.

In-between spaces, for their transitory and transformative qualities, are resistant to fixed classification within binary logics (Carmona, 2010). Accordingly, they can be systematized through different approaches. For instance, they may be categorized according to their predominant dimension—design, socio-cultural, ownership, or climatic—or by their spatial relationship within the urban fabric: in-between spaces directly related to buildings, whether internal or external, often semi-public or private, such as courtyards, gardens, and shared residential areas; spaces between buildings, hosting a wide range of essential and optional urban activities, including streets, squares, parks, and residual voids. At a larger scale, networks of in-between spaces can be conceived as synergistic systems of interconnected typologies that collectively structure urban life (Tucci et al., 2023).

These spaces frequently accommodate hybrid functions—circulation, encounter, rest, or transition (Ghel, 2011). Their physical attributes, including enclosure, visibility, accessibility, and sensory qualities, vary widely yet consistently enable multisensory engagement and social affordance, making them dynamic environments strategically designed to support interaction, reflection, and sustainable practices.

A Holistic Design for In-between Spaces

Designing in-between spaces as catalysts for behavioral change requires strategies that integrate green and blue infrastructure, enhance functional proximity, and support circular and sharing economies.

Nature-based strategies, such as the enhancement of vegetation, water and soil, improve microclimatic comfort, enhance CO_2 absorption, foster biodiversity, and strengthen neighbourhood resilience to extreme events. Embedding green and blue networks across multiple scales—from building courtyards to metropolitan parks—and ensuring access to natural areas promotes both physical and psychological well-being.

Strategies of proximity emphasize functional and social diversity, sustainable mobility, and urban vitality, reinforcing belonging, safety, inclusivity and equity while supporting healthier lifestyles. Mixed-use development, where essential destinations are within walking or cycling distance, fosters active mobility. Public spaces with active frontages, well-lit pathways, bike lanes, and recreation areas promote safety, livability, and social cohesion. Spatial rhythms, sightlines, and sensory gradients (light, sound, texture) can modulate attention, encourage exploration, and ensure accessibility for all users, regardless of age or ability.

Several international projects illustrate the transformative potential of in-between spaces.

The skyscraper Capitaspring (BIG and CRA, 2021), Singapore, hosts a Green Oasis that mimics tropical rainforests. The green buffer is extended across four central floors, connected by a spiral walkway, and offers a variety of spaces for work, relaxation, exercise or events. Together with the roof garden guaranties a 1:1,4 ratio of ground surface/green areas, providing tenants and residents with abundant access to green spaces.

Tainan Spring (MVRDV, 2020) is a virtuous reuse of an abandoned shopping centre in the city centre of Singapore into a urban lagoon, that connect city and nature through large planting areas, providing multiple layers of vegetation, according to the active street frontage. During hot periods, nebulizers improve microclimate condition with a positive impact both on the heat island phenomenon and on the reduction of air conditioning use.

The Central Park of Taichung (Rahm Architects, 2020), Taiwan, was realized on an abandoned airport and designed according to the specific climate to offer cooler, drier, and less polluted places, encouraging outdoor activities. The park acts as retention basins, preventing flooding. Walkers can choose paths on their smartphone, thanks to a real-time map of climatic variations, measured through heat, humidity, and air pollution sensors. At night lighting is

dimmed to preserve the circadian biological cycles of animals. The photovoltaic canopies produce all the energy used in the park, which is thus totally carbon neutral.

Park'n'Play (JAJA Architects, 2016) is a parking house in Copenhagen with a vibrant rooftop, equipped with a playground and spaces for physical exercise. Incorporating playful elements in the building and in the plaza nearby, make them more engaging and inviting for physical activity. Similarly, in Karen Blixen Plads (Cobe, 2019) the domes offer shelter for an hypogeal bike parkings and on top stages or community places, connecting the plaza to the natural area nearby.

Using a repeatable approach to sustainable urban development, One Green Mile (MVRDV, 2022) transforms the space beneath the flyover concrete structure of one of the major roads of Mumbai, into a safe pedestrian insula with amenities and greenery. The sinuous blue stripes create a cohesive visual identity across all elements of the space and a strong visual identity, making it a new benchmark for underused space. On the other side, in Seoul, Seoullo 7017 converts the former highway into a skygarden that connect the city to nature (MVRDV, 2017).

These cases highlight how reimagining in-between spaces can expand ecological performance, promote active mobility, and foster inclusive urban life. By strategically repurposed neglected or residual sites, cities can transform structural voids into vibrant hubs that simultaneously advance sustainability, resilience, and collective well-being.

Conclusion

As sustainability challenges intensify, design must expand its focus from technical efficiency to lived experience. In-between spaces hold significant potential to foster sustainability through perception, affect, and behavior. Informed by neuroarchitecture and environmental psychology, these thresholds can be reframed as perceptually rich environments that prime individuals for pro-environmental action.

Well-designed neighborhoods exemplify this shift by repurposing underutilized areas, encouraging active lifestyles, and promoting engagement through participatory and collaborative initiatives. Within this framework, circular and sharing strategies, supported by behavioral nudges, enable practices such as waste reduction, resource recovery, and energy self-sufficiency.

Despite methodological challenges—such as measuring neural responses in dynamic contexts and accounting for cultural heterogeneity—the implications are substantial. For urban

planning, it suggests a transition from infrastructure-centred paradigms to user-centred and perception-based approaches. For architecture, it calls for design strategies that integrate sensory richness, inclusivity, and ecological performance. For policymakers and communities, it underscores the importance of fostering environments where sustainability is not an abstract goal but a distributed, tangible, and lived experience.

Ultimately, sustainability should not only be encoded in buildings as technical performance indicators but also embedded in the experiential logic of space. Transitional environments are catalysts of awareness, social connection, and sustainable action. Applying the lens of neuroarchitecture to in-between spaces provides a powerful paradigm shift: rethinking "the spaces between" as generators of well-being, relationality, and ecological responsibility.

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NEUROARCHITECTURE AND PENAL REHABILITATION: THE EMPHATIC AND SUSTAINABLE MODEL OF HALDEN PRISON

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Neuroarchitecture and Penal Rehabilitation: The Empathic and Sustainable Model of Halden Prison

Abstract: Halden Prison in Norway represents an innovative example of the application of neuroarchitecture, a discipline that integrates neuroscience and architectural design to create spaces that promote psychological and physical well-being. Conceived not as a punitive facility but as a rehabilitative environment, Halden adopts an empathetic and sustainable architectural approach that positively influences inmates' behaviour and emotional states. Bright interiors, natural materials, integration with the surrounding landscape, and relational spaces stimulate the prefrontal cortex, reduce stress and aggression, and foster self-control and empathy. The responsibility-based regime encourages autonomy and self-awareness, within a context where every spatial element—from individual cells to communal areas and the landscape—is designed to support personal transformation. With one of the lowest recidivism rates in the world, Halden demonstrates that an architecture grounded in neuroscientific principles can turn imprisonment into an effective tool for rehabilitation and social reintegration.

Keywords: Neuroarchitecture, Sustainability, Rehabilitation, Technology, Well-being.

Introduction

In the current context of architectural sciences and penal policies, a profound revision of the detention paradigm is urgently needed, given the ineffectiveness of traditional models, which are often rooted in repression and dehumanization. This study aims to investigate the transformative role of architecture within correctional institutions, with particular attention to neuroarchitecture and its application in Halden Prison in Norway.

Neuroarchitecture, a discipline that integrates cognitive neuroscience, environmental psychology, and architectural design, considers the built environment as an active agent in neuropsychological and behavioral processes. Over the past two decades, scientific literature (*Küller, Sternberg, Eberhard*) has highlighted how environmental quality influences stress, empathy, and decision-making processes. However, while much research has focused on healthcare or educational contexts, the penal environment remains largely underexplored, with the exception of some Northern European studies (*Fridh, Moran, Jewkes*).

This research addresses that gap by analyzing Halden Prison as a paradigmatic case of the systematic application of neuroarchitectural principles—capable of redefining the relationship between punishment, space, and subjectivity. Halden is not merely a sustainable or rehabilitative prison; it is a deliberate architectural project aimed at modulating behavior and emotion through compositional, material, and landscape choices.

The objective is twofold: to provide an interdisciplinary analysis of Halden in its architectural, neurocognitive, environmental, and socio-pedagogical dimensions; and to contribute theoretically to an integrated vision that connects neuroscience, prison architecture, and human rights. The significance of this study lies in the potential to transfer such principles, with appropriate contextual adaptations, to other prison systems—promoting an ethics of dignity and transformation.

This research does not seek to analyze either the technical-structural aspects of the prison or the Norwegian penal system. Rather, it focuses on perceptual and cognitive dimensions, adopting a qualitative and theoretical-critical approach grounded in scientific literature, architectural documentation, and case studies. The goal is not to provide a replicable model, but to stimulate critical reflection on the therapeutic and empathetic potential of architecture.

Literature Review

The reflection on the interaction between built space and psychological well-being finds its roots in Richard Neutra's biopsychology of architecture and has evolved through Colin Ellard's studies on the emotional experience of places, as well as the contributions of the *Academy of Neuroscience for Architecture (ANFA)* and the Center for Health Design, which have highlighted the environmental impact on stress, empathy, memory, and decision-making processes *(Sternberg, 2009; Eberhard, 2007*). Much of the existing literature, however, has focused on healthcare and educational settings, leaving the prison environment relatively underexplored. Some exceptions can be found in the works of *Moran and Jewkes (2015), Fridh (2018)*, and other Northern European studies that begin to outline the features of a more humane and rehabilitative prison architecture.

Despite these contributions, a theoretical and practical gap remains concerning the systemic integration of neuroarchitectural principles in correctional contexts. The present study aims to address this void by offering an interdisciplinary interpretation of Halden Prison as a paradigmatic case. Compared to existing literature, it distinguishes itself through the combined analysis of design, neurocognitive, environmental, and pedagogical dimensions, demonstrating how architectural design can function as an active tool for identity transformation and the fostering of personal responsibility, thus transcending the dichotomy between punishment and reform.

Methods

The methodology adopted for this study is grounded in a qualitative, interdisciplinary, and comparative approach aimed at exploring the connections between architectural design, cognitive neuroscience, and contemporary penal models, with a focus on Halden Prison as an exemplary case study. The methodological framework integrates tools from architectural analysis, neuroscientific reflection, and sociological interpretation, in order to provide a comprehensive and multifaceted understanding of the context under examination.

The first phase involved an in-depth documentary analysis, through the consultation of academic sources, scientific articles, and official publications regarding the operation, design philosophy, and spatial organization of Halden Prison. This provided the theoretical foundation for critical interpretation. In parallel, a targeted investigation was conducted on the architectural morphology, functional composition, materials, perceptual quality of spaces, and the relationship with the surrounding landscape.

A central aspect of the research was the review of contemporary neuroscientific literature, with particular attention to the effects of physical space on cognitive processes, emotions, social behavior, and mental health. Relevant neuroarchitectural parameters—such as natural light, access to greenery, materials, privacy, and acoustic quality—were identified and employed as interpretative keys in the analysis of Halden's structure.

The architectural analysis developed through a critical reading of the project, including functional mapping of spaces based on neuroscientific criteria, in order to understand how design choices influence the subjective perception and behavior of inmates. Supporting this reflection, a qualitative comparison was carried out between Halden and traditional prison models, highlighting differences in terms of psychological impact, rehabilitative effectiveness, and transformative potential.

Finally, a phenomenological approach was adopted, oriented towards the subjective experience of lived space, to hypothesize—on the basis of neuroscientific evidence—the cognitive, emotional, and identity-related effects of a correctional environment designed according to the principles of neuroarchitecture. The entire methodological framework was guided by the intention to integrate diverse bodies of knowledge, recognizing in the convergence between neuroscience and architecture an opportunity to reimagine custodial spaces in a profoundly humanizing light.

Findings and Discussion

The findings from the analysis of Halden Prison confirm the effectiveness of Neuroarchitecture within the penitentiary context, demonstrating how the built environment can positively influence inmate behavior, psychophysical well-being, and the rehabilitative process. A correctional setting designed according to neuroscientific principles stimulates the prefrontal cortex—enhancing self-control, empathy, and reflection—while reducing activation of the limbic system, which is responsible for impulsive reactions and chronic stress. The use of natural light, warm materials, expansive open spaces, and the presence of greenery work in synergy to create a sensorially positive and humanizing environment.

The facility, organized into residential units with single rooms and self-managed communal areas, fosters voluntary social interactions and a sense of personal responsibility. Daily activities—such as cooking, work, and study—are not merely re-educational tools but actively stimulate neural plasticity and support the inmate's identity reconstruction. In this context, the environment becomes not merely a container for punishment, but an active agent in the process of transformation.

Objective data reinforce this perspective: Norway reports a recidivism rate of less than 20%, one of the lowest in the world, attesting to the validity of a model that integrates empathetic architecture, environmental sustainability, and a neuroscientific approach. Halden Prison thus stands as a paradigm of a new ontology of punishment—one founded not on retribution, but on care, responsibility, and the recognition of the individual as a being in constant evolution. Neuroarchitecture therefore emerges as a fundamental discipline for reimagining carceral infrastructures in a humanistic, rehabilitative, and culturally advanced framework.

Conclusion

The analysis of Halden Prison has highlighted how architecture consciously shaped by the principles of Neuroarchitecture can serve as a concrete instrument of individual and social transformation. The results demonstrate that spaces designed to stimulate empathy, selfregulation, and psychophysical well-being significantly contribute to reducing recidivism and enhancing the success of rehabilitative pathways. The Halden model exemplifies a new ontology of punishment, grounded in personal responsibility, humanization, and neurocognitive regeneration.

However, the transferability of such a model encounters cultural and systemic limitations, tied to the ideological and political foundations of each penal system. Nevertheless, the architectural generalizations that emerged—such as the centrality of natural light, greenery, privacy, and the multisensory quality of spaces—are broadly applicable, provided that the custodial paradigm is recalibrated with respect for human dignity.

From a theoretical standpoint, the study strengthens the link between neuroscience and architecture, proposing an integrated perspective capable of informing more ethical and effective design practices grounded in scientific evidence. On a practical level, it underscores the urgency of rethinking correctional facilities not as mere punitive containers, but as therapeutic and transformative environments. It is therefore recommended that neuroarchitectural criteria be adopted in the design of detention spaces and that penal policies be promoted with a rehabilitative orientation, within a framework of social justice and longterm prevention.

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SUSTAINABILITY FOR CULTURAL HERITAGE AND HISTORICAL STUDIES

Energy Retrofit of Heritage Buildings
Climate-Resilient Heritage Preservation
Community-Centric Heritage Conservation
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SUSTAINABLE CONSERVATION OF UNESCO WORLD HERITAGE SITES THROUGH MONITORING: GÖREME NATIONAL PARK AND THE ROCK SITES OF CAPPADOCIA

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Sustainable Conservation of UNESCO World Heritage Sites through Monitoring: Göreme National Park and the Rock Sites of Cappadocia

Abstract: Ensuring the sustainability of World Heritage Sites requires monitoring and reporting activities carried out within an effective management framework. This study evaluates Göreme National Park and the Rock Sites of Cappadocia, one of Türkiye's first World Heritage Sites, from a sustainable conservation perspective in line with United Nations Educational, Scientific and Cultural Organisation (UNESCO) documents and the activities of the State Party. The evaluation of monitoring and reporting activities revealed that the heritage site is under pressure from visitors, natural disasters and climate threats, and faces problems arising from management and legal frameworks. Although conservation progress was identified in the site's reports following the establishment of the Cappadocia Site Management Directorate in 2019, the lack of an approved management plan and the continuation of pressures are affecting the site's sustainability.

Keywords: sustainable conservation, cultural heritage, UNESCO world heritage sites, monitoring

Introduction

The concept of cultural heritage encompasses all tangible and intangible values, beliefs, knowledge and traditions that have been passed down from the past to the present and will be left to future generations. Conservation activities are important to ensure the continuity of these values, which establish an identity link between the past, present and future. While early conservation approaches involved individual and local efforts, these efforts have evolved into a universal responsibility over the time. The concept of sustainable conservation has also been addressed in these studies. This concept aims to transmit cultural and natural values to future generations through a participatory, integrated, and planned conservation approach.

The aim of this study is to discuss the impact of monitoring and reporting activities on conservation approaches to ensure the sustainable conservation of UNESCO World Heritage Sites, by considering the concept of sustainability as a tool used in conservation processes rather than a descriptive term. Subsequently, this paper examines the conservation status of Göreme National Park and the Rock Sites of Cappadocia, a world heritage site, based on the results of monitoring and reporting activities, and provides recommendations for sustainable conservation of the site.

Literature Review: Sustainable Conservation and World Heritage Sites

Following World War II, increased industrial development, population growth and, as a result, excessive consumption of natural resources brought the concepts of environment and sustainability to the forefront. Studies on the subject were conducted at the 1972 Stockholm, 1976 Vancouver, 1992 Rio de Janeiro, and 1996 Istanbul Second Habitat Conferences (Feilden

and Jokilehto, 1998). In the Brundtland Report published by the United Nations World Commission on Environment and Development in 1987, sustainability was defined as ensuring that future generations are able to meet their own needs (WCED, 1987).

Although the concept of sustainability initially emerged with the idea of protecting ecology, it has now developed into a framework that encompasses many fields of study, including heritage conservation. The fact that the concept of conservation is based on the desire to pass on cultural heritage to future generations demonstrates that the concept of sustainability is closely related to cultural heritage (Günay, 2010). Efforts by international organisations to preserve cultural heritage in a sustainable manner are of great importance (see Figure 1).

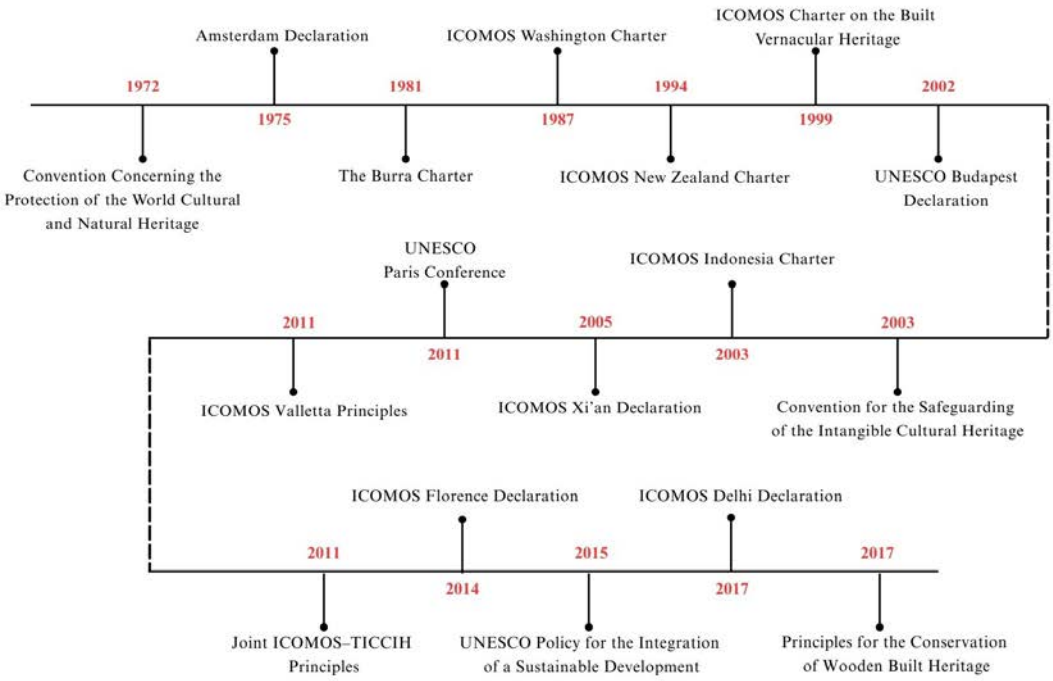

Figure 1. International regulations that include sustainable heritage conservation approaches.

UNESCO and the 1972 World Heritage Convention, which provide the most comprehensive framework for global conservation, have established the international foundation for sustainable conservation. The fourth article of the World Heritage Convention states that 'the transmission of heritage sites to future generations' ensures the sustainability of heritage (UNESCO, 1972). To date, a total of 1,248 heritage sites are registerred under UNESCO's sustainable conservation approach, including 972 cultural, 235 natural, and 41 mixed sites (UNESCO WHC).

Effective management covering disaster, risk and visitor regulations with planned strategies is required to ensure the continuity of world heritage sites. The concept of heritage

management was first introduced in the Management Guidelines for World Cultural Heritage Sites published by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in 1993, and the basic requirement defined as the conservation of cultural resources (Feilden, Jokilehto, 1993).

The 1994 version of the UNESCO Operational Guidelines, which define the applicability of the World Heritage Convention and the basic principles related to heritage sites, includes a statement regarding heritage site management plans. If a heritage site does not have a management plan, the relevant state party must specify the schedule for its preparation and the resources necessary for its implementation (Operational Guidelines, 1994).

Another important aspect in order to ensure sustainable conservation is monitoring and reporting activities aimed at tracking the status of heritage sites in the face of potential risks. UNESCO expects signatory states adhere to with certain principles and decisions to establish a common approach to the conservation of all heritage sites. The systematic evaluation of this process is ensured through monitoring and reporting activities.

The monitoring process for World Heritage Sites began in 1979 with the creation of State of Conservation Reports (SOC) by the World Heritage Centre and Advisory Bodies. Following this, the concepts of “Reactive Monitoring” and “Periodic Reporting” played an important role in the conservation of World Heritage Sites and were incorporated into the process. The World Heritage Committee made the monitoring of all heritage sites mandatory in 1995 (Dinçer et al., 2009). For this reason, heritage sites are monitored and reported on at specific intervals by the state party, Advisory Bodies, the World Heritage Centre, and UNESCO experts. These processes have been prepared in accordance with the principles defined in the Operational Guidelines (see Figure 2).

	Periodic Reporting	**Reactive Monitoring**	**State of Conservation Report (SOC)**
Frequency of Preparation	Every 6-8 years	Varies depending on the request of the World Heritage Committee	Annually
Responsible for Preparation	State party	State party, Advisory body	World Heritage Centre, Advisory bodies
Examining / Reviewing Body	World Heritage Centre, World Heritage Committee, Advisory bodies	World Heritage Centre, Advisory bodies	World Heritage Centre, Advisory bodies
Submitting / Decision-Making Body	World Heritage Committee	World Heritage Committee	World Heritage Committee

Figure 2. Monitoring, Reporting and Decision-Making Process.

Periodic Reporting is a self-reporting activity prepared by the state (UNESCO, 2023). SOC includes information obtained from third parties, news reports, mission reports, and feedback from the State Party and Advisory Bodies. Reactive Monitoring, on the other hand, is a report that provides information on the state of conservation of heritage sites threatened by significant deterioration of their Outstanding Universal Value (OUV). The Committee considers the removal of a heritage site from the list as a last resort and therefore cooperates with the State Party to implement the necessary conservation measures to ensure the continuity of the world heritage site (UNESCO, 2023).

Türkiye's World Heritage Sites and the Monitoring and Reporting Process

The UNESCO World Heritage Convention was approved by Türkiye in 1982. As of 2025, 22 sites in Türkiye, of which 20 are cultural and 2 are mixed, are on the World Heritage List; 79 sites, including 72 cultural, 4 mixed, and 3 natural sites, are on the Tentative List (Türkiye UNESCO National Commission and UNESCO WHC).

The conservation of cultural heritage sites in Türkiye is legally guaranteed under Law No. 2863 on the Conservation of Cultural and Natural Assets. As a signatory to the UNESCO World Heritage Convention, Türkiye is expected to fulfil its obligations under the Convention and comply with the Committee’s decisions regarding heritage sites. According to the Committee's decisions, management plans for the sites must be prepared, regularly monitored and reported on.

Heritage sites in Türkiye have been subject to periodic reporting surveys in 2006, 2014 and 2024, based on the years they were inscribed in the list, and SOC and reactive monitoring reports have been prepared in accordance with the Committee's decisions. The conservation status of heritage sites, the threats they face, and the measures that need to be taken can be examined through these reports to ensure the sustainability of heritage sites. However, there is no approved management plan for Göreme National Park and the Rock Sites of Cappadocia and six other world heritage sites, which are necessary to increase the applicability of these measures.

Methods

This study examines the monitoring reports on the conservation status of Göreme National Park and the Rock Sites of Cappadocia, one of Türkiye's first heritage sites to be inscribed to the World Heritage List, and evaluates them within the framework of sustainable

conservation. The study's materials include Periodic Reporting, SOC reports, Committee Decisions, and reports from Advisory Bodies and the Cappadocia Regional Directorate. In addition, the assessments of Demirçivi (2017) and Ayhan (2020), who conducted their studies based on the 2006 and 2014 periodic reporting surveys, were also consulted. These documents were systematically examined to identify factors affecting the site and to analyse the management's response to these factors. Based on the findings, recommendations were made for sustainable conservation.

Findings and Discussion

Göreme National Park and the Rock Sites of Cappadocia have been settled by many communities between the 4th and 13th centuries AD. The site is known for its easily shaped and hollowed-out rocks and underground cities, which are among the largest cave settlement complexes (Demirçivi, 2017, UNESCO WHC). In 1983, the Director-General of UNESCO emphasised the need to ensure the preservation of the churches, rock-cut sturctures, and wall paintings in the area at an international level (ICOMOS, 1985). As a result, the mixed heritage site, which meets criteria i, iii, v, and vii of the cultural and natural heritage site selection criteria, became one of the first sites from Türkiye to be inscribed on the World Heritage List in 1985.

The heritage site is protected by Law No. 2863, 7174 on the Cappadocia Site, Principle Decision No. 658 on Archaeological Sites and zoning plans for environmental planning and conservation plans. The site, which was protected under the National Parks Law until 2019, was removed from National Park status due to the coexistence of multiple conservation statuses.

Although the heritage site has strong conservation implementation in place, it still faces certain challenge. These include visitor congestion and natural degradation, as well as conflicts of authority, site management and legal regulations, communication problems and lack of awareness among stakeholders, visual pollution, construction, demolition of some buildings, and infrastructure problems (Somuncu and Yiğit, 2008). In addition, after the 2018 amnesty on construction, the structures within the site and the unauthorised additions and illegal spaces received building registration certificates, which affected the heritage site visually (Solmaz Şakar, 2021). In this context, the elements affecting the heritage site were identified in detail by examining UNESCO documents, and the state party's measures were evaluated to determine the conservation status of the heritage site.

The UNESCO documents on the heritage site include the reports of ICOMOS and the International Union for Conservation of Nature (IUCN), committee decisions, maps, periodic reports prepared in 2006, 2014 and 2024, and SOC reports. The first documents related to the site were prepared by advisory bodies in 1985, and based on these reports, the Committee decided at its 9th session that the site should be inscribed on the World Heritage List in the same year.

The SOC reports on the heritage site indicate that the negative factors affecting the site are large visitor accommodation facilities, damage to rock and wall paintings, and infrastructure problems. In addition to these issues, the negative factors impacting the site were evaluated using periodic reporting surveys from 2006, 2014, and 2024, as well as IUCN reports from 2014, 2017, and 2020. These factors are shown in Figure 3, while the conservation activities undertaken by the state party in response in Figure 4.

Threats/Years	2006 PR	2014 IUCN	2014 PR	2017 IUCN	2020 IUCN	2024 PR
Physical development	⚠	⚠	⚠	⚠	⚠	⚠
Visitors and tourism	⚠	⚠	⚠	⚠	⚠	⚠
Land transport	-	-	⚠	⚠	⚠	⚠
Service infrastructure	-	-	⚠	⚠	⚠	⚠
Pollution	-	-	⚠	-	-	⚠
Land conversion	-	-	⚠	-	-	⚠
Quarrying	-	-	-	-	-	⚠
Society's value of heritage	-	-	⚠	-	-	⚠
Changes in traditional lifestyles and knowledge systems	-	-	⚠	-	-	⚠
Changes in identity, social cohesion, local population and community	-	-	⚠	-	-	⚠
Intentional destruction	-	-	-	-	-	⚠
Illegal activities	-	⚠	⚠	⚠	⚠	⚠
Climate	-	⚠	⚠	⚠	⚠	⚠
Natural disasters	⚠	⚠	⚠	⚠	⚠	⚠

⚠: Threat present

Figure 3. Threats affecting the heritage site according to reports.

Activities/Years	2006 PR	2014 IUCN	2014 PR	2017 IUCN	2020 IUCN	2024 PR
Management system/activities	✗	✗	✗	✗	✗	✔
Legal framework	✔	✔	✗	✔	✔	✔
Management plan	✗	✗	✗	✗	✗	-
Work/action plan	-	-	✗	-	-	✔
Area boundaries	✔	✔	✔	✔	✔	✔
Buffer zone	✔	✔	✗	✔	✔	✔
Monitoring	✔	✗	✗	✗	✗	✔
Human resources	✗	✗	✗	✗	✗	✔
Financial resources	✗	✗	✗	✗	✗	✔
Awareness	✔	✔	✗	✔	✔	✔
Coordination	✗	✗	✗	✗	✗	✔
Visitor management	✗	✔	✗	✗	✗	✗

✔: active ✗: inactive -: no information

Figure 4. Conservation activities carried out in the heritage site according to reports.

The most recent report on the heritage site is the periodic reporting survey prepared in 2024. This report highlights that the management factors previously identified as negatively affecting the site are now showing positive trends. The management system and activities, legal framework, governance, human resources, monitoring and research activities were assessed as being at a good level. Although tourism activity, changes in population dynamics, and the pressure of natural activities on the site continue, the management's response to factors that significantly affect the site at a high level and to factors that affect it at a lower level at a moderate level presents a positive picture when the site is evaluated in terms of sustainable conservation.

The reason for the progress in conservation activities in the heritage site is the Law on the Cappadocia Site, which came into effect in 2019, and the establishment of the site management directorate. Strategic plans have been developed by the site management directorate for the 2021-2025 and 2024-2028 periods, and these plans specify targets for nearly all conservation activities in the heritage site that were identified as having a low impact level according to the reports. However, many of the intended targets have not been achieved. In particular, the success rate of the first period strategic plan is quite low in terms of conservation, planning, enhancement of the site's value and tourism activities, awareness-raising and

management objectives. In the first year of the second period activity report, nearly half of the targets were successfully achieved.

According to the latest activity report, although the targets for developing financial resources, visitor numbers and awareness-raising activities were not fully achieved, effective work was carried out in the majority of cases, and the conservation and tourism targets also presented a more positive picture. However, it is noteworthy that planning did not reach the desired level. Due to a court decision cancelling the higher-level plans, the management plan, lower-level plans and maps could not be prepared. In addition, the targets related to coordination and human resources were not achieved. This situation impacts the conservation, management and sustainability of the heritage site.

Conclusion

When assessing the overall conservation state of Göreme National Park and the Rock Sites of Cappadocia and the state party's conservation strategy, it becomes evident that various processes and issues have arisen. The confusion over authority that long-standing has led to conservation problems and delays in planning decisions for the heritage site. As observed in the 2006 and 2014 periodic reports, the management structure and legal framework have been among the factors negatively affecting the heritage site and slowing down its development.

The proposal by UNESCO officials in 1994 to enact a law related to the site was realised 25 years later, and despite the delay, this proposal has made a significant contribution to the development of the heritage site. With the contribution of the law enacted in 2019 and the establishment of the site management directorate, the 2024 periodic reporting survey noted that management and legal activities affecting the heritage site were positive, and that the management's response to negative factors was generally strong. This indicates that a sustainable approach has been adopted in the conservation of the heritage site.

Monitoring and reporting activities have made it possible to follow these developments. These activities are important for the continuity of the site, as they allow for the identification of elements that threaten the site and prevent inadequate conservation practices. Management plans need to be prepared in order to make the monitoring and reporting process more systematic. Although the site management directorate was established in 2019, the absence of a management plan for the heritage site raises questions about whether the site has sustainable conservation. Therefore, the following recommendations have been made within the framework of the sustainable conservation approach for the heritage site:

- Eliminating the negative aspects of the planning process and preparing and approving a comprehensive management plan that includes long-, medium- and short-term strategies for visitor, disaster, climate and risk management as soon as possible.
- Strengthening coordination among stakeholders and continuing site promotion and awareness programmes.
- Improving financial and human resources.
- Facilitating monitoring and reporting processes,
- Implementing the objectives outlined in the strategic plan.

In conclusion, although strong protective measures have been taken and advanced precautions have begun to be applied to conserve the heritage site, the implementation of the recommended measures will make it possible to preserve the OUV and its transmission on to future generations while ensuring its sustainability.

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RESEARCH LINES IN THE HISTORY OF ENVIRONMENTAL ARCHITECTURE. THE SME POWER STATION BY RENATO AVOLIO DE MARTINO IN SAN GIOVANNI A TEDUCCIO, NAPLES

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Research Lines in the History Of Environmental Architecture. The SME Power Station by Renato Avolio De Martino in San Giovanni A Teduccio, Naples

Abstract: The paper introduces a new approach to the history of architecture and cities from an environmental perspective. The genre begins to take shape through a strand of scientific literature to which the first part is dedicated. Through this lens, it is possible to reinterpret the history of the city and post-industrial architecture and landscapes with the aim of restoring and rehabilitating them. The second part of the paper attempts to outline environmental history research applied to the suburbs of eastern Naples, where the SME power station in Vigliena, designed by Renato Avolio De Martino between 1950 and 1954, is located.

Keywords: post-industrial city; energy sources; pollution.

Introduction. History of architecture and the environment

Since the First Industrial Revolution, a series of factors such as air and soil pollution, deforestation, intensive farming, construction techniques, and the supply and use of raw materials, including cement, energy sources coinciding with fossil fuels, together with other factors, have contributed to altering the ecosystems and biodiversity of our planet, leading to global warming. The different forms of coexistence of species, including humans, but also plants, are constantly forced to readjust, triggering new selection processes for survival. The case of the SARS COV-2 virus is the most striking example, but it is only the latest in a series of zoonoses involving the transmission of a pathogen from one species to another (Quammen, 2020).

Architecture, like other disciplines focused on humans and their habitat, faces an urgent challenge on these issues, both in theory and in practice.

An environmental approach to architectural history and theory began to emerge in the 1960s, coinciding with the birth of a globally conscious modern environmentalism (Isenberg, 2014, 1–20). The first theoretical reasoning on the subject was developed in Reyner Banham's famous essay “The Architecture of the Well-Tempered Environment” (Banham, 1969), in which architecture is considered in terms of energy and climate, heralding new aesthetic values. This is not an ecological approach, since here nature, in a typically modern way, was analysed and bent to the needs of human well-being, as a “force” to be controlled or filtered. According to Banham, Joseph Paxton's greenhouse was the forerunner of “controlled environments for living organisms”. Greenhouses, but also aquariums, are the first types of buildings in which the need for the survival of plants and animals respectively led to technological adaptation of the interiors. This technological trend flourished above all in the 1970s and focused on experimental habitats that exploited energy or statics in such a way as to foreshadow utopian environments and territories (Buckminster Fuller, Archigram, Radical Architecture, Megastructures, high tech). Even today, it remains an important sector of so-called sustainable design, between design and planning, understood as research into components, systems, materials, and architectural details.

Recently, environmental issues have been addressed from an even broader and more complex perspective. Partly because of the worsening climate conditions caused by global warming, a theoretical debate has begun, emphasizing environmental issues cannot simply be added to the body of study, effectively changing the terms of analysis and urgently requiring new conceptual frameworks. In the history of architecture, along with categories, methods and concepts, the very division into eras, canons and works have been called into question (Barber, Stickells, 2018).

According to this ecological approach, architecture, understood as a constructed object that draws on resources and is placed in a context to respond to social demands, could always be conceived as a man-made object with environmental value that triggers ecological dynamics. In fact, it is both an environment, with its energy and microclimatic needs, and an artifact that establishes a relationship with the environment, understood as an external habitat. A reflection on the relationship between modern architecture, energy sources and climate control in buildings was carried out by Daniel A. Barber, also author of the installation Terms and Conditions (with Transolar, Blige Kobas, and Sonia Seneviratne), which marks the entry of the Corderie dell'Arsenale into the latest Venice Architecture Biennale (2025) curated by Carlo Ratti and focused on the theme "Intelligens. Natural. Artificial. Collective". In his extensive scientific work, Barber has examined how climate influenced the design strategies of modern architects before the introduction of air conditioning, with regard to American works after World War II (Barber, 2016; Barber, 2020).

The recent Biennale di Architettura of Venice also demonstrated how research in the fields of composition and technology is now focused on identifying new types of buildings and new construction methods that subvert design and construction practices in a sustainable way, to the point of hypothesizing a new alliance, a co-production, between nature and architecture and between cities, suburbs and the surrounding area (Biennale Architettura 2025, 2025, Koolhaas, 2020). The planting of trees in open spaces and even on buildings is one of the solutions that is gaining ground in Italy and abroad to balance excessive CO2 production (Mancuso, 2019). The vertical forest in Milan designed by Studio Boeri is one of the best-known examples of this practice, which aims to hybridize nature and artifice in high-rise buildings.

From an ecological perspective, the environmental issue also becomes key to a bio-political interpretation of the role played today by humans in modifying the environment. It therefore allows us to re-examine our era as the Anthropocene and highlight the imbalances linked to development (Costa Meyer, 2016). This type of interpretation can be found in some post-colonial studies, such as Jiat-Hwee Chang's analysis of Singapore, which focuses on "tropical architecture" that conceals behind its high-performance facades the desire to subject local populations to supranational economic logic (Gissen, 2016).

David Gissen noted that since the end of the 19th century, nature has been seen as a tool "that cleans the world, increases productivity and efficiency, and transforms our existing natural relationship, while advancing the social sphere as it is", with a particular hatred for dust, smog, weeds and pests associated with the lower classes, which ultimately represent forms of resistance against those in power: nothing could be further from an awareness of the interrelationship between the animal and plant worlds and between ecosystems (Gissen, 2009, Clement, 2004).

A strand of research linked to economic studies is beginning to emerge, particularly about the history of production and energy processes, in some cases focusing on non-Western and pre-modern human history (Wrigley, 2016; Kander, Malanima, Warde, 2014; Smil, 2017). This type of approach helps to identify the trajectory of a process that is now historicized, highlighting how much (or how little) the environmental issue has been considered in the design and construction of buildings, both materially and symbolically.

Barnabas Calder's "Architecture: From Prehistory to Climate Emergency" (Calder, 2021), recently translated into Italian by Einaudi (2022), reinterprets the history of architecture from prehistory to the present day, analysing how energy sources have influenced architecture and cities over the centuries. The transition from pre-capitalist to industrial cities, marked by the introduction of coal, is one of the key points of the book, which clearly illustrates how hydrocarbons and energy sources in general are the basis of our contemporary life, from which we must start our transition to renewable energy.

Towards an environmental interpretation of post-industrial sites: the SME power station in Vigliena, Naples

In her book **"**Oil Spaces. Exploring the global petroleumscape**"** (2022), Carola Hein illustrates the concept of "petroleumscape". The term is a neologism that refers to the landscape created by oil settlements from the first industrial drilling in the US in the mid-19th century to the present day, when there is talk of moving beyond oil, but with only partial success. The author demonstrates precisely how the oil landscape is also pervasive due to the use of plastic in the manufacture of many of our utensils. Oil architecture, oil-fired factories and power stations, tanks and the entire storage, recycling and disposal chain, infrastructure, oil pipelines and tankers represent a real landscape waiting to be described by architectural history, even in post-colonial countries, where it occupies huge areas of sea and land.

In the historic suburbs of Naples, as in many European cities, large industrial complexes that are no longer in use remain as silent cathedrals of the various phases of industrialization. Examining their history from the point of view of energy sources and according to an approach that ranges from the scale of the building to that of the landscape could become an important challenge for thinking in environmental terms with a view to urban regeneration. Bagnoli in the west and San Giovanni a Teduccio-Barra in the east of Naples are post-industrial areas of this type that should be studied using such an approach.

The eastern area of Naples was historically characterized by wetlands, fertile fields, and a thriving horticultural economy. Although drainage and urbanization reshaped the landscape over decades, agriculture and local cultivation remained vital well into the mid-20th century. The eastern plains supported a mosaic of mills, orchards, and market gardens, reflecting a strong agrarian identity that persisted despite growing industrial pressures. It became a hub of production settlements since the Seventeenth century given the presence of water sources, the coast, and the port. With Law 351/1904, 'Provisions for the economic revival of the city of Naples,' promoted by Francesco Nitti, the old mills of the first factories were replaced by new large metalworking, chemical, and electrical industries that began to locate in the area. All factories began operating on coal and petrol starting from that period. Even today, the landscape bears the signs of the three most productive municipal mills in Naples: Porta Nolana, Carmine and Porta Capuana, which operated until 1890. In 1927, the Porta Nolana mill was given in concession to SET, the telecommunications company which managed the telephone network throughout the South. The Petriccione Distillery installed in 1894 and now it is in a state of decay was other mill (Parisi, 1998**,** 20-29).

Around the fort of Vigliena, built in the early 18th century and destroyed in 1799, during the 19th century, thanks also to the presence along the coast of the railway line to Portici (1839) and in Pietrarsa of the Royal Bourbon Factory (1842), several industries were established, including Giacomo Corradini's important metallurgical and mechanical plant (1888), which consists of 54 units, distributed over an area of 5 hectares (Parisi, 1998, 163-67).

The area's productive vocation was consolidated at the beginning of the 20th century, when via Vigliena was built. It was in this area, next to the pier of the same name and the Corradini, that the Società Meridionale Elettricità (SME) built its first power station along the coastline, the "Maurizio Capuano", named after the company's first president, which was built between 1924 and 1926 to a design by architect Marcello Canino (Mortara, 1928). It was a power station fuelled by liquid (naphtha) and solid (coal) fuels. Shortly afterwards, starting in 1928, the imposing and avant-garde reinforced concrete building designed by Angelo and Alessandro Trevisan was built right next door, housing the headquarters of the Cirio Food Preserves Company (Parisi, 1998 161-67).

In 1926, when was established to start the oil products industry, the Azienda Generale Italiana Petroli (Agip) located their companies specializing in the oil sector in the area, a little

further north, near of the Circumvesuviana railway, occupying a surface area of 50,000 square meters, with 17 tanks and a shed. Mobil Oil arrived 10 years later, activating a production of 6 million tons of crude oil per year and occupied a surface area of 600,000 square meters. In the 1970s, production even increased to 7 million tons per year (Castronovo, 174, 278, 289).

The ambitious SME electrification program dated back to 1922 and mainly involved the exploitation of the Sila water networks in Calabria, creating a transport network that would allow large-scale energy distribution throughout the territory, as far as Campania, Puglia and Sicily. After the Second World War, to increase thermoelectric production, thanks to reconstruction funding, Meridionale continued its project by building numerous power stations in central and southern Italy. New works were also planned in Naples, thanks to European Recovery Plan (ERP) funds allocated for reconstruction. Furthermore, the extensive damage to the Capuano power station caused by bombing made it necessary to restore and increase production by building a new power station called "Vigliena", designed by Renato Avolio De Martino (1950-54). Located in the area adjacent to the existing power station, near the oil dock, it produced 106,000 kWh. Its covered area reached 4,800 square metres, while the external installations covered 20,000 square meters. For its construction, the land was expanded by filling in 60 meters of sea and raising a 190-meter quay to increase the possibility of oil tankers docking. The covered areas were the boiler room, ancillary rooms (coal silos and pulverizing mills, heating, control room), engine room and electrical panels. The power station was fuelled by naphtha and coal (Ingrosso, 2023, 1311-1320).

The box-like structures designed by Renato Avolio De Martino to house the machinery were not without morphological research. The horizontal lines of the volumes, with their narrow windows, were contradicted by the verticality of the chimneys and inclined lifts for transporting materials. The building to the west, bearing the company's sign, provided access to the complex and featured exposed stone cladding, as well as alternating solid and hollow strips that gave it an extremely light and elegant appearance.

At the end of the 1950s, SME decided to build another power station, known as Levante, covering 80,000 square meters, fuelled by coal, residual oil and gas, in the area in front of the Corradini factory, next to "Vigliena", so as to use the same piers for the docking of ships carrying fuel. Today, only a few buildings remain of the Vigliena power station. After a long decommissioning process that began in the 1980s, the plant was almost completely demolished in March 2002, while Corradini and Cirio were transformed into educational and cultural facilities, in line with the implementation rules of the 1999 PRG (General Town Plan) amendment, which provided for the redevelopment of the coastal strip of the San Giovanni district, from the Granili bridge to Pietrarsa.

The Cirio has been in disuse since 1949 and despite has been declared a heritage site to be protected under the law 1089/39, it is in partial state of abandonment. Only a small part of the ancient complex has been recently (2007) renovated and converted into the "Officine San Carlo", a training and production centre under the management of the Neapolitan theatre.

Since 2010, an important urban and cultural regeneration project has come to life thanks to the University Federico II, with the creation of the Polo Tecnologico di San Giovanni a Teduccio in the ancient Corradini. In 2016, the Apple Developer Academy was inaugurated in this site. The Levante power plant, which was first transferred to Enel and then to Interpower S.p.A., is not scheduled for decommissioning but will be converted into a new-generation combined cycle gas and steam power plant. Neighbourhood associations have strongly opposed this decision, while important issues remain unresolved, such as the environmental redevelopment of the area and the restoration of the beautiful beaches and sea that border the industrial sites (Iannello, Morreale, 2006).

Conclusion

The area examined, located on the eastern outskirts of Naples, is now a reserve in need of regeneration, but also a place whose past must be studied from an environmental perspective to understand its future development. Industrial activities have left a heavy legacy on the environment: pollution of the soil and aquifer sand the presence of asbestos and other hazardous materials. Large industrial buildings and the names of their clients and architects take us back to the now defunct era of industrialism and development, which we now urgently need to come to terms with in order to move beyond it. Avolio De Martino, an important Neapolitan professional who spent his entire life working on commissions for the SME group and then Enel, leaves behind a great legacy that has yet to be fully explored and appreciated.

For historians of architecture and cities, the challenge of updating their methods of investigation and analysis is urgent. As a result, the environmental issue becomes a sort of transdisciplinary discursive space in which historiography is called upon to investigate the relationships between design, construction, social uses of space and the use of natural resources and energy sources, observing architecture, cities and territories through the lens of their changing relationship with the environment and therefore with other animal and plant species, for the benefit of geographical and biophysical conditions.

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EVALUATION OF PHOTOVOLTAIC POTENTIAL IN AHMET PIRISTINA CITY ARCHIVE AND MUSEUM

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Evaluation of Photovoltaic Potential in Ahmet Piristina City Archive and Museum

Abstract: This study will examine how the integration of solar energy systems into cultural heritage buildings affects the energy conversion process. Ahmet Piriştina City Archive and Museum (APIKAM) located in Izmir was selected as a case study. The energy savings potential created by the photovoltaic (PV) panel integration planned to be applied to the roof of APIKAM were evaluated. Online simulation tools PVGIS and PV*SOL will be used in the study; annual production values, performance rates and shading effects will be analyzed with different scenarios. The findings show that PV integration is possible with structure-integrated solutions (e.g. parapet- back placement, BIPV) for heritage building structures such as APIKAM to compensate energy consumption with renewable energy sources.

Keywords: cultural heritage structures; PVGIS; PV*SOL Online; solar PV simulation.

Introduction

According to the IEA, building operations will account for approximately 30% of global energy consumption and 26% of associated emissions in 2022.

Today, energy efficiency and the use of renewable energy sources have become a priority item in the global agenda to reduce the environmental impact of the construction sector as highlighted by the International Energy Agency (IEA, 2023). It is important to increase energy efficiency by ensuring sustainable urban development, meeting increasing energy demand and responding to the challenges of climate change. As urbanization and population growth accelerate, energy-efficient building practices are now essential to achieve sustainability goals (Polesello & Johnson, 2016; Al-Obaidi et.al., 2022).

Today, increasing demands for energy have led to new possibilities for the use of renewable energy sources. The fact that the sun is accessible everywhere positions it as a strategic resource in sustainable energy transformation.

Before taking steps towards electricity generation, solar energy was used for thermal applications. The first steps towards electricity generation were made possible by Edmond Becquerel's discovery of the photovoltaic effect in 1839. The process that started with the first solar cell in 1883, over time, with the advancement of technology in the field of materials, photovoltaic systems have become important renewable sources today (Jayachandran et al., 2024).

In the solar renewable transformation process, in addition to new buildings, the existing building stock should also be evaluated. In this instance, as the majority of European nations deal with cultural heritage building stock in urban areas, it is crucial to make cultural heritage structures in the current building stock energy-sensitive to meet climate targets. However, there

are drawbacks to making cultural heritage structures energy-sensitive, including the loss of historical context and aesthetic integrity (Fouseki & Cassar, 2014).

In this context, the energy savings that will be created by the integration of PV systems into the structure, specifically for the Ahmet Piriştina City Archive and Museum (APIKAM) cultural heritage structures located in the Konak district of İzmir, have been emphasized. The energy needs of lighting and air conditioning systems are constant and continuous during the day, especially in public buildings such as museums, archives and cultural centers. In this case, the energy generated by PV systems will be used inside, lowering energy expenses and reliance on outside sources. In addition to its financial advantages, this self-sufficient system will also make a significant contribution to sustainability by lowering carbon emissions.

APIKAM was built in 1932 as a fire station; it was restored in 2004 with the vision of the late Mayor Ahmet Piriştina to strengthen the collective memory of the city and started to be used as a museum and archive. This building, which bears the plain and symmetrical character and traces of the architecture of the early Republican period, is a symbolic public building of Izmir (Ahmet Piriştina City Archive and Museum [APİKAM], n.d.). In this respect, APIKAM, which has a reinforced concrete structure, three floors and a sloping roof, is suitable for our case study when evaluated in terms of the applicability of energy conversion systems with its central location and roof typology and lighting, air conditioning and digital equipment that have constant energy consumption throughout the day. The important advantage for the efficient operation of PV systems due to the fact that Türkiye is located in the 2nd-degree hot and dry summer, mild winter climate region and the annual sunshine duration is high with over 300 days of abundant sunshine in the Konak area.

Literature Review

Integrating photovoltaic systems into culturally significant buildings requires consideration of both energy performance and aesthetic compatibility. Polo López and Frontini (2014) emphasized that PV systems should function as architectural elements, not merely energy generators. Lingfors et al. (2019) introduced a visibility-based system to evaluate visual impacts on heritage structures, while Freitas et al. (2015) highlighted the importance of considering geometry, shading, and GIS tools for solar energy potential in urban contexts. However, the present study focuses on the energy contribution of PV systems integrated into the APIKAM, assessing their impact on annual building energy consumption. Future research may explore visual and spatial integration in more depth.

Simulation tools like PVGIS and PVSOL are widely used to estimate PV system performance (Milosavljevic et al., 2022). PVGIS offers rapid, climate-based estimates, whereas PVSOL provides detailed visual modeling, including shading analysis and roof layout. Milosavljevic et al. (2022) found that PVGIS yielded the lowest deviation among 14 tools compared to actual measurements, confirming its reliability. Similarly, Klise and Stein (2012) reviewed performance evaluation models for PV systems.

In related studies, Ebhota and Tabakov (2025) examined optimal slopes for rooftop PV in Nigeria using PVSOL, emphasizing orientation and temperature effects. Shukla et al. (2018) compared multiple simulation tools, including PVGIS and PVSOL, for a small residence in India, concluding PV*SOL provided the most user-friendly and accurate results. These studies demonstrate how tool selection affects modeling outcomes.

Building on this literature, this study employs PVGIS and PV*SOL Online to estimate annual energy production, performance ratios, and shading impacts of PV systems for the APIKAM, aiming to assess potential contributions to the building's energy performance.

Methods

In the study, the energy production potential of the APIKAM PV panel systems will be evaluated with digital simulation tools.

In the simulations, two different scenarios will be applied for the integration of PV panels. The first is the system where the panel is placed on the roof with a 40° slope together with the carrier system and targets annual optimum production. The 40° slope was preferred according to the existing roof slope. In the second scenario, the pergolas facing the courtyard of the APIKAM will be evaluated for the integration of PV panels.

In addition to the main structure of the APIKAM, the south-facing roof surface of the café extension will also be evaluated within the scope of PV integration in the study. The south-facing roof surface of the main structure, approximately 320 m², will be considered for panel placement. Considering the necessary technical spaces and a typical PV panel covering an area of approximately 1.7 m², it is predicted that 160 panels with a power of 300 W can be placed. Thus, an installed power of approximately 48 kWh has been reached.

With similar calculations, the 170 m² roof surface of the cafe extension facing south was evaluated and 70 panels were placed. In this case, it is seen that 230 panels can be placed by using 80% of the 490 m² combined roof area that can be used effectively and 69 kWh installed power can be reached. In these two structures, which will be examined as a single

system, it is aimed to reach a higher production capacity and contribute to meeting a significant part of the building's energy needs.

In the scenario where the pergolas of the café extension are considered, a south-facing area of 40 m² has been evaluated. Assuming that 80% of this area can be effectively utilized, it is estimated that approximately 18 panels can be installed, resulting in an installed capacity of around 5.4 kWh.

These scenarios will be applied separately with both simulation tools; different scenarios will be developed within each simulation tool. The method is planned in two stages.

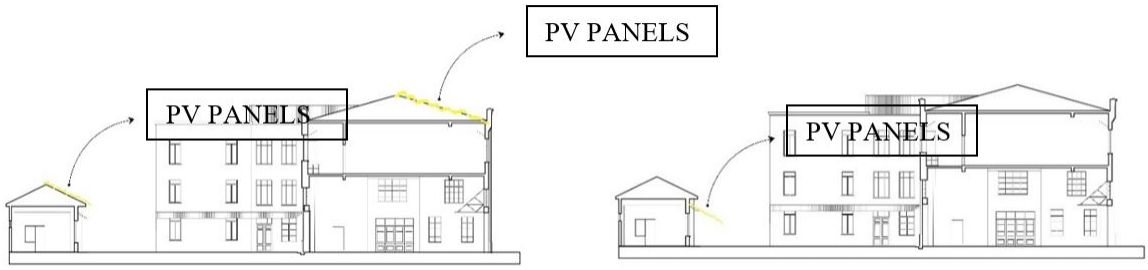

Figure 1. Simulation Scenarios.

Energy simulations were conducted using PVGIS and PVSOL Online for the APIKAM. PVGIS provided annual and monthly energy estimates based on panel slope (40°), azimuth (37°), and monocrystalline panels (69 kWh and 5.4 kWh). PVSOL Online incorporated detailed roof geometry, shading, and system efficiency, modeling two scenarios with 230 and 18 panels, respectively. Shading ratios (0% and 10%), pollution (3%), and albedo (20%) were considered. A SUN2000L-4.6KTL inverter was used in both simulations. Results compared the energy yield across tools and configurations, evaluating seasonal performance and building integration of PV systems.

Findings and Discussion

a. PVGIS Simulation

Table 1. PVGIS Simulation Comparison of Scenario 1 and 2.

	Parameter	Scenario 1	Scenario 2
1	Slope Angle [°]	40°	40°
2	Azimuth Angle [°]	37°	37°
3	Yearly PV Energy Production [Kwh]	100,0083.83 kWh	7,832.65 kWh
4	Yearly In-Plane Irradiation [Kwh/M²]	1978.31 kWh/m²	1978.31 kWh/m²
5	Year-To-Year Variability [Kwh]	2452.38 kWh	191.93 kWh
6	Angle Of Incidence Loss [%]	2.72%	2.72%
7	Spectral Effects [%]	0.49%	0.49%
8	Temperature And Low Irradiance [%]	12.79%	12.79%
9	Total Loss [%]	26.68%	26.68%

In both PVGIS scenarios, the panel technology, inclination and orientation are kept constant, only the installed power amount is changed. Since scenario 1 has approximately 13 times more installed power, the production amount is also much higher. The production variability within the year is also more pronounced in larger systems. The loss rates are the same in both scenarios, indicating that the effects of system design and environmental conditions are similar. This shows that systems can be designed with different installation capacities in different areas and that energy output can be directly increased with scaling.

b. PV*SOL Online Simulation

The annual total energy consumption defined for the APIKAM building, 4700 kWh, was obtained from measurements based on the use of lighting, air conditioning and digital equipment of the building. The building type was selected as "business (G3)" and a monthly consumption profile was created. The reason for selecting the Business (G3) profile is that it is a standard load profile for commercial use and represents the energy usage characteristics of public cultural buildings such as offices, archives and museums.

In the first scenario, PV modules were selected with a power of 69 kWh, and 230 units of 300 Wp monocrystalline panels were used. The system installation was evaluated on the roof with the option "Roof parallel – good rear ventilation". The albedo value was entered as 20%, the soiling rate as 3% and shadowing 0%.

In the second scenario, PV modules were selected with a power of 5.4 kWh, and 18 units of 300 Wp monocrystalline panels were used. The system installation was evaluated on the roof with the option "Roof parallel – good rear ventilation". The albedo value was entered as 20%, the soiling rate as 3% and the shadowing 10%. Between the two scenarios, the number of PV modules was varied (from 230 to 18), and the shadowing effect was adjusted to 10%.

In the simulation, Huawei SUN2000L-4.6KTL model inverter is used. The dimensioning factor value in the system is 130.4%, which indicates that the production in the morning and evening hours can be increased and the inverter can work more efficiently.

Table 2. PV*SOL Online Simulation Comparison of Scenario 1 and 2.

Parameter	Scenario 1	Scenario 2
Annual PV Energy Production	64,855 kWh	4,604 kWh
Own Consumption	2,471 kWh	1,949 kWh (42.3%)
Grid Feed-in	62,384 kWh	2,655 kWh
Total Consumption	4,700 kWh	4,700 kWh
Consumption Covered by PV	2,471 kWh	1,949 kWh
Consumption Covered by Grid	2,229 kWh	2,818 kWh
Solar Fraction	52.6%	41.5%
Performance Ratio	89.49%	89.6%
Avoided CO_2 Emissions	34,697 kg/year	2,463 kg/year

According to the comparative analysis of the two scenarios, the highest annual PV energy production was obtained in Scenario 1 with 64,855 kWh, where the panels were installed at a 40° slope and 0% shading rate. In Scenario 2, which features a smaller system with a 40° slope and the 10% shading rate, the annual production was only 4,604 kWh. While both scenarios used the same total consumption value (4,700 kWh), Scenario 1 achieved a higher solar fraction (52.6%) and significantly more CO_2 emissions were avoided (34,697 kg/year vs. 2,463 kg/year).

However, Scenario 2 resulted in a higher self-consumption rate (42.3%) compared to 3.8% in Scenario 1, indicating that smaller systems may better match the building's immediate energy use. Despite the difference in scale, both scenarios showed similar performance ratios (~89.5%), confirming stable system efficiency under different conditions.

These findings suggest that while increasing installed capacity boosts total energy production, a balanced design that considers building demand, self-consumption, and potential storage integration can enhance the overall system performance and sustainability.

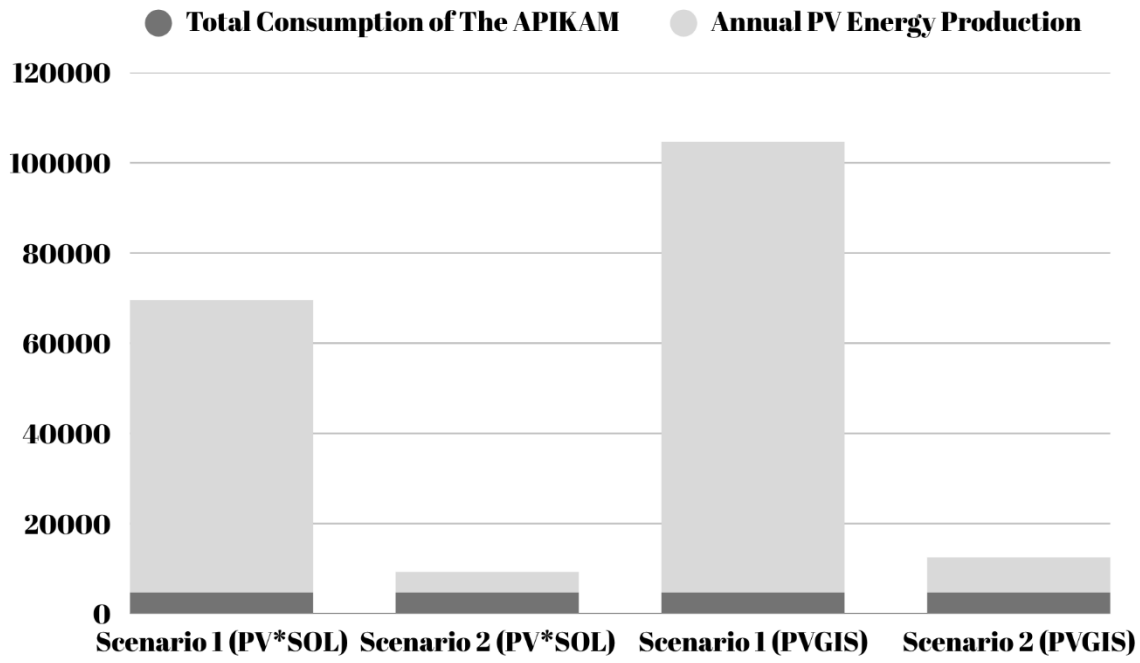

Figure 2. Annual PV Energy Production by Simulation Tool and Scenario.

Conclusion

The evaluations of solar energy production potential were carried out on scenarios made with two different simulation tools and different parameters entered in each scenario.

According to two different scenarios made with the PVSOL Online, the annual energy production of PV systems varied between 64,855 kWh and 4,604 kWh. It was observed that parameters such as installed capacity and shading effect used in simulations have significant effects on the production potential. These findings show that increasing the installed capacity increases the total energy production, and a balanced design considering building demand, self-consumption and potential storage integration can increase the overall system performance and sustainability.

When two different scenarios were compared with each other using the PVGIS simulation tool, similar results were obtained. The production potential of the system increased significantly with a larger installed capacity, but very similar results were obtained in terms of efficiency and loss rates.

When PVGIS and PVSOL Online simulations, which were performed with the same parameters that can be entered in both simulation tools such as system power, panel slopes, project location, were compared, PVGIS results showed a much higher annual energy production than PVSOL. This difference is due to PVGIS generally calculating according to ideal conditions and not taking local consumption data into account. PVSOL, on the other hand, provides a more realistic result by modeling losses such as consumption profile, shading, and pollution in more detail. PVSOL also provides a more comprehensive evaluation of the energy and environmental performance of the investment by detailing self- consumption, grid usage, and CO_2 emission reduction.

As a result, PVGIS provides more general and high estimated production data, while PV*SOL provides lower but more practical and detailed analyses. According to the simulation results for Scenario 1, the preferred number of panels and the system power related to it caused the energy produced to be well above the building's consumption. The panel placement calculation made according to the south-facing roof surface of the building shows the high technical potential of the system. When the production potential is evaluated in general, it is seen that the production values obtained are quite positive in terms of both economic gain and carbon emission reduction. In Scenario 2, a system production closer to the annual energy consumption of the building was realized.

Although the simulation results are promising, there are various limiting factors in real-world application. First of all, since the building has a cultural heritage status, the effect of PV panels on the historical texture is an important topic of discussion. The visibility of the panels, the integrity of the facade and the roof should be taken into consideration.

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SUSTAINABLE DESIGN PRINCIPLES IN TRADITIONAL GAZIANTEP HOUSES

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Sustainable Design Principles in Traditional Gaziantep Houses

Abstract: This study explores sustainable design principles inherent in traditional Gaziantep houses, focusing on how historical, cultural, and environmental factors shaped their architectural forms. The research investigates spatial organization, material use, and social practices that contribute to sustainability, emphasizing inward-oriented courtyard designs, passive climate control, and community-based living patterns. Employing qualitative methods, including literature review and field observations, the study reveals that traditional Gaziantep houses embody ecological sensitivity and cultural continuity. Findings highlight the integration of local materials, natural ventilation, and multifunctional spaces as key sustainable features. The study contributes to understanding vernacular architecture's role in contemporary sustainable design, offering insights for modern housing that respect cultural identity and environmental context. Ultimately, this research supports the value of integrating traditional wisdom with modern sustainability efforts to foster resilient and culturally rich living environments.

Keywords: Sustainable Design, Cultural Heritage, Traditional Gaziantep Houses

Introduction

The traditional houses of Gaziantep, located in south-eastern Türkiye, represent a unique blend of cultural, environmental and social values embedded in architectural form. These houses embody centuries-old local design principles that respond to the climatic conditions of the region, the use of local materials and the socio-cultural structure of the user. In recent years, the concept of sustainability has come to the fore in architecture, emphasizing not only environmental performance but also cultural and social continuity. The biggest problem that people face today is the fight against the climate crisis. The main cause of the climate crisis is the production of buildings that are incompatible with nature. Examining examples of buildings and spaces that are in harmony with nature, use resources efficiently and adopt sustainable approaches can guide designers and decision-makers. When we look at these examples, traditional buildings have important lessons to teach us. It is possible to design a sustainable built environment by using lessons learned from the past while shaping the architecture of the future. This study aims to explore how traditional Gaziantep houses reflect sustainable design principles and how these elements can affect contemporary housing design.

Literature Review

The intersection of sustainable architecture and traditional housing has increasingly drawn attention in academic discourse, particularly in light of growing concerns about climate change, energy efficiency, and cultural identity. Numerous studies have highlighted the sustainable qualities inherent in traditional architectural practices, which are often rooted in local climates, materials, and social customs.

Sustainable design principles have been developed to ensure environmental, economic, and socio-cultural sustainability in architecture and urban design. Christopher Alexander highlights the timeless and universal principles of traditional architecture, shedding light on design approaches that harmonize with local culture (Alexander, 1979). The use of local materials, passive design techniques, natural ventilation, and daylight utilization are fundamental elements of sustainability in traditional architecture (Vale & Vale, 1991). Additionally, Rapoport (1969) emphasizes the influence of culture on architectural space design, drawing attention to the social dimension of sustainable design. Contemporary sustainability approaches prioritize improving building performance through renewable energy sources and advanced technical systems; however, the ecological and cultural values of traditional buildings continue to serve as important guides in contemporary design (Hegger et al., 2008). Modern sustainability frameworks—such as LEED, BREEAM, and the Living Building Challenge—have begun to incorporate principles long embedded in vernacular architecture. For example, passive solar design, use of renewable materials, and life-cycle thinking are now essential components of green architecture (Kibert, 2016). These overlaps have led to a growing recognition of the value in adapting traditional knowledge for contemporary use.

In conclusion, the literature suggests that vernacular architecture offers a repository of sustainable design principles that are both environmentally sound and culturally meaningful. Reinterpreting these principles in the context of contemporary needs may not only enhance architectural sustainability but also reinforce regional identity and social cohesion.

Methods

In this study employs a qualitative research design, integrating historical and inductive approaches. Historical analysis reviews archival materials, previous research, and field surveys to document traditional Gaziantep houses' architectural features. Inductive reasoning facilitates the identification and synthesis of sustainable design principles from observed data. The research includes site visits to existing traditional houses, photographic documentation, and semi-structured interviews with local residents and experts in vernacular architecture. Data triangulation ensures reliability by comparing literature findings, physical observations, and oral histories.

4. Findings

This study highlights the main sustainable design strategies found in the traditional houses of Gaziantep. Based on field visits, spatial observations, and cultural knowledge, the following themes stand out in terms of climate responsiveness, material use, and daily life practices.

4.1 Climate-Responsive Design:

Traditional Gaziantep houses were designed in harmony with the region's hot and dry climate. The positioning of the houses, the use of inner courtyards, and the thick stone walls help balance indoor temperatures. While the houses stay cool during the hot summer months, they also preserve warmth in winter. Courtyards (hayat) support ventilation and daylight while creating a comfortable private outdoor space.

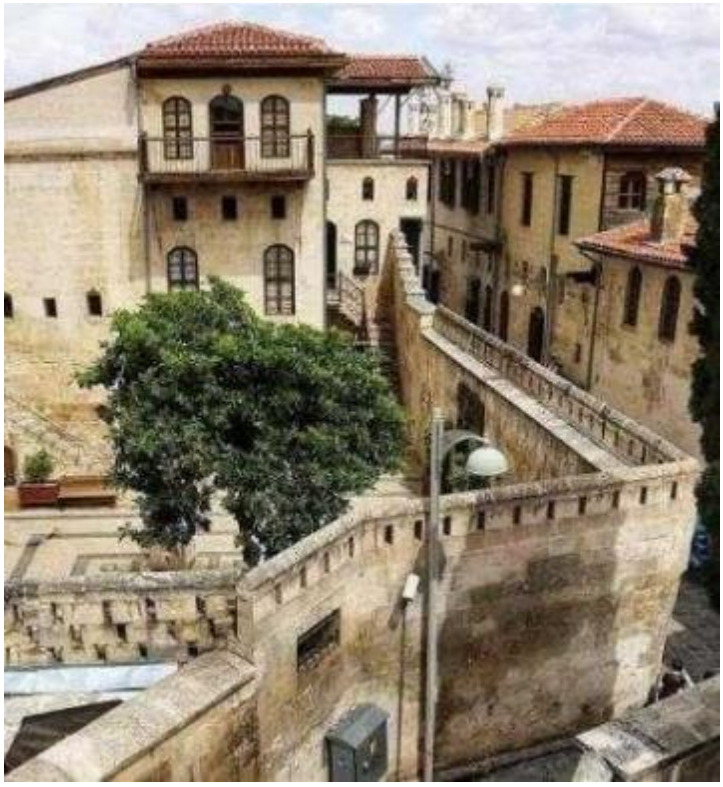

Figure 1. Traditional Gaziantep houses with thick stone walls separating it from the street (Yazgan S. E. archive)

The hot and dry climate in Gaziantep and its surroundings, and the fact that most of the year is rainless, made it necessary to create spaces open to the outside as much as possible in the houses. For this purpose, the desired environment was tried to be provided with the help of

large windows on the facades of the houses opening to the courtyard (hayat), bird windows (kuş penceresi), livan (eyvan) that provide both a connection between the rooms and a semi-open living space, and summer houses that create a cool sleeping space in the summer. (Fig.2 Fig 3) On the ground floors, the pool (gane) in the middle of the courtyard, the wall fountain and, in recent times, the fountains on the livan (eyvan) wall on the upper floors were also included in the planning as elements that provide coolness. (Fig 4)The thick stone walls of the buildings allowed the interior spaces to remain cool in the summer and warm in the winter.

Figure 2. Livan (Eyvan) (Yazgan S. E. archive)

Due to the prevailing northwest wind in the winter months in the region, the houses were generally oriented south, taking into account the prevailing wind direction. Since the weather is generally hot and sunny, special arrangements have been made outside the building; the streets are kept narrow, and the buildings and courtyard walls on both sides of the street provide shade to the street at all hours of the day. The passages, which are formed by the buildings continuing over the road in some places and are called "Kabaltı" in the region, create both shade and a wind corridor, providing cool spaces on the street during hot summer days. (Fig. 5)

Figure3.Bird windows (kuş penceresi)

Figure 4. Pool at the courtyard (gane)

Figure 5. Kabaltı (Yazgan S. E. archive)

4.2 Use of Local and Natural Materials:

The construction technique used in local architecture in Gaziantep is stacked stone. The structure is created with a box wall with a thickness varying between 50-60 cm. Stone materials such as basalt, havara, and keymuk were taken directly from the region and used in construction.

Stone has a high thermal mass, allowing it to absorb heat during the day and release it slowly at night. This helps regulate indoor temperatures, providing passive thermal comfort especially in regions with high diurnal temperature variations. Their use not only reduces environmental impact but also keeps a strong connection with the local identity and landscape. As well as stone materials such as havara and keymuk, lime mortar and timber details also contribute to a healthier indoor environment. (Fig. 6)

Figure 6. Use of Local and natural materials in Gaziantep houses (URL 1)

4.3 Passive Heating, Cooling, and Lighting:

Achieving thermal comfort without mechanical intervention is a defining feature of the architectural wisdom embedded in Gaziantep's vernacular dwellings. Rather than relying on technology, these homes utilize form, orientation, and materials to passively manage indoor temperature and lighting conditions.

High ceilings and thick stone walls mitigate extreme heat and cold, while small, strategically positioned windows near the ceiling optimize cross-ventilation and daylighting. These windows also limit direct solar gain, helping interiors remain cool during the scorching summer months. Central courtyards function as thermal moderators, where shade, airflow, and sometimes vegetation work together to reduce ambient temperature. (Fig. 7)

Seasonal flexibility is also integral to the layout: ground-floor semi-open spaces are used in the summer for sleeping and lounging, while enclosed upper-floor rooms are preferred in colder months. The thermal mass of local stone materials slows down heat transfer, contributing to a stable and comfortable interior climate. These strategies reflect a sophisticated understanding of passive environmental control, offering valuable lessons for contemporary sustainable design..

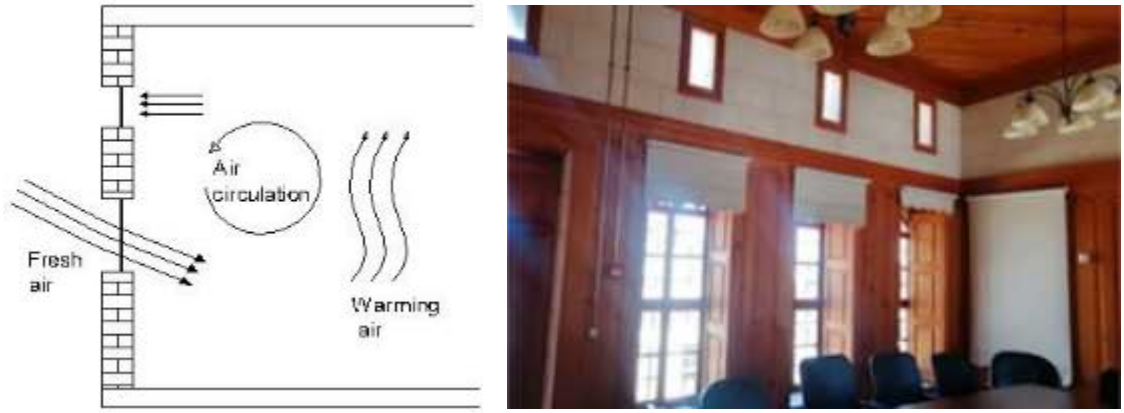

Figure 7. Passive ventilation system in Gaziantep houses (Yazgan S. E. archive)

4.4. Water Management and Storage:

Kastels and livas, which are only found in Gaziantep in Anatolia, are known as the water distribution system of the past. The historical infrastructure of Gaziantep consists of underground water facilities; kastels, and drinking water network; livas. (Fig. 8)

Even though the region is semi-arid, water was used carefully in traditional homes. Some houses were connected to underground channels (livas), and rainwater was collected for daily use. Simple systems like cisterns or clay pipes helped store and reuse water, showing a practical approach to sustainability.

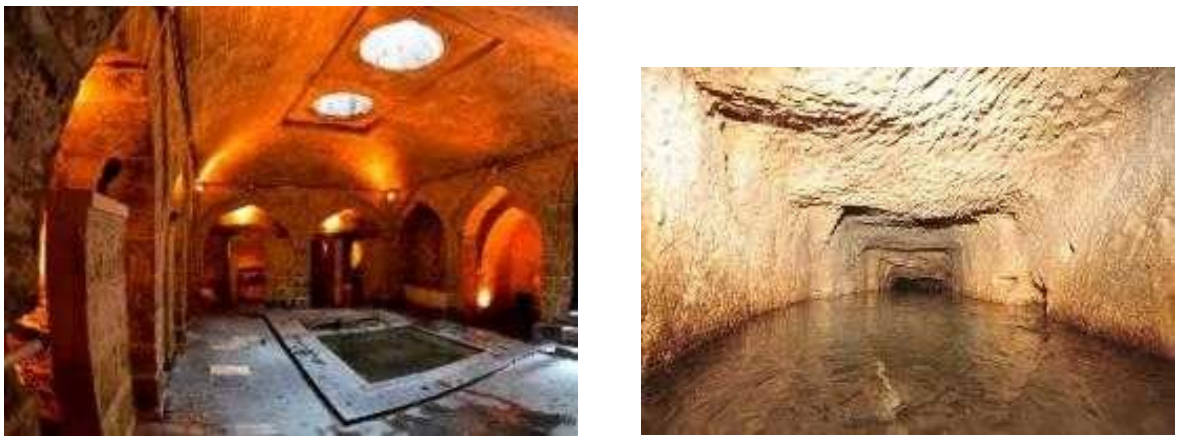

Figure 8. The historical infrastructure of Gaziantep; Kastels and Livas (URL 2)

4.5. Food Production and Storage Integration:

Sustainability in Gaziantep's traditional homes extended far beyond architecture—it encompassed everyday life, including food practices rooted in efficiency and seasonality. Houses were equipped with spaces specifically designed for food preparation, storage, and preservation. Underground haznas (cool storage rooms), outdoor ocaklık (stone ovens), and courtyard gardens allowed families to grow, process, and store their own food. These spaces supported a self-sufficient lifestyle while promoting ecological responsibility.(Fig.9)

Haznas provided natural refrigeration by maintaining low temperatures through thermal insulation and below-ground positioning. Food items such as fruits, grains, and legumes were dried, jarred, or stored in clay containers and suspended from ceilings to prevent spoilage. This system reduced waste and dependence on external supply chains.

The integration of food storage and production within the household layout highlights a deeply rooted relationship between architecture and sustainable living practices. This functional symbiosis reinforces not only environmental awareness but also food security and health. Traditional houses had spaces like hazna (cool storage rooms), gardens, and ovens (ocaklık) that supported self-sufficient food systems. Foods were dried and hung under the ceiling or kept underground to stay cool. These methods reduced waste and allowed families to store seasonal food.

Figure 9. Food production and storage in houses (Yazgan S. E. archive)

4.6. Social Sustainability and Community Life:

The traditional houses of Gaziantep are not only environmentally responsive but also socially sustainable. Their spatial configurations were designed to strengthen family bonds and community interactions. The central courtyard (hayat) functioned as the heart of the home—serving not only as a microclimate regulator but also as a shared social space where daily life unfolded collectively.

These courtyards facilitated various communal activities such as preparing winter food (e.g., drying vegetables, making tomato paste), baking bread in communal ovens, and celebrating cultural rituals. The open and semi-open spaces encouraged interaction among family members of different generations and between neighboring households. This physical proximity cultivated a strong sense of social cohesion and mutual support, key elements of sustainable communities.(Fig.10)

Gender roles and privacy considerations were also embedded within the architectural design. While there were no rigid architectural barriers, the spatial arrangement allowed for the flexible and respectful use of space according to cultural norms. Women could participate in social and domestic life comfortably, while private spaces such as guest rooms or upper-floor living areas ensured personal boundaries were maintained when needed.

Moreover, the neighborhood layout—narrow streets, shared entrances, and covered passages (kabaltı)—reinforced a culture of neighborliness. These features promoted social interaction, safety, and collective stewardship of the environment. Such human-centered design principles emphasize the importance of community resilience, interdependence, and cultural continuity—qualities that are often lacking in modern housing developments.

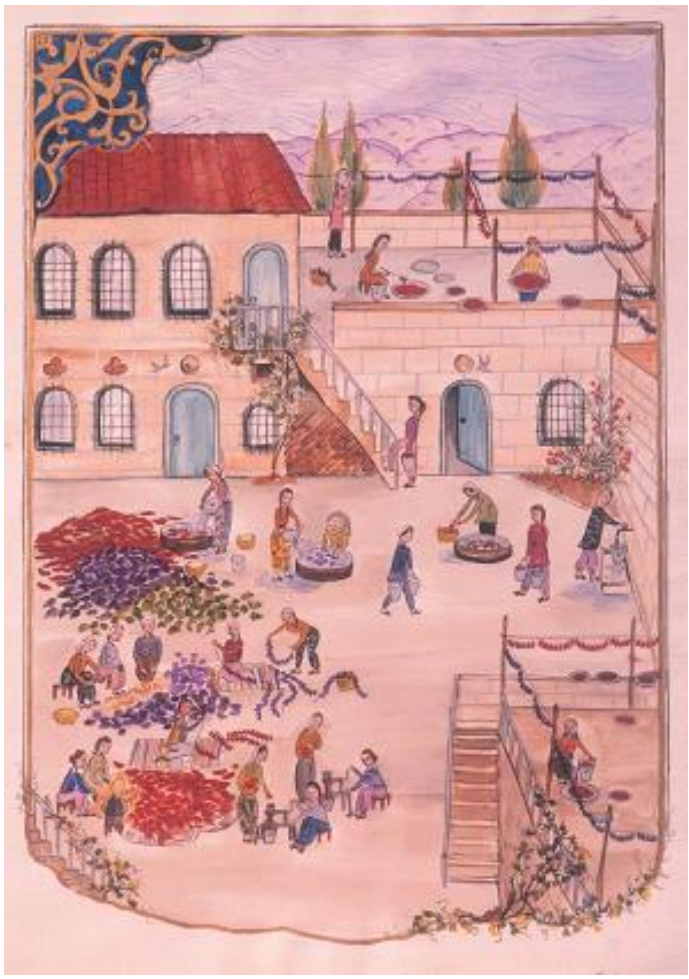

Figure 10. Social andcommunity life in the courtyard (hayat) (Coşkun D. archive)

4.7. Adaptability and Longevity:

Traditional houses in Gaziantep were built not only to meet the immediate needs of their inhabitants but also to adapt to evolving family structures and changing environmental conditions over time. Their spatial flexibility allowed rooms to serve multiple functions depending on the season or the users' needs. For example, a room might function as a cool bedroom during summer and later be used as a guest room or workspace during winter.

This adaptability enabled households to repurpose spaces easily without altering the building's core structure. As families grew or generations expanded, homes could be extended vertically or horizontally—by adding new floors or enclosing sections of the courtyard—while maintaining architectural harmony. This flexible and modular approach supported intergenerational continuity and prolonged the life cycle of the building. (Fig. 11)

Furthermore, the use of locally sourced, natural materials—such as stone, wood, and lime—made repairs and modifications both practical and sustainable. These materials not only

enhanced the durability of the structure but also ensured that maintenance could be done using traditional techniques and local craftsmanship. As a result, homes remained functional and livable for decades, often passed down through generations.

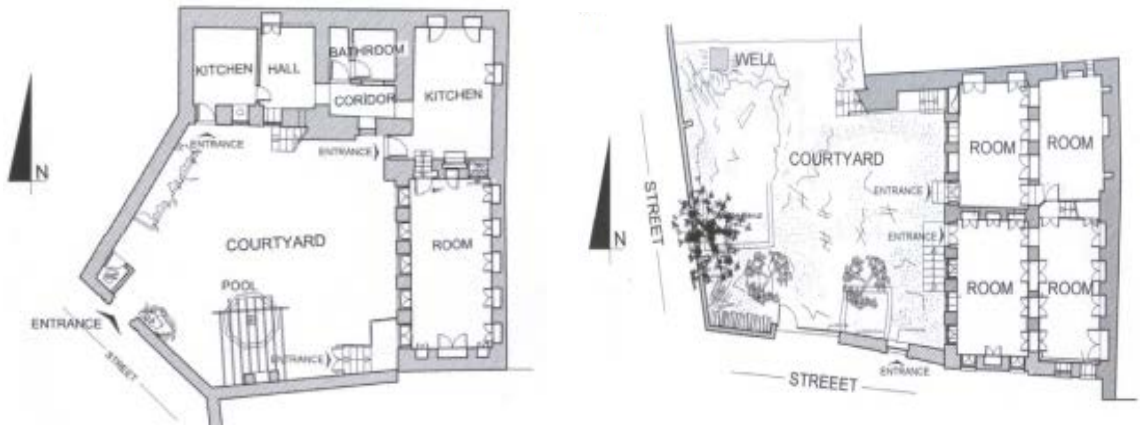

Figure 11. Plans of traditional Gaziantep houses (Korumaz M., Canan F., Güleç A.S., 2006).

The design philosophy behind these houses aligns closely with contemporary sustainability goals, including adaptability, resource efficiency, and resilience. Long before modern concepts like modularity or circular design emerged, Gaziantep's vernacular architecture had already embraced these values through user-centered and climate-conscious planning

5. Conclusion

Traditional Gaziantep houses offer an exceptional model of how vernacular architecture can inherently embody sustainable design principles that are both environmentally effective and culturally rooted. Through their use of local materials such as basalt and havara, strategic spatial organization around courtyards (hayat), and climate-responsive features like thick stone walls, bird windows, and semi-open spaces (livan), these houses achieve thermal comfort without relying on mechanical systems. Passive heating, cooling, and ventilation systems are seamlessly integrated into the architecture, demonstrating a deep understanding of the regional climate and natural resources.

Moreover, traditional water management systems like kastels and livas, along with food storage spaces such as hazna and garden areas, reflect a lifestyle that prioritized self-sufficiency and resource conservation. The multifunctionality and adaptability of interior spaces further support the longevity of these structures, enabling them to evolve with the needs of their users

over time. Equally important is the social and cultural sustainability embedded within the spatial organization. Shared courtyards encouraged collective living and supported gender-sensitive spatial use without rigid separations. Community-based production and rituals took place in these spaces, creating strong social cohesion and a sense of belonging.

In light of contemporary climate challenges and the increasing urgency to create sustainable living environments, the design principles observed in Gaziantep's traditional houses remain highly relevant. This study argues that integrating vernacular strategies into modern architectural practice can lead to more resilient, culturally meaningful, and environmentally responsible solutions. By bridging traditional knowledge with modern sustainability frameworks, architects and planners can shape built environments that are not only efficient but also deeply connected to place, identity, and heritage. Traditional Gaziantep houses offer valuable insights into sustainable design by harmonizing environmental adaptation with cultural and social needs. Their design principles centered on the hayat, use of local materials, and social spatial organization—can inform contemporary sustainable architecture, especially in regions with similar climatic and cultural contexts. Future housing designs should consider these vernacular strategies to enhance sustainability while preserving cultural identity. This study underscores the importance of integrating heritage knowledge into modern practices to create resilient and meaningful living environments.

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TOWARDS SUSTAINABLE HERITAGE CONSERVATION: AN EXAMINATION THROUGH THREE HISTORIC DISTRICTS IN ANKARA

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Towards Sustainable Heritage Conservation: An Examination Through Three Historic Districts in Ankara

Abstract: Ankara is an ancient city with a long history of human settlement. The Ankara Castle District, İstiklal (Jewish) District, and Hamamönü (Hacettepe) District are among the historic residential areas that have remained intact to the present day. These neighborhoods hold significant cultural value due to their historical character. Over time, various measures have been taken to preserve this cultural heritage. This study seeks to examine the different conservation strategies and intervention approaches applied to these three neighborhoods and assess whether they have successfully preserved their cultural significance. The research involves both literature and archival reviews to identify the cultural values and document the interventions. Ultimately, the study evaluates how the differing preservation approaches have influenced the cultural values of these historic districts.

Keywords: Conservation of Cultural Heritage, Identity, Heritage Value

Introduction

Ankara is a city located in the center of Anatolia that has been home to various civilizations since prehistoric times. The area surrounding Ankara Castle, the İstiklal (Jewish) Quarter, and Hamamönü (Hacettepe) are important historical residential areas that have survived to the present day with their original urban fabric and architectural structures. These neighborhoods are significant not only for their physical environment but also for the cultural and historical identity they embody.

Studies in the literature on historic neighborhoods in Ankara have generally focused on a single area or specific restoration interventions. While these studies emphasize the importance of physical interventions, they have not comparatively examined the effects of different conservation strategies on the cultural values of the neighborhoods.

This study aims to evaluate how well these practices preserve cultural values by examining the conservation strategies and intervention approaches implemented in the three historic neighborhoods in question. The research combines archival and literature reviews to provide an assessment.

Literature Review

The conservation and restoration of historic residential areas in Ankara have been addressed in both national and international literature. International organizations such as UNESCO and ICOMOS have established the fundamental principles for cultural heritage conservation, providing a framework for scholarly and practical studies (UNESCO, 2011; ICOMOS, 2013). In this regard, ICOMOS and UNESCO emphasize several key principles that

must be considered in the preservation of historic cities. Among these, the conservation of authenticity, the safeguarding of integrity, and the principle of minimum intervention are particularly significant. Authenticity refers to the preservation of the identity and original values of historic areas, while integrity encompasses the protection of the site within its spatial, cultural, and social context. The principle of minimum intervention advocates avoiding unnecessary or excessive alterations to structures or their surroundings, thereby preserving existing conditions as much as possible. Collectively, these approaches highlight that historic environments should not be regarded merely as physical assets, but also as integral components of social life, cultural practices, and collective memory (UNESCO, 2011; ICOMOS, 2013).

In the literature, studies on Ankara Castle have explored the impacts of restoration practices on architectural authenticity, revealing both positive and negative aspects. Research focusing on the İstiklal (Jewish) Quarter has examined the urban fabric and social context, underscoring the tensions between modern urban demands and the preservation of historical heritage. Studies concerning the Hacettepe Quarter, however, have largely been limited to documenting specific restoration projects, without providing a comprehensive analysis of the effects of interventions on cultural values.

A review of the existing works shows that most studies have concentrated on individual districts or specific interventions, while comparative evaluations of different conservation approaches across multiple neighborhoods remain limited. Addressing this gap, the present study adopts a comparative approach to examine Ankara Castle, the İstiklal (Jewish) Quarter, and the Hacettepe Quarter, aiming to evaluate the impacts of diverse conservation strategies on both architectural integrity and cultural values through archival research and literature review.

Furthermore, the distinction between tangible and intangible cultural heritage, as well as the classification of cultural values, constitutes a central framework for this research (UNESCO, 2003; ICOMOS, 2013). Tangible values are identified through aspects such as structural authenticity, material use, and spatial organization, while intangible values include collective memory, ways of life, beliefs, and cultural practices. This perspective demonstrates that the conservation of historic residential areas should ensure not only the continuity of their physical fabric but also the sustainability of their social and cultural contexts.

For this study, a literature review was conducted using academic databases. Relevant sources were identified through specific keywords (e.g., “historic residential areas in Ankara,” “conservation,” “restoration,” “cultural heritage”), allowing for a comprehensive assessment of

both the reflections of international principles in local practices and the current academic debates concerning historic residential areas in Ankara.

Methods

This study focuses on three historic areas in Ankara. It aims to evaluate the conservation strategies applied in Ankara Castle, İstiklal (Jewish) Quarter, and Hacettepe Quarter (Hamamönü). The methodology combines archival research and literature review, allowing for an assessment of the interventions implemented.

Archival research was conducted to collect information on past interventions, restoration projects, and future urban development approaches in the selected neighborhoods. Relevant documents were obtained from municipal archives, the National Thesis Center, and academic publications. Archival sources provided insights into the historical development of the neighborhoods and the types of conservation measures implemented. This approach parallels previous studies that emphasize the importance of archival documentation in understanding the evolution of historic urban areas and the extent to which their original characteristics have been preserved over time.

The literature review covered journal articles, theses, and conference proceedings related to heritage conservation, urban restoration techniques, and the evaluation of cultural values. In addition, the conservation principles established by UNESCO and ICOMOS were examined to support the conceptual framework of this study (UNESCO, 2003; UNESCO, 2011; ICOMOS, 2013).

The literature review not only provided information on previous case studies but also highlighted gaps in comparative analyses across multiple historic districts. In accordance with heritage studies methodology, the review was conducted systematically using academic databases, and relevant sources were identified using keywords such as "*historic residential areas in Ankara*," "*conservation*," "*restoration*," and "*cultural heritage*."

Findings and Discussion

To examine the different conservation strategies and intervention approaches applied to these three neighborhoods, these three cases are addressed and discussed individually. Afterwards, in the conclusion part, an overall assessment of whether they have successfully preserved their cultural significance is considered.

Ankara Castle

Ankara Castle is one of the oldest settlement areas of the city and has served different functions throughout history during the Phrygian, Roman, Byzantine, Seljuk, and Ottoman periods (Ergenç, 1984). In the 16th century, the castle and its surroundings were referred to as “Upper Side” and “Lower Side,” while the inner castle area became a residential zone for the city’s prestigious houses.

The castle walls were initially formed during the Roman period and were subsequently reinforced and repaired by various civilizations. During the Ottoman period, the inner castle settlement, with its narrow streets and houses featuring courtyards, exemplified the characteristic features of traditional Turkish-Islamic urban fabric (Urak & Çelik, 2002). This information provides an important foundation for understanding the architectural and social structure of the city in different periods.

Ankara Castle has undergone numerous interventions throughout history. At various times, the castle walls have been repaired and reinforced with stone renewal works. With its designation as a protected site in the 2000s, projects aimed at preserving and revitalizing the residential fabric gained momentum. In this context, the demolition of some traditional houses and their replacement with buildings that lack traces of the past has damaged the original texture. Today, comprehensive restoration efforts are being carried out in collaboration between Ankara Metropolitan Municipality and the Ministry of Culture (Ankara Büyükşehir Belediyesi, 2020).

Figure 1: Ankara Castle (Ankara Metropolitan Municipality Kudeb Archive, 2021)

Ankara Castle is a settlement that has hosted the lives of different civilizations from the past to the present. Having suffered various deteriorations throughout its history, the castle has occasionally undergone restoration, reconstruction, and reorganization interventions.

Table 1: Interventions carried out in past periods (Sansar & Akyol, 2023).

Period	Date(s)	Intervention(s)
Roman Period	A.D. 216	Caracalla Period: first consolidation and construction work carried out.
	A.D. 222–260	Severus Alexander and Valerian: extensive restorations after Persian attacks.
	After A.D. 260	Outer walls completely rebuilt after Persian and Gothic attacks.
Byzantine Period	641–668	Constans II: inner castle reconstructed.
	720–740	Leo III: walls heightened after Arab attacks.
	805	Nikephoros Phokas: restoration works.
	859	Michael III: southern inner castle and Şark Castle repaired; tower added.
	—	Use of Spolia: Roman columns, capitals, and bases reused in restorations.
Seljuk Period	1211	Alaeddin Keykubad I: inner castle and outer walls repaired.
	1249–1250	Keykavus II: Akkale added, northern wall built, wooden beams used.
Ottoman Period	1607	Cenabı Ahmed Pasha: city surrounded with additional walls after rebellions.
	1832	İbrahim Pasha: castle and walls repaired.
	1892	Akkale decorated with Ottoman coat of arms.
Republican Period	Until 1948	Akkale used as Ankara's first museum.
	1960s–1990s	Major restorations, wall joint repairs, and consolidation work.
	1999–2000	Restorations and joint works at Şark Castle.
	2020	Metal railings added to Şark Castle for security.
	2022	Archaeopark project: documentation, repair, cleaning, consolidation works.

Ankara Castle is significant not only as a structure used for military defence but also as a center of the city's social, cultural, and commercial life. There are significant tangible values, such as the Castle walls, traditional Ankara houses, narrow street layout, monuments like inns, and mosques, as well as intangible values, such as neighborhood life, neighbourly relations, handicrafts, and local culinary culture; the continuity of values passed down from the past to the present. Moreover, the castle and the historic tissue also highlight the history of Ankara and serve as a point of interest and curiosity for tourists with their identity and touristic value.

Hamamönü

Located in Ankara's Altındağ district, Hamamönü is an Ottoman settlement that developed around Hacı Bayram-ı Veli Mosque and Taceddin Dergah. Hamamönü, named after the Karacabey Bath, forms part of an area that characterizes Ottoman urban structure and contains a mosque, bath, caravanserai, and soup kitchens. In the past, it was known as the Karacabey imaret (Ergenç, 1995:50). From the 18th century onwards, it became one of the city's religious and cultural centers. The neighborhood reflects typical central Anatolian traditional residential architecture through timber frame upper floors with projections that sit on the masonry ground floors commonly seen in traditional Ankara houses.

Hamamönü remained neglected for many years, and by the mid-20th century, it had largely been abandoned and turned into an area of physical decay. In 2006, comprehensive street rehabilitation and restoration projects initiated by Altındağ Municipality breathed new life into the district (Altındağ Belediyesi İmar ve Şehircilik Müdürlüğü, 2010).

Within the scope of this revitalization project, most of the traditional houses were restored, new functions were added (cafés, cultural centers, art workshops), street fabric was renewed, and infrastructure was modernized. However, the issue of "authenticity" generated debate during the restoration process. In some cases, the use of modern materials instead of traditional ones was criticized for damaging the original fabric of the area and erasing traces of its past.

Figure 2: Beynamlızade Mansion Before and After Intervention (Altındağ Municipality, 2018)

Before restoration, the area was characterized by dilapidated, abandoned houses and deteriorated streets. Afterwards, it transformed into an urban fabric revived with clean façades and turned into tourist-oriented spaces. The areas around Taceddin Dergah and the Mehmet Akif Ersoy House are emblematic of this transformation.

The area stands out with its tangible and intangible cultural values. Tangible values include traditional Ankara houses, mosques, and the Taceddin Dergah, which together represent authentic examples of the Ottoman urban fabric. In terms of intangible values, the Hacı Bayram tradition, religious events, and neighborhood life reflect the continuity of the area's cultural heritage. From the perspective of identity value, the area is one of the few that preserves the urban texture of the Ottoman period. Regarding its social value, following the restoration works, the area has once again become a vibrant center of social life, hosting festivals, handicrafts, and cultural events, and has emerged as one of the city's preferred urban hubs.

İstiklal (Jewish) Quarter

İstiklal Quarter, also known as the Jewish Quarter, was a settlement in Ankara where Jews lived predominantly from the mid-19th century onwards. The neighborhood contained a synagogue, shops, and traditional houses. The presence of this community continued during the early years of the Republic; however, due to migrations in the mid-20th century, the Jewish population in the area rapidly declined. In the post-Republican period, the social structure of the neighborhood changed, and houses were used for purposes other than their original functions. (Hosanlı & Altınöz, 2016).

From the 1980s onwards, as part of urban renewal efforts, some buildings were demolished, while others were replaced with modern residences through interventions and restoration works. Although there were initiatives to preserve the synagogue and surrounding structures, the overall integrity of the neighborhood was largely lost. In the 2000s, despite being a protected site, modern construction continued, and the number of buildings preserved from the past to the present has decreased (Hosanlı & Altınöz, 2016).

The area embodies both tangible and intangible cultural values associated with Ankara's Jewish heritage. Tangible values are represented by the synagogue and a few remaining examples of residential architecture, which together serve as significant physical reminders of the community's historical presence. Intangible values include the religious and social traditions of the Jewish community, reflecting the collective memory and continuity of their cultural practices. In terms of identity value, the area constitutes an important element of Ankara's multicultural character, symbolizing the city's diverse historical and cultural layers.

Comparative Assessment and Conclusion

Three historic residential areas show different results in terms of the sustainability of cultural values and conservation approaches. Ankara Castle continues to preserve its tangible and intangible cultural values to a large extent. However, increasing tourist use threatens the unique continuity of neighborhood life and leads to the gradual weakening of traditional activities. Hamamönü has become a vibrant center for cultural events, social activities, and tourist use following its restoration. However, intensive interventions and the use of modern materials carry the risk of completely erasing the area's authentic fabric. The İstiklal (Jewish) Neighborhood stands out as the most at-risk area. The neighborhood's identity and memory value have largely been lost; traces of its past are limited to only a few buildings and symbolic elements. This situation places the area in the most vulnerable position in terms of sustainability.

In terms of differences, Ankara Castle stands out for its military and historical identity, Hamamönü for its religious and cultural structure, and the İstiklal Neighborhood for its multicultural heritage. When examining the commonalities, the fundamental problems that emerge in all three areas are the pressure of urban transformation, loss of identity due to functional changes, and the gradual disappearance of traces from the past.

This study analyzes Ankara Castle, Hamamönü, and the İstiklal (Jewish) Quarter within their historical contexts, focusing on the conservation and intervention strategies implemented in these areas. The findings reveal that conservation efforts should extend beyond the preservation of physical structures to include the safeguarding of social and cultural values that shape the identity of historic environments. While Ankara Castle has largely retained its cultural heritage, certain traditional structures have been irretrievably lost. The restoration initiatives in Hamamönü have successfully revitalized social life and contributed to the continuity of cultural practices. Conversely, in the İstiklal Quarter, some interventions have resulted in the erosion of the area’s original character and authenticity.

In conclusion, sustainable conservation in historic residential areas requires a holistic approach that balances the protection of tangible and intangible heritage with the dynamic needs of contemporary urban life. Ensuring the sustainable integration of cultural heritage into the urban fabric is essential for maintaining the continuity of historical layers and transmitting the traces of the past to future generations.

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PERFORMING SUSTAINABILITY: THE VENICE ARCHITECTURE BIENNALE AS A STAGE OF DISCOURSE, DISPLAY, AND DISSONANCE

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Performing Sustainability: The Venice Architecture Biennale as a Stage of Discourse, Display, and Dissonance

Abstract: The Venice Architecture Biennale is one of the most influential cultural platforms shaping global architectural discourse. In recent editions, sustainability has emerged as a central theme, reflecting growing awareness of the **global climate crisis**, **ecological justice**, and **sustainable design qualities**. This research aims to analyze how selected national pavilions represent and interpret sustainability through curatorial narratives, spatial design, and material choices. The study applies a literature review visual analysis and scientific studies. The analysis examines how countries use the Biennale to communicate their national approaches to sustainability and how these are expressed both symbolically and materially. The findings reveal that while some pavilions adopt sustainability as a visual or promotional concept, others demonstrate authentic environmental and social engagement, positioning the Biennale as a stage of **performative sustainability**.

Keywords: The Venice Architecture Biennale, Global Climate Crisis, Ecological Justice, Sustainable Design Qualities, Performative Sustainability

Introduction

The Venice Architecture Biennale is one of the most influential events shaping global architectural discourse. It brings together nations, institutions, and architecture professionals to explore how architecture reflects social, political, and environmental changes. Over the years, the Biennale has evolved from a stage of design excellence into a platform where global issues are discussed through curatorial and spatial expression. The editions of 2021 “How Will We Live Together?” and 2023 “The Laboratory of the Future” particularly emphasized sustainability, ecological justice, and collective futures. Within these frameworks, sustainability evolved from a technical concern into a holistic cultural and ethical issue, positioning architecture as a potential solution maker.

This study aims to analyze how national pavilions interpret and represent sustainability within these two Biennale editions. These two editions were selected because they represent the most recent and thematically relevant moments in the Biennale’s history, reflecting the postpandemic shift in global priorities where climate consciousness and social resilience became central to architectural discourse. By combining a literature review, discourse analysis, and visual interpretation, it examines how participants use the Biennale to communicate their national approaches to sustainability and how these narratives are reflected in curatorial texts, design decisions, and material choices. The study focuses on a group of national pavilions from the 2021 and 2023 editions that explicitly address sustainability through contrasting approaches, treating it as a genuine environmental commitment, others as a symbolic or performative display. These cases were chosen because they clearly represent the diversity of curatorial strategies and material practices related to sustainability within the Biennale. The research

contributes to a broader understanding of how cultural platforms negotiate the tension between ethical intention and aesthetic display in an era of growing climate consciousness.

Literature Review

The Venice Architecture Biennale has a long historical heritage as a key platform for examining the relationship between architecture and global socio-political dynamics. Kazandere (2024) also emphasizes that the Biennale functions as a space where ideological and national narratives are visually constructed and contested through architectural representation. Scholars such as McQuire (2010) and Yaneva (2017) argue that architectural exhibitions extend beyond design discourse, functioning as performative arenas where national identities, ideologies, and global narratives are negotiated. Within this context, sustainability has become one of the most debated themes in contemporary architecture. As Graham (2015) and Geertman & Rocco (2020) point out, it often intersects with issues of geopolitical soft power and national branding, turning environmental awareness into a form of cultural diplomacy.

Recent studies have also highlighted the superficial use of sustainability in such large-scale cultural events. Di Marino and Lapintie (2017) describe how sustainability is frequently presented as an aestheticized commitment rather than a structural agenda. Bozsik (2022) expands on this critique, identifying a growing pattern of greenwashing, in which ecological values are represented symbolically but not implemented through concrete actions. These critiques reflect wider debates about the contradictions of sustainability within cultural and artistic contexts, particularly in high-carbon events such as biennales. For this reason, the concept of performative sustainability has emerged in architecture. This perspective reveals how the act of "performing" sustainability often masks unresolved structural issues within the production of cultural events. This research builds upon these theoretical foundations but differs from previous studies in both its focus and scope. By analyzing a group of national pavilions from the 2021 and 2023 editions of the Venice Architecture Biennale that represent both performative and community-based approaches to sustainability, this study seeks to bridge the gap between aesthetic critique and sustainability intentions. These cases were chosen for their thematic diversity and their capacity to illustrate how sustainability is simultaneously performed and debated within the Biennale context. The literature reviewed above provides the conceptual framework for understanding how sustainability narratives are performed and contested.

Methods

This study adopts two main approaches. The first is a discourse analysis, and the second is a visual and spatial analysis. Both approaches are based on a qualitative and interpretive research framework, focusing on the visual and discursive examination of selected national pavilions from 2021 and 2023 of the Venice Architecture Biennale.

The first method is discourse analysis. Curatorial texts, official Biennale publications, and pavilion statements were examined to understand how sustainability is defined and communicated. Key questions guiding this analysis included. How is sustainability framed? Is it presented as a call for systemic change, or used merely for symbolic and promotional purposes?

The second method is visual and spatial analysis. The design elements of the pavilions, including spatial layout, material choices, and exhibition strategies, were studied through photographs, videos, and digital documentation. This helped determine whether the environmental claims were supported by the architectural and design context.

These methods show a pattern. Some pavilions use sustainability as a rhetorical or aesthetic tool, while others demonstrate deeper, more engaged approaches. This contradiction creates to the Biennale as a stage of "performative sustainability."

Findings and Discussion

The analysis of national pavilions from the 2021 and 2023 editions of the Venice Architecture Biennale shows a clear contrast in how sustainability is represented. Building on Kazandere (2024), which examines the ideological and national dimensions of architectural representation, this study extends that framework to sustainability narratives within the Biennale context. The findings reveal two dominant approaches: symbolic and performative representations on one hand, and materially grounded, community-based interpretations on the other

A considerable number of pavilions demonstrated what can be described as strategic greenwashing. The use of sustainability as a visual or diplomatic tool rather than a genuine environmental commitment. In several exhibitions, sustainability appeared mainly through aesthetic gestures such as the use of recycled materials, slogans about climate change, or natural colour palettes. However, these gestures were rarely supported by transparent information about the environmental footprint of the installations or the logistics behind their production.

This pattern was most visible in well-funded pavilions that prioritized visual impact. Despite their impressive design, the curatorial narratives often lacked depth or critical engagement with sustainability itself. These cases reflect the concerns raised by Di Marino and Lapintie (2017) and Bozsik (2022), who argue that sustainability in architectural exhibitions is frequently reduced to a surface-level performance rather than a structural practice.

In contrast, several pavilions proposed more meaningful interpretations of sustainability, emphasizing social, cultural, and material awareness. The Nordic Pavilion exhibitions at 2021 and 2023 for instance, explored themes of climate displacement and coexistence by presenting participatory design projects developed with Indigenous and refugee communities. Instead of focusing on technological innovation, it highlighted the human and ethical dimensions of sustainability.

Similarly, the Philippines Pavilion presented a curatorial narrative centered on Indigenous ecological knowledge and community empowerment. The exhibition drew attention to traditional environmental practices and local material use, showing sustainability as part of a cultural code. These pavilions embodied what scholars describe as decolonial sustainability. These approaches connect ecology with cultural identity.

Across the analyzed examples, a recurring contradiction emerged between the sustainability goals declared in curatorial narratives and the carbon-heavy production methods used in practice. This inconsistency highlights a crucial question. Can a pavilion claim ecological responsibility while relying on unsustainable production methods? The gap between curatorial intentions and material realities illustrates how sustainability often remains performed rather than practiced.

The findings emphasize a fundamental tension within the Biennale. The findings emphasize that the Biennale operates simultaneously as a platform for climate discourse and as an instrument of national representation. While certain pavilions succeed in reframing sustainability through collaboration, locality, and reflection. Many pavilions remain constrained by the visual language of progress and spectacle. Overall, the Venice Architecture Biennale emerges not only as a site of exhibition but also as an active agent shaping the global discourse on sustainability.

Conclusion

This study examined how national pavilions in the 2021 and 2023 editions of the Venice Architecture Biennale approach sustainability. The findings show two main patterns. Some

pavilions used sustainability as part of their national image or exhibition aesthetics, creating symbolic or promotional gestures that did not always correspond to their design or production methods. On the other hand, several pavilions developed more authentic interpretations, linking sustainability to community values, social inclusion, and cultural identity.

These results indicate that the Biennale functions simultaneously as a space for global reflection on sustainability and as a medium through which nations present and promote their cultural identities. These functions explain why sustainability often appears as a performance rather than a consistent practice. The Biennale reflects the ambitions and contradictions of contemporary culture. This promotes environmental awareness while depending on systems that remain environmentally costly.

Greater transparency in exhibition production and curatorial planning, the use of local resources, and long-term material strategies could transform the Biennale into a model of sustainable cultural production rather than a temporary performance of ecological concern.

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CLIMATE CHANGE AND OTHER SOURCES OF STRESS ON CULTURAL LANDSCAPES: THE CASE OF CAPPADOCIA

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Climate Change and Other Sources of Stress on Cultural Landscapes: The Case of Cappadocia

Abstract: Cultural landscapes are shaped by long-term interactions between people and their environments and embody both tangible and intangible values. This paper examines how climate change and other stressors threaten their sustainability, focusing on Cappadocia in central Türkiye. Formed by volcanic activity and ongoing erosion, Cappadocia's distinctive topography and extensive rock-cut architecture create a mixed-heritage setting in which nature and culture are inseparable. The paper synthesizes climate-related risks—flooding, drought, temperature and moisture fluctuations, and wind erosion—together with locally intensified pressures from mass tourism. Particular attention is given to the vulnerabilities of rock-cut façades; rooms with roof openings; floor-level archaeological traces and carved furnishings; and Byzantine wall paintings. The paper argues that the environmental, social, cultural, and economic dimensions of sustainability are interdependent and that formal recognition of Cappadocia in its entirety as a cultural landscape—paired with measures to reduce climatic and non-climatic stressors—is urgently needed to ensure long-term resilience.

Keywords: cultural landscape; Cappadocia; climate change; World Heritage; resilience

Introduction

In 1992, cultural landscape was introduced as a heritage category to define "combined works of nature and of man" (Araoz, 2008, p. 33, 36; Jokilehto, 2013, p. 1).[1] Shaped by interactions between people and their environments, cultural landscapes are repositories of cultural, social, and economic practices. As such, they encompass both tangible and intangible values.

Cultural landscapes take diverse forms within three categories defined by UNESCO: the "landscape designed and created intentionally by man," such as gardens and parks; the "organically evolved landscape," such as agricultural terraces; and the "associative cultural landscape," such as sites with strong religious connotations (UNESCO, 2008).

Cultural landscapes and communities worldwide face significant physical, social, and economic change. Natural and cultural heritage have become vulnerable to the combined effects of economic crises, tourism, and, increasingly, climate-change-related disasters (Öztürk Büke, 2023, 474).

This paper calls attention to climate change and other sources of stress on cultural landscapes with particular focus on Cappadocia, a human-altered volcanic landscape in central Türkiye. It argues that environmental, cultural, social, and economic sustainability cannot be addressed in isolation and are best understood in a cultural landscape framework such as

[1] The World Heritage Convention in 1992 was the first international attempt to recognize and protect cultural landscapes (UNESCO World Heritage Centre, n.d.-a).

Cappadocia. Official recognition of the region in its entirety as a cultural landscape would be a critical first step toward its sustainability.

Cultural Landscape of Cappadocia

Now a popular tourist destination, Cappadocia is known for its distinctive landscape, Byzantine heritage, and rupestrian settlements. With natural formations and rock-cut architecture interwoven, Cappadocia exemplifies a cultural landscape in which the boundary between nature and culture is blurred. The region, characterized by unique geological formations, carved structures, and traditional settlements, broadly corresponds to the area encompassed by the contemporary provinces of Aksaray, Nevşehir, Kayseri, and Niğde.

Volcanic activity from now-dormant mountains such as Mt. Erciyes (3,917 m) and Mt. Hasan (3,268 m), together with continuing erosion, produced the area's otherworldly topography and its abundance of rock-cut architecture. The Kızılırmak River (ancient Halys) forms a natural boundary to the north and has enabled settlement under harsh continental conditions for millennia. The morphology ranges from low mountains to floodplains, with table-like (mesa) outcrops dominating the landscape.

Traditional settlements were adapted to the local physical and environmental context and are well suited to the climate. "Castle settlements" were carved and built on pointed hills (e.g., Uçhisar and Ortahisar), while "valley settlements" were carved and built along volcanic valleys (e.g., Zelve). There are also "underground cities" carved in multiple layers below ground (e.g., Kaymaklı and Derinkuyu). While underground cities were likely used as temporary shelters, castle and valley settlements served varied functions and include diverse building types (e.g., dwellings, religious structures, agrarian installations), constructed with various materials and techniques (rock-cut, masonry, and hybrid), and connected by rock-cut paths, stairs, and tunnels (Öztürk Büke, 2023, 476). Together with the natural formations, these features comprise a mixed heritage in which nature and culture are inseparable—what we call the Cappadocian cultural landscape.

In 1985, the region between the cities of Nevşehir, Ürgüp, and Avanos, along with several singled-out sites, was inscribed on the UNESCO World Heritage List as Göreme National Park and the Rock Sites of Cappadocia. The inscription emphasizes both the density of rock formations (nature) and rock-cut architecture (culture) and describes the area as "one of the world's most striking and largest cave-dwelling complexes" (UNESCO World Heritage Centre, n.d.-b).

As Jokilehto notes, the recent trend has been toward larger nominated properties—especially cultural landscapes and historic towns—reflecting a more holistic definition of sites and an emphasis on integrity (Jokilehto, 2006). Nevertheless, the integrity of Cappadocia as a cultural landscape has not yet been fully recognized in national policy. In 2011, Decree-Law 648 (KHK 648) in Türkiye removed natural heritage sites from the jurisdiction of the Ministry of Culture and Tourism (T.C. Resmi Gazete, 2011). This decision risks mixed (natural and cultural) heritage areas such as Cappadocia that require holistic protection (ICOMOS Turkey National Committee, 2012). In practice, institutions continue to distinguish between natural and cultural heritage. Yet nature and culture are intertwined and interdependent (Tarihi Kentler Birliği, 2023), and the long-standing "false dichotomy" between them is increasingly questioned (Wells, 2016, p. 219).

In response, the ICOMOS Turkey National Committee issued the Cappadocia Declaration (2012), urging a holistic approach aligned with evolving international concepts of heritage and recommending that the Ministry update conservation terminology to include cultural landscape in legislation.

Such holistic thinking is now more urgent than ever as climate change threatens the sustainability of cultural landscapes. Climate change affects both natural and cultural heritage and their tangible and intangible dimensions; not only historic buildings but also communities are impacted (UNESCO World Heritage Centre, 2007, p. 23).

Impacts of Climate Change and Other Sources of Stress

When Cappadocia was inscribed in 1985, it was already noted as "an outstanding example of a traditional human settlement which has become vulnerable under the combined effects of natural erosion and, more recently, tourism" (UNESCO World Heritage Centre, n.d.-b). According to UNESCO's report on climate change and World Heritage, "Climate change has now emerged as one of the most serious threats impacting on the conservation of this heritage" (UNESCO World Heritage Centre, 2007, p. 3).

The United Nations Framework Convention on Climate Change (UNFCCC, 1992) aims to stabilize greenhouse gas concentrations at a level that prevents "dangerous anthropogenic interference with the climate system" (United Nations, 1992, p. 9). The Kyoto Protocol (1997) and the Paris Agreement (2015) build upon this foundational convention (United Nations Framework Convention on Climate Change [UNFCCC], n.d.-a, n.d.-b).

ICOMOS similarly stresses that "climate change is already impacting communities and heritage globally, and these trends are rapidly worsening" (ICOMOS Climate Change and Cultural Heritage Working Group, 2019).

Major climate indicators include shifts in atmospheric moisture and temperature, desertification, and wind regimes; principal risks are numerous. Flooding at one extreme and drought at the other—together with groundwater changes, wind-driven sand, heat waves, and declining water tables—affect natural and cultural heritage in Cappadocia (UNESCO World Heritage Centre, 2007).

Erosion, which produced Cappadocia's unique formations, continues. While some features diminish, new ones emerge under wind and rain. Climate change and intensified human activity accelerate these processes unevenly. As a result, some medieval churches documented in the 19th and early 20th centuries survived into the modern era but have recently been lost.

Façades and rooms with roof openings—such as kitchens with conical chimney-vaults—are particularly vulnerable to weathering and erosion. Flooding poses additional risks in a region where many historic structures are hewn from living rock: prolonged saturation can damage materials not designed for immersion; subsequent drying can encourage mould growth; and fast-flowing water can erode and weaken structures (UNESCO World Heritage Centre, 2007, p. 23). Rock-cut furniture—key evidence for identifying and differentiating historic functions (e.g., stables, monastic refectories)—and other floor-level traces (e.g., graves, hearths) are especially susceptible to fluvial erosion. Above all, fluctuations in atmospheric moisture threaten Byzantine wall paintings; rising soil moisture increases salt mobilization which, upon drying, can cause damaging crystallization on decorated surfaces (UNESCO World Heritage Centre, 2007, p. 23).

Although UNESCO recommends "increasing the resilience of a site by reducing non-climatic sources of stress" (UNESCO World Heritage Centre, 2007), mass tourism and its instruments in Cappadocia—e.g., road and building construction, inappropriate interventions on heritage sites, and balloon, ATV, horse-riding, safari, and rally tours—amplify climate impacts.

Concluding Remarks

Cultural heritage is both threatened by climate change and an asset for adaptation and mitigation. The Sustainable Development Goals and the Paris Agreement recognize that cultural heritage can guide actions that support resilience and sustainability (Tarihi Kentler

Birliği, 2023). Likewise, international disaster-risk frameworks (e.g., Hyogo[2] and Sendai[3]) emphasize links among heritage, risk reduction, and resilience (Tarihi Kentler Birliği, 2023).

Cultural heritage can foster a clean, circular economy by supporting nature-friendly lifeways and ecological design, contributing to social and environmental sustainability (Gençer, 2022, p. 38). Building resilience at historic sites requires addressing both chronic climate stresses and acute shocks from other hazards (Tarihi Kentler Birliği, 2023, p. 121).

For Cappadocia, urgent steps include recognizing the cultural landscape and its integrity; acknowledging the inseparability of natural and cultural assets and their tangible and intangible values; and reducing non-climatic stressors alongside climate-related risks.

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BETWEEN PRESERVATION AND ADAPTIVE REUSE THE MEASUREMENT OF RESILIENCE TOWARDS CLIMATE NEUTRALITY OF CULTURAL HERITAGE

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Between Preservation and Adaptive Reuse the Measurement of Resilience Towards Climate Neutrality of Cultural Heritage

Abstract: This paper explores resilience in historic cultural heritage, framing adaptive reuse and preservation as complementary strategies to safeguard the intrinsic value of buildings over time. A methodological framework is proposed, combining top-down and bottom-up perspectives: the top-down approach defines strategies and tools to guide interventions toward resilience, while the bottom-up approach examines international case studies to evaluate the effectiveness of implemented design actions.

The evaluation process integrates qualitative and quantitative methods across three project phases—concept, design/execution, and management/end-of-life—and is structured into four main areas: value/preservation, accessibility/comfort, circularity, and energy, enabling monitoring of sustainability and cultural value preservation. Analysis of twelve case studies reveals that interventions are often fragmented, with limited integration between evaluation frameworks and design practice. The proposed methodology highlights gaps and opportunities, providing a comprehensive approach to measure heritage resilience and support interventions that balance sustainability, conservation, and value enhancement in historic and sensitive contexts.

Keywords: resilience, adaptive reuse, heritage preservation, circular approach, accessibility.

Adaptive reuse and preservation for resilient cultural heritage

In consolidated and historical contexts, the terms preservation and adaptive reuse have always progressed in parallel as, although sometimes read antithetically, they both pursue the concept of handing down a "value" to the future: in the first case by preserving what is original, in the second case by pursuing an idea of integrated preservation (Amsterdam Declaration, 1975) that envisages identifying a right use of the good as its measure of preservation and maintenance over time (Carbonara, 2021).

The adaptive reuse of cultural heritage enables the implementation of energy transition strategies and circular resource economy (Baiani et al 2024a, 2024b). On the environmental side, it contributes to reducing environmental impact through reduced consumption of natural resources, reduced demolition waste and embodied carbon savings. On the economic and sociocultural side, reuse also makes it possible to return buildings to the community, so that they once again take on the function of common goods. In this way, the recovered heritage becomes an opportunity for inclusion, social cohesion and neighbourhood revitalisation, contributing to regenerate urban and community fabrics (Foster, 2020), responding - in a logic of punctual and careful intervention - to the need to meet current standards and needs (Hu & Świerzawski, 2024).

Preservation and adaptive reuse operations are therefore part of the strategies, programmes and interventions aimed at a broad concept of "project quality" that must

integrate - even for protected contexts - the ability to govern the ways, times and cultural and technical contents of the project production process, in line with the application of the Do Not Significant Harm (DNSH) and Environmental, Social, Governance (ESG) criteria (Mussinelli, 2024; Tartaglia et al 2024; Piperata, 2024).

In this context, evaluating the quality of this planning process means measuring the resilience of heritage to change (EU, 2009; Ahern, 2011; Altay-Kaya et al 2025) as advocated more than 30 years ago among the objectives of Agenda 21 (UN 1992), where it was explicitly suggested that in order to monitor and evaluate progress towards sustainable development, it would be necessary to adopt indicators capable of measuring change across economic, social and environmental dimensions.

Cultural heritage resilience: a systematic analysis

The paper analyses the concept of resilience as a key factor for conscious interventions of reuse, conservation and valorisation of the historical built heritage, from the perspective of climate neutrality. In this context, working on the concept of resilience means identifying capacities and conditions according to which a system (territory, city, building) is able to adapt and react positively to changes and transformations (Folke, Colding and Berkes, 2003; Colucci, 2012) while maintaining the recognisability that has determined its intrinsic value over time. Resilience thus offers a criterion for assessing the compatibility of transformations, acting as a bridge between heritage valorisation and protection.

The different interventions must therefore be evaluated according to a ‘case-by-case’ approach that must aim towards an adaptation of the different strategies in a transition process that meets the 6 taxonomic objectives (Regulation (EU) 2020/852).

In an attempt to read again in a more accurate and specific way these 6 international objectives, the research -here briefly presented- has as its prevailing objective the construction of a methodological flow useful to systemise paths and evaluation systems of an intervention in the specific historical and consolidated context, which can lead to a “weighted” measurement of the resilience of the heritage in the light of the most up-to-date climate neutrality objectives. The key research question is to understand the process of “measuring” the resilience of the architectural heritage in historical and consolidated contexts, systemising the value of the assets with the contemporary needs of use/reuse.

The heritage taken into consideration is the historical built heritage that is part of sensitive contexts, not only from a historical-cultural point of view, but also in the framework

of the increasing climatic threats, with a high hydrogeological risk, as well as problems related to the loss of natural habitats and biodiversity (Baiani et al, 2023).

The achievement of this objective required a critical reinterpretation of the main resilience assessment tools, qualitative parameters, indices or indicators, systematised in a manner functional to the research objectives into 4 prevailing areas of assessment (all obviously related to the specific field of investigation):

1. **value/preservation field**, connected to the evaluation of the degree of adaptation of climatic-environmental strategies to the specificity of the historical-cultural heritage, with attention to the preservation issue;
2. **accessibility/comfort field**: connected to the broad evaluation of the concept of accessibility of the asset, both from the physical point of view and at the level of use of space and comfort for the user;
3. **circularity field**, connected to the evaluation of transition strategies towards a circular economy, starting from a compatible reuse of space to the remanufacturing and reuse of systems and components and the recycling of materials;
4. **energy field**, connected to the assessment of effectiveness and efficiency strategies in terms of a wide-ranging energy transition.

Ambits of assessment that can be structured in relation to three levels representative of the three phases of the building process (Dodd, Donatello & Cordella, 2021), starting from the design concept phase, through to construction and end-of-life management.

A Top-Down and Bottom-Up approach to evaluation

In historical and consolidated contexts, the intervention must necessarily be related not only to the contemporary needs of use, but also to the intrinsic cultural values of the asset, both on a material and immaterial level, reinterpreting resilience as the key term of the design process towards a rethinking of strategies not only in terms of the boundaries of investigation, but also in terms of the effects of the intervention. (Lucarelli et al 2018).

In the research, the resilience approach was analysed following two complementary points of view:

- top-down, through the definition of strategies and actions that can direct project action towards resilience;
- bottom-up, through the description of how, in the design field, the idea of resilience is concretely interpreted - or in some cases how it is disregarded.

These two perspectives fit with the different timeframes of design making and - in this specific research work - with the different scales of measurement of the design process which, in order to be correctly ‘measured’, must take into account (EU, 2009; Eurostat 2024) the different levels of depth in terms of accuracy and reliability of data, the existing potential and performance required, as well as the degree of professional skills and competences involved.

If the design process involves:

- a concept level: a basic level involving knowledge and interpretation of the existing situation and the preparation of action strategies aimed at the specific context, with initial qualitative assessments for the design concept and for the communication of what is required;
- a detailed design and construction level: an intermediate level of materialisation of the requirements that have emerged into physical elements, involving a quantitative assessment of performance and monitoring according to standardised units and methods;
- an 'in-use' project management level that involving the monitoring and tracking of activity in both the construction and operation phases;

These three macro-moments can be associated with assessment levels that are built up in accordance with the organisation of the project and the variables involved.

Although all three phases have their own specific relevance, the first phase is hinged on those steering tools that are necessary to develop a correct workflow and acquires greater weight where practical activities are to be hinged towards a process that can be defined as truly resilient. This is undoubtedly the most critical moment in a transformative process in historical and consolidated contexts that aims to achieve climate neutrality goals from which not even cultural heritage can - with due care - elude.

Given the subject of the analysis - historical heritage in sensitive contexts - the variables at stake must first and foremost represent all those qualitative aspects, i.e. extrinsic values of the asset that are often difficult to assess from a quantitative point of view. This does not mean that the qualitative prevails over the quantitative, but that an initial qualitative approach must necessarily be preceded by a subsequent quantitative approach that - in parallel with the indepth study of the design process itself - can highlight increasingly measurable and comparable aspects.

Therefore, the option pursued in this work is to consider as the first evaluation factor the predominantly qualitative one, which can better address performance choices with the preservation of often intangible values, and then move on to a more qualitative-quantitative evaluation that can help us measure and compare the different practices in place to achieve a correct intervention. This will lead to the selection of indicators that can help in the evaluation process that must be read as tools of a resilient process.

The top-down point of view:

Based on the first approach, defined above, specific c and qualitative parameters extracted from the three different “databases” chosen as exemplifying three macro domains of evaluation were critically reviewed:

- Level(s): common EU framework for assessing sustainability in the built environment, applicable from the early stages of conceptual design with a specific asset on the life cycle of the intervention (JRC, 2021);
- GBC Historic Building: a framework for actions on historic buildings that analyses different thematic areas, which act as sustainability indicators, to ensure that interventions respect and enhance the existing. (GBC, 2017);
- Culture2030/UNESCO: framework that analyses, measures and monitors, in the sociocultural field, the status of culture's contribution to the national and local implementation of the goals of the 2030 Agenda for Sustainable Development across sectors.

These tools were reinterpreted and systematised according to the 4 evaluation fields identified in the research, namely: value/preservation field; accessibility/comfort field; circularity field; energy field (see Table 1).

Table 1. Table of indicators from Level(s), GBC Historic Building, Culture2030/UNESCO

		Level(s)_level 1	gbc Historic building	Culture2030/UNESCO
Type of intervention Existing building (renovation) New construction Urban regeneration			A historic building is a pre-1945 construction that preserves at least 50% of its original technical elements, built with local pre-industrial methods, materials, and techniques, and serving as material evidence of civilizational value.	Urban regeneration
			Buildings eligible for GBC Historic Building® certification must undergo major renovations - such as restoration, redevelopment, or partial integration - that involve key systems and interior reorganization, while seeking improvements to the building envelope. All interventions must remain compatible with the preservation of the building's original typological and construction features, made with pre-industrial processes, materials, and techniques.	
Intervention scale		Building	Building	City, open spaces
Evaluation areas				
ST_9.2.1: adaptation of climate mitigation/adaptation strategies to the specific nature of historical and cultural heritage				This area aims to provide an overall framework of the strengths and weaknesses of public action aimed at protecting and promoting the sustainability of heritage, both from a managerial perspective and from a training/design perspective.
Indicators	**Information and training**			**CAR**_Evidence of integrating cultural factors, including knowledge, traditions and practices of all people and communities, into local strategies on environmental sustainability.
				CAR_Evidence of training in the techniques of sustainable or natural construction
	Compatibility with existing buildings		**SS_C1:** Recovery and Rehabilitation of Degraded (Brownfield) Sites	
			HS_C3.1: Compatibility of Building Use and Community/ Settlement Benefits	
	Risk management	**L5.2_2.** Evaluate the primary risks and vulnerabilities of the building site to extreme weather events		**SMH**_Explicit reference to the role of cultural heritage for sustainable development integrated into the current national development plans.
		L5.2_3. Identify potential climate adaptation measures		
		L5.2_4. Evaluate the costs and benefits of proposed adaptation measures		
		L5.3_2. Assess the potential flood risk at the site		
		L5.3_3. Consult relevant professionals and organizations at the beginning of the design process		
		L5.3_4. Define the structure and design scheme of the sustainable drainage system		
		L5.3_5. Assess the costs and benefits of a sustainable drainage system		
ST_9.2.3: adaptation of strategies for improving environmental comfort, reducing pollution, and protecting human health to the specificity of the historical-cultural heritage				This area addresses accessibility and cultural participation, evaluating involvement in decision-making, the variety and distribution of cultural facilities, and their integration into the city. It aims to measure how these spaces foster community engagement, professional activity, and business development, while highlighting areas with sufficient or insufficient cultural resources.
Indicators	**Urban policy**			**CF**_This section assesses the capacity of facilities, focusing on seating or floor space. It considers whether the city offers both large venues, like theatres, and smaller ones to serve different community needs.
				CF_This section evaluates the total area dedicated to cultural functions, including both indoor and outdoor spaces. It considers multi-storey buildings with different rooms and complexes that combine interior and exterior areas for various activities.
				CF_Diversity. This section examines the diversity of cultural facilities, considering whether the city offers venues for different groups and spaces dedicated to specific aspects of local culture, such as community centers or specialized museums.
	Participation			**PP**_Evidence of community involvement during the decisionmaking process of identifying and registering heritage elements (tangible)
				PP_Evidence of community-led processes during inventorying of intangible heritage elements
	Comfort	**L4.1_1.** Consideration of how the building will be used and the level of expectations of future occupants		**PP**_Evidence that local communities undertake scientific, technical and cultural studies on ICH
		L4.1_3. Preferred ventilation strategy (in the context of the planned use of different building zones)		
		L4.1_4. Localized ventilation strategies to control point sources in parts of the building		
		L4.1_5. The importance of on-site monitoring	**IEQ_C1**: Indoor Air Quality Monitoring	
		L4.2_2. Design for Comfortable Thermal Conditions. This section evaluates site and landscape design, focusing on vegetation in various areas, the inclusion of water features, and the use of unpaved rather than hard or dark surfaces.	**IEQ_C7.1**: Thermal Comfort Conditions	
		L4.2_2. Design for Comfortable Thermal Conditions. Site and Landscape Design considers vegetation in streets, courtyards, patios, roofs, and facades, the inclusion of water features, and the use of unpaved surfaces over hard or dark materials.		
		L4.2_3. Consider the specific site conditions (microclimate)		
		L4.2_4. This section considers renovation conditions, including façade and roof orientation, surface and ventilation layout, existing solar controls, seasonal building envelope performance, and current technical systems.		
		L4.3_1. Daylight: Maximize useful contribution and minimize negative impacts on visual comfort.		
		L4.3_2. Light levels and light distribution: For visual comfort.		
		L4.3_3. Control: Automated and personalized control of visual comfort.		
		L4.3_4. Light Source Quality (color, variable lighting)		
		L4.4_1. Facade Acoustic Insulation: Protection against noise from outside		
		L4.4_5. Acoustic Absorption in Enclosed Spaces / Room Acoustics: Acoustic comfort of enclosed spaces		
	Digitization			**SMH**_Evidence of programmes and progress of museums and galleries in digitizing their collections (archiving and promotion) (number of museums and galleries implementing)

ST_9.2.2: adaptation of transition strategies towards the circular economy and the bioeconomy, and of ecologically effective and efficient resource management, to the specificity of the historic-cultural heritage			**HV_C2**: Reversibility of the Conservation Intervention	This area is addressed by analyzing actions and environmental impacts of interventions, from the policy scale down to the scale of materials.
Indicators	**Refunctionalisation**	**L2.3_1.** Changes to the distribution of interior spaces	**HV_C3.3**: Structural Compatibility with the Existing Structure	
	RRR components and materials (Reduce, Reuse, Recycle)		**MR_P3**: Reuse of Existing Buildings	**CAR**_Evidence of policies or actions to reduce environmental impact at heritage sites (energy consumption, waste, etc.)
		L2.2_3. Pre-demolition Check (if demolition activities take place): Identify building elements, materials, and potential waste, and plan their management through decontamination, detachment, selective dismantling, and sorting, considering project constraints and regional handling options.	**MR_C1**: Reuse of Existing Buildings – Preservation of Technical Components and Finishes	**CAR**_Trends in the number of buildings built with sustainable or natural techniques/materials as a percentage of all new construction
		L2.2_6. BAMB Principles (Buildings As Material Banks): Consider the possible ways of applying BAMB principles to the conceptual design of the building.	**MR_C3** Reuse of materials	
		L2.4_1. Ease of disassembly for recovery; 2.Ease of recycling; 3.Ease of reuse.		
			MR_C5 Extracted, processed, and produced materials at limited distance	
		L2.2_1. Definition of objectives and key performance indicators in accordance with the EU waste hierarchy and the EU Waste List: "The material contained in the Level 1 technical guidance was consulted, and the following objectives were defined: ≤10% landfill disposal for non-hazardous waste; ≥40% recycling + reuse of all inert waste, and ≥95% recovery + recycling + reuse of materials for inert waste fractions derived from separate collection."		
	Water resource	**L3.1_3.** Examine the possibility of sing non-potable water as a substitute to meet the potable water demand		
		L3.1_4. Water-efficient green areas		
ST_9.2.4: adaptation of strategies for effectiveness and efficiency in clean and renewable energy production, distribution, management, and consumption to the specificities of the context.		**L1.1.** Energy Performance During Operation		This area is addressed by analyzing actions and policies aimed at reducing consumption.
Indicators	**Efficiency**	**1.** Minimum Energy Performance Requirements and Nearly Zero-Energy Building Design – Minimize energy use for heating, cooling, and building lighting	**EA_C1** Optimization of energy performance	**CAR**_Evidence of policies or actions to reduce environmental impact at heritage sites (energy consumption, waste, etc.)
		1. Minimum Energy Performance Requirements and Nearly Zero-Energy Building Design – Use renewable energy technologies to supply, as far as possible, the remaining energy demand of the building	**EA_C2** Renewable energy	
		2. Site-Specific Design – Design based on site climate to reduce energy demand for heating, cooling, hot water, ventilation, and lighting, and to guide the use of non-combustion renewable energy technologies.		
		3. Renovation-Specific Design – Use baseline survey data to tailor improvements to the existing building, considering its construction, envelope, structure, services, and the effects of orientation and surface layout on climate exposure, daylight, and ventilation.		
		4. High-Quality Building Services and Envelope – Reduce gaps between design and actual performance by ensuring high-quality design, detailing, construction, and installation of the building envelope and technical systems, focusing on airtightness, thermal continuity, and proper HVAC system function.		
	Management and monitoring	**5.** Intelligent Control and Monitoring Systems – Install systems that provide real-time energy use information to occupants and managers and help maximize on-site renewable energy self-consumption.		
	Improvement / Adaptation	**L1.2.** Global Warming Potential		
		1. Efficient Building Form and Configuration – Reduce surface-to-volume ratio and building height to enhance material efficiency and lower energy consumption.		
		2. Optimized Construction of Nearly Zero-Energy Buildings – Weigh operational CO_2 reduction for near-zero-energy performance against embodied CO_2 from materials like insulation, façades, walls, windows, structural mass, and renewable technologies.		
		3. Optimization of Material Use and Circular Value - Evaluate reusing existing structures or optimizing new designs to reduce material use, and explore ways to minimize or eliminate waste during manufacturing and construction.		
		4. Extend the Service Life of Buildings and Components - Consider options to extend the service life of major building components and to minimize the number of replacement and renovation cycles.		
		5. Design for Adaptability - Design buildings to adapt to future market and occupant needs, extending the lifespan of the structure and key components.		
		6. Design for Deconstruction - Assess how building design and material tracking can support future deconstruction, enabling material recovery for reuse and recycling.		
Design Phase		Conceptual Design Phase	All Levels of Architectural Design	Conceptual Design Phase
Stages of the Building Process (Preliminary)		- Design, material selection, and detailed specification in accordance with the principles of minimum requirements for optimal cost levels and nearly zero-energy buildings. - Selection of tailored solutions for major renovation works.		

Notes. ST_9.2.1: cultural value scope; ST_9.2.3: scope of cultural accessibility; ST_9.2.2: Circularity Scope; ST_9.2.4: Energy Scope. (level(s) abbreviations) L5.2: Increased Risk of Extreme Weather Events; L5.3: Sustainable Drainage; L4.1: Indoor Air Quality; L4.2: Time Outside the Thermal Comfort Range; L4.3: Lighting and Visual Comfort; L4.4: Acoustics and Noise Protection; L2.2: Waste and Construction & Demolition Materials; L2.3: Design for adaptability and refurbishment; L2.4:Design for Deconstruction; L3.1: Water Consumption During Operation; L1.1:Energy Performance During Operation; L1.2:Global Warming Potential. (gbc abbreviations) SS: Site Sustainability; HS: Historic Significance; IEQ: Indoor Environmental Quality; HV: Historic Value; MR: Materials and Resources; EA: Energy and Atmosphere. (Culture2030 abbreviations) CAR: Climate Adaptation and Resilience; SMH: Sustainable Management of Heritage; CF: Cultural facilities; PP: Participatory process; SMH: Sustainable Management of Heritage.

Various items and indicators were critically linked to the 4 evaluation fields identified, attempting to give a typological and scalar interpretation, as well as an evaluation of their use

in the various process phases. The result is a systematised framework useful for identifying evaluation prevalences by macro domains and evaluation gaps whose definition would help to improve the decision-making process.

The bottom-up point of view:

In an attempt to assess the overall aspects of resilience, primarily those considered in a deficient manner by the tools in use, a bottom-up approach was used to search for guidelines and actions that start from common practice in the international context and aim to achieve the requirement of resilience with a "quality" project. From a selection of international case studies, analysed at different scales, recurrences of project actions belonging to three macro-areas of intervention were extrapolated:

- energy efficiency;
- accessibility and cultural value; - circularity of resources; evaluating, on the one hand, their influence in terms of increasing the resilience of the asset and, on the other, their effectiveness over time.

The energy aspect of the projects was analysed mainly by considering interventions on the envelope, plants and bioclimatic aspects. Accessibility and cultural value were investigated from several points of view: firstly, distinguishing between physical and urban accessibility and cultural and communicative accessibility, as well as involvement and safety; secondly, distinguishing between buildings subject to architectural and/or landscape constraints and those that are not, but whose identity aspects have been preserved, even in the absence of regulatory provisions.

Finally, with regard to the circularity aspect, the analysis was divided into two subcategories: materials/structures and natural resources.

Twelve selected case studies, realised in the last twenty-five years, represent interesting examples of adaptive reuse oriented to cultural functions in the international panorama. Almost all of the selected interventions belong to the categories "Culture and Arts" (41.7%) and "Community and Society" (41.7%), and 16.7% to "Innovation and Sustainability". All interventions are located in urbanised contexts and play a fundamental and multifactorial role in the urban context, contributing to a sustainable and resilient development of cities (Borsacchi, 2020).

In addition, the case studies belong to different types of facilities with three prevalent uses:

military, justice/prison and industrial/manufacturing (see Table 2).

Table 2. Case study details.

ID	Name	Intervention	Typology	City	New use	Years
01	Tate Modern		Industrial	London, UK	Culture and Arts	2000
		Switch House				2016
02	Maradero		Industrial	Madrid, ES	Culture and Arts	2006
		Intermediae				2007
		Central del Diseño				2007
		Nave 16				2011
		Cineteca				2011
		Nave de Música (RBMA)				2011
		Casa del Lector				2012
		Factoría Cultural				2014
03	ZAC Bastide Niel	ZAC Bastide Niel	Military	Bordeaux, FR	Community and Society	2010
		DARWIN - l'écosystème de la caserne Niel				2013
04	Cristalleries Planell		Industrial	Barcelona, ES	Community and Society	2016
05	Tai Kwun		Military	Hong Kong, HK	Cultural and Arts	2018
06	Wolves Lane Centre		Industrial	London, UK	Community and Society	2019
07	Cukrarna		Industrial	Ljubljana, SI	Cultural and Arts	2021
08	Fenix		Industrial	Rotterdam, NL	Cultural and Arts	2021
09	Usquare		Military	Brussels, BE	Innovation and Sustainability	2021
10	El Roser		Prison	Reus, ES	Community and Society	2022
11	kHaus		Military	Basel, CH	Community and Society	2022
12	Hub Criativo do Beato		Industrial	Lisbon, PT	Innovation and Sustainability	2022

Findings and Discussion

The analysis conducted following two different and complementary points of view allowed for the identification of both potentials and systemic failures in the process of

'measuring' the resilience of architectural heritage in historical and consolidated contexts. Crossing the evaluations that emerged from the top-down analysis, aimed at defining strategies and actions that address resilience, with the bottom-up analysis, aimed at assessing the direct influence of the themes in design practice, a gap emerges between the availability of evaluation tools - starting from qualitative ones - and specific actions on heritage.

		Project	Indicators/ parameters
Culture and Arts	value/ preservation field	9,4%	18%
Community and Society	accessibility/ comfort field	28,2%	35,4%
Innovation and Sustainability	circularity field	11,4%	21,5%
	energy field	51%	24,6%

Figure 1 comparison between the top-down and the bottom-up point of view

In line with the strong international interest in the topic, cultural aspects, related to heritage conservation and protection assessments, are closely evaluated in relation to climate change mitigation and adaptation issues. This fact, however, is not found with the same frequency in contemporary design practice.

Similarly, also for energy transition issues (included in the Innovation and Sustainability macro-category), the greatest attention is focused on compartmentalised aspects relating to plant and envelope-related factors (32%), with interest in restoring the building's bioclimatic behaviour (42%), but with less attention given to aspects of useful life management and the end of life of materials, components and systems. An emblematic

example is the Civic Centre Cristalleries Planell 1015 in Barcelona, in which the study of passive factors (lighting and natural ventilation) are put into a system respecting the envelope and its thermal inertia and at the same time integrated with devices, such as the solar chimney, which increase its effectiveness.

On the topic of circularity, useful tools for their evaluation are being developed over the last decade, based on the most recent regulations on the subject, but an operational approach that evaluates the various aspects in a systemic and complete manner is still lacking. In the majority of projects (11% of the total), the reuse of local materials, derived from renovations and demolitions, or the use of bio-based materials, integrated with flexible structures (as in the case of the Usquare-former Ixelles Barracks site in Brussels) facilitating the adaptation of existing spaces to new functions, is noted.

On the subject of accessibility, the main operational and evaluation aspects focus mainly on the physical overcoming of architectural barriers (with an average recurrence in the twelve case studies analysed of 44%). A significant example is the project of the Tai Kwun, Centre for Heritage & Art in Hong Kong, which is interesting from the point of view of accessibility, not only physical - even at urban level - but also cultural and communicative.

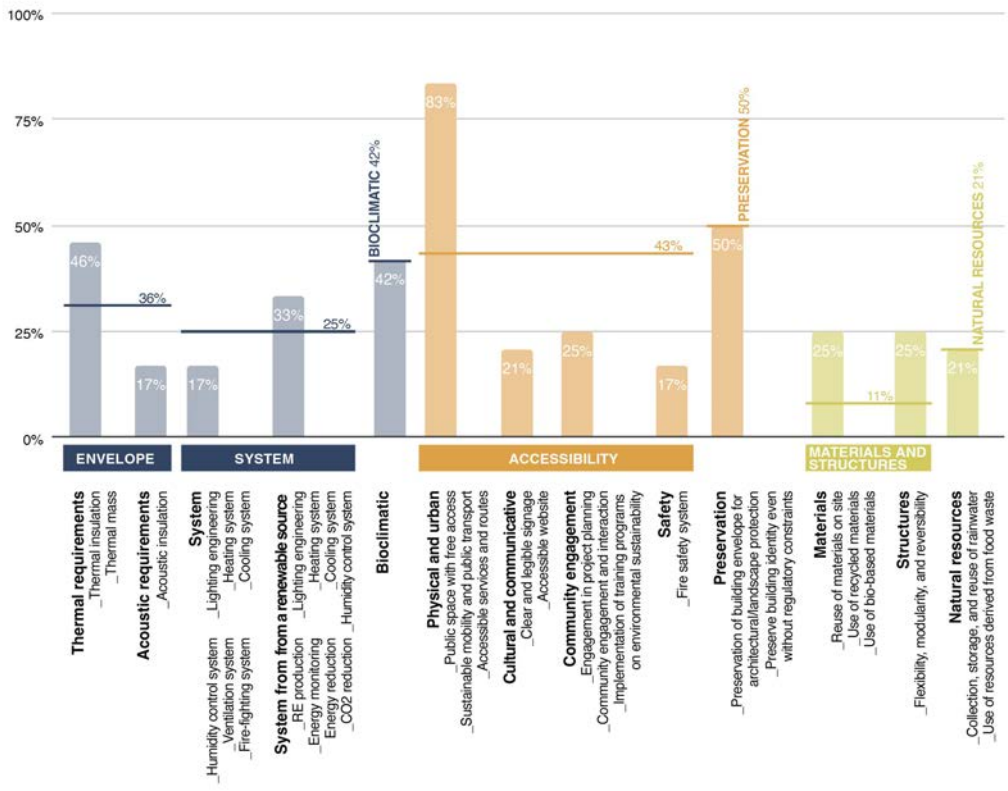

Figure 2. Percentage calculation - The qualitative analysis, based on yes/no answers, produced results that can be summarised by calculating the percentage of recurrence.

Conclusion

The analysis clearly reveals a lack of balance between evaluation tools and project actions. Often the interventions respond only to single criteria, there is hardly a systemic reading of the analysed themes and often this subdivision responds to a fragmentation of the project process which presents itself as an element of weakness for the achievement of an overall objective of sustainability. This implies the consideration that the interventions act only partially in a regenerative perspective, making only a partial contribution to the resilience objective, making a complete and overall assessment difficult and compromising its effectiveness.

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PRESERVING CULTURAL HERITAGE IN ITALIAN INNER AREAS: THE KEY ROLE OF PARTICIPATORY PROCESSES

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Preserving Cultural Heritage in Italian Inner Areas: The Key Role of Participatory Processes

Abstract:
Based on the principles of the Faro Convention, this paper highlights the key role of community-driven processes to preserve and enhance cultural heritage in inner areas. In detail, the research work has been focused on collaborative mapping processes as key tools to revitalise inner areas. A step-by-step method to renew the linkages among people, places, and practices and trigger community activation has been developed and tested on the municipality of Guardia Sanframondi, located in the inner area of Tammaro-Titerno in the Campania region. The main finding can be traced into the development of Atlases of territorial heritage conceived as dynamic, critical, and relational tools, capable of engaging with the inherent complexity of place and revealing the multiple, overlapping layers of meaning that define local values and spatial belonging.

Keywords: inner areas; cultural heritage; community engagement, cooperative mapping

Introduction

In recent years, cultural heritage has been increasingly recognized not just as a collection of tangible assets but as the result of a dynamic, community-driven process, aimed at highlighting what people living in a given area recognize as an expression of their constantly evolving values, beliefs, knowledge, and traditions.

This is especially relevant in peripheral or marginal territories, such as Italian inner areas, where chronic depopulation, aging population, and socio-economic decline threaten the very survival of their cultural heritage, by progressively severing the links between people and places.

Nevertheless, inner areas may still play a crucial role — yet often underestimated — in ensuring a sustainable development, due to their cultural and ecological diversity. Beyond their marginal demographic and economic profiles, these territories still provide essential ecosystem services to wider regional areas (Carrosio 2019, De Toni et al. 2020). However, according to Magnaghi (2020), such contributions can only be fully understood and sustained by reframing the concept of service provision through the lens of eco-territorial services. This perspective goes beyond the instrumental logic of “use value” and incorporates the “existence value” of local cultures, places, landscapes, and practices — elements that contribute to the liveability and sustainability of the territory itself, regardless of their economic utility.

Drawing on the principles of the Faro Convention (Council of Europe, 2005), this paper explores how a community-based approach to heritage preservation and enhancement can generate new forms of sustainable development.

In Italian inner areas, decades of depopulation and marginalization compromised the capacity of local communities to become active agents of both local and regional development. On the opposite, a community-driven process aimed at reimagining heritage — both tangible and intangible — might contribute to revitalise these territories and renewing their role within the wider regional dynamics.

By exploring the role of community in cultural heritage preservation and considering cultural heritage itself as the engine of sustainable development, the paper presents a community-driven process aimed at triggering valorisation actions. Focusing on the case study of Guardia Sanframondi, a municipality located in the inner area of Tammaro-Titerno (Campania Region), a collaborative mapping process, aimed at renewing connections between people, places, and practices and triggering community activation, is presented and discussed. The research work clearly highlights how inner areas can become laboratories for innovative planning approaches that integrate local values with regional sustainability objectives.

A brief literature review

In recent years, participatory governance has gained increasing visibility within the fields of heritage management and policy. Also, the European Commission and Council have reinforced participatory governance of cultural heritage through policy instruments like the "Towards an integrated approach to cultural heritage for Europe" (Mazas Pérez-Oleaga 2015). At its core, participatory governance emphasizes direct involvement of citizen in public decision-making, positioning such engagement as a fundamental pillar. In this framework, cultural heritage must be seen not merely as a resource to be preserved but as a living system of relationships, embedded in everyday life and territorial dynamics.

Conventional approaches to heritage conservation, often based on institutional recognition and material restoration, are insufficient, particularly in inner areas, where they risk producing "musealization" processes (Rossitti & Torrieri, 2022) that may preserve architectural forms but fail to reverse chronic depopulation and abandonment and to support active and future-oriented regeneration. Effective heritage conservation in inner areas thus requires a dual shift: first, the strengthening of communities' perception and recognition of their own heritage, especially its informal, non-codified, or intangible forms; second, the triggering of

enhancement processes, enabling local actors to reinterpret and strategically mobilize their cultural heritage in relation to contemporary needs and aspirations.

This echoes the principles of the Faro Convention (CoE, 2005), which redefines heritage as a collective right and responsibility, placing communities at the centre of interpretation and stewardship. The Faro Convention (CoE, 2005) introduced the concept of *heritage communities*, intended as groups of people who value specific elements of cultural heritage and commit to sustaining them for future generations. This framework relocates heritage from institutional control to collective stewardship, urging a more democratic and inclusive interpretation (CoE, 2005; Fabbricatti et al., 2020).

In contexts of marginalization and abandonment, this reframing becomes particularly important. Scholars like Wilson & Sanyal (2013), Carrosio et al. (2018), and Pappalardo & Sajia (2020) have underlined the essential role of community engagement in fostering resilient and sustainable strategies for territorial development. Meanwhile, Magnaghi (2010) highlights the importance of place-based knowledge and identity as foundations for local autonomy and sustainability, moving beyond technocratic planning to embrace territorial and cultural specificity. From this perspective, heritage can be understood as a relational infrastructure — a dynamic framework of connections between people, places, and practices — that enables communities to reweave the spatial and social fabric of their territories. In this line, the research work refers not only to landmarks as scattered heritage elements but to a broader notion of cultural heritage, which holds together material and immaterial, past and present, nature and architecture and anchors collective agency in the lived relationship between communities and their environment.

A step-by-step method to re-discover territorial heritage in inner areas

"A heritage regime is the result of socio-historical, political, and cultural processes of classification (definitions, hierarchies, inclusion, and exclusion), labelling, and support." (Sokka et al., 2021, p. 7). For this reason, the participatory process grounds on the active engagement of the local community. The process integrates participatory tools with technical procedures, structured within a step-by-step process.

I step: Community engagement. As mentioned, involving actors across different scales and backgrounds — from local institutions and cultural associations to youths, from locals to new residents and temporary inhabitants — is the preliminary step aimed to establish trust and build inclusive platforms for dialogue. The engagement step is framed as a transversal process,

enabling inhabitants to articulate their personal and collective understandings of cultural heritage — encompassing not only physical spaces but also practices, knowledge systems, and the cultural landscape — thus strengthening community consciousness and awareness (Badia & Donato, 2023).

II step: Understanding and Mapping Cultural Heritage. This step is addressed to recognize and establish a thematic systematization of the heritage concept. Through interviews, focus groups, mapping workshops, and walking explorations, maps of the multifaceted local knowledge come out, facilitating an open-ended interpretation of what the local community considers valuable and worth sustaining. Data collection is both spatial and abstract. Information can be collected in multiple formats: oral narratives, maps, photographs, sketches, local bibliography. In this way, maps serve as tools for the recognition of places related to both tangible and intangible heritage and as means of narrating and strengthening territorial values (Carta, 2005; Carta, 2011).

III step: Cultural Heritage Interpretation. This phase synthesizes the outputs of the previous one and reveals the underlying relationships between heritage and community. The collaborative mapping process shed light, rather than on a mere "loss of memory", on the fragmented understanding of how heritage could act as a catalyst for contemporary life and future development. The practice of Heritage Interpretation was born at the end of the Nineteenth Century with the milestone book of Tilden "Interpreting our Heritage", but it arrived in Europe only in 1975, with the foundation of the English Society for the Interpretation of Patrimony and it reinforced its activity definitively in 2010, with the foundation of Interpret Europe (Continenza et al., 2017). Heritage Interpretation represents a key tool to foster communities' awareness and may represents a foundational step toward the planning of a sustainable future.

Findings and Open Discussion: The Territorial Atlas

The step-by-step method has been tested on the Guardia Sanframondi municipality: a town of approximately 5,000 inhabitants that has lost over 1,000 residents since 2001, located in the inner area of Tammaro Titerno in the Campania region. It presents a complex yet fertile field for experimenting with community-based heritage approaches. Despite the progressive abandonment of its medieval historic centre, Guardia still hosts a lively cultural ecosystem, including contemporary art initiatives and theatre laboratories. However, the ineffectiveness of heritage policies in recent decades has led to a widespread sense of disconnection and

resignation. The participatory process revealed this not as a lack of interest, but as a difficulty in recognizing how heritage could be proactively engaged in shaping the local future.

This description reflects a recurring dynamic in many of Italian inner areas, where territorial marginality is often accompanied by fragmented development strategies. In such contexts, as we demonstrate below, there is an urgent need to introduce a new dimension of community-based planning and communication, one that actively incorporates local knowledge, narratives, and lived experiences (Ausilio, 2022). This approach is essential not only to reframe the relationships between different parts of the territory but also to envision and co-design a more sustainable and inclusive future for these areas.

In Guardia Sanframondi, the collaborative mapping process (Figure 1) led to the creation of Atlases of territorial heritage. These were not conceived as static repositories of data, but as dynamic, critical, and relational tools—capable of engaging with the inherent complexity of place and of revealing the multiple, overlapping layers of meaning that define local identity and spatial belonging.

According to Carta (2011), territory is inherently complex and never fully knowable, our knowledge of it remains partial, situated, and constantly evolving. In this context, the Atlas served as a synthesis device. Atlases of territorial heritage are cognitive and interpretative frameworks giving form to the layered deposits of local memories (Magnaghi 2005). They are tools for documenting the territory and its heritage as well as supporting a sustainable development of the territory.

The Atlases were not endpoints but platforms for returning the outcomes of the collaborative mapping process to the community in a form that could inform dialogue, foster recognition, and support future actions. They rooted in the idea that heritage is not a static object to be preserved, but a living relational infrastructure to be interpreted and valued collectively. This assertion serves as the foundation for a strategy that moves towards a territorial approach with a heritage-based vision. The entire process was conceived as cyclical and iterative, where the initial phase of community engagement progressively evolved into a deeper form of community empowerment, enabling local actors not only to recognize their own heritage, but also to actively shape its future meaning and role within the territory.

Figure 1. The collaborative mapping process carried out in Guardia Sanframondi

Conclusions

Although still in progress, this research already allows some reflections on both the effectiveness of the participatory processes and the outcomes emerging from the case study. The case study encompasses a vast tangible and intangible heritage, including landscapes, historical and architectural assets, traditions and rituals, historical and contemporary artworks, and local literature. The decision to promote and facilitate, through a collaborative mapping process, the re-cognition and re-connection between the community and its heritage has enabled both the systematization of information — through the thematic Atlases — and the spatialization of individual elements, uncovering meaningful relationships among them. These relationships lay the groundwork for potential strategy for heritage revitalization and local development.

Furthermore, the interpretation phase led to identifying three itineraries strongly rooted in the idea of cultural heritage expressed by the community. These itineraries, far from being mere tourist paths, serve as the guiding thread for broader territorial development initiatives,

thus positioning heritage interpretation not only as a cultural practice but also as a strategic tool for a sustainable and comprehensive territorial regeneration strategy.

In fact, while individual – even innovative – actions have attempted to reverse the trend of abandonment over the past recent years, what has often been lacking is a comprehensive vision of the territory — and, consequently, of the actions themselves as part of a system — as well as an effective collective awareness within the community. This collaborative mapping process rests on two key elements: first, the active involvement of the community throughout the process has supported a growing consciousness of place and an increased awareness of the heritage values; second, the capacity to visualize on the territory the key elements needed to trigger an enhancement strategy, as well as the relationships among places and between people and places, ensures that no single action remains isolated, but instead has the potential to spark virtuous, interconnected processes in a proactive logic that goes beyond the mere heritage preservation. This aspect is particularly relevant for the case study, where the physical appearance of the place does not fully reflect the vitality of its inhabitants — their activism, cultural initiatives, and the strong, transgenerational sense of belonging to the place — nor the widespread knowledge of the local historical values shared among residents, newcomers, students, artists, and scholars.

An indirect, yet perhaps even more significant, outcome of this process has been the awakening, among some of the groups involved, of a renewed awareness of their role as direct agents of change.

Finally, it worths to be noted that strengthening the bond between heritage and community can enhance the effectiveness of public action in addressing complex and expensive challenges, such as the conservation of historical and architectural heritage. Without a recognized and meaningful role within the community, public conservation efforts risk remaining ineffective and disconnected from the local context.

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COMMUNITY-CENTERED USE ADAPTATIONS AS A MEANS TO ENHANCE SOCIAL SUSTAINABILITY: THE CASE OF ISTANBUL'S PIERS

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BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

Community-Centered Use Adaptations as a Means to Enhance Social Sustainability: The Case of Istanbul's Piers

Abstract: Use adaptations have been an integral part of conservation practices, particularly in terms of ensuring the continued social use of heritage. However, relatively recent perspectives rooted in the pursuit of the broader principle of sustainability have further heightened the importance of community-centered adaptation processes. Accordingly, this paper aims to evaluate such practices within this framework, taking the piers of Istanbul as a case study. Adopting a twofold research methodology, this study first identifies the fundamental dimensions of use adaptations at the architectural/building scale in relation to social sustainability. Based on this six-dimensional framework developed as part of the research, selected piers in Istanbul are then evaluated. In this context, evaluations of the instrumentalization of this distinctive heritage, together with the contributions it provides and the significance it embodies, constitute the main areas of focus of this study.

Keywords: community-centeredness; use adaptation; social sustainability; Istanbul's piers

Introduction

Community-centered practices across all areas have come to the forefront, particularly since the last quarter of the past century. However, the continued social use of heritage and its recognition as a foundational value is not a new concept. This can be traced back to the earliest doctrinal documents in the field of conservation, including the Athens Charter for the Restoration of Historic Monuments (1931), and it has consistently been addressed in many documents up to the present day (e.g., ICOMOS 2011; UNESCO WHC, 2025). Nevertheless, the introduction of sustainability thinking has reinforced and expanded approaches in this area, as the relationship between heritage and sustainability has become increasingly integral.

In this context, in addition to developing reuse proposals for buildings that have lost their original functions over time, the adaptation of actively used buildings through mixed-use strategies to support community-centered services and development has also emerged as a notable phenomenon. Underpinning this idea, the recent use adaptations of transportation heritage in Istanbul, more specifically, the piers, represent a particularly compelling field for community-centered initiatives. Rooted in the concepts of transience and the provision of transport services, these structures—perhaps in a sense describable as 'threshold spaces'—form the core focus of this study through their (re)transformation into spaces of public gathering.

Within this scope, this paper traces the transformations driven by the prioritization of the social use of heritage, using Istanbul's piers as a point of departure, and aims to shed light on the instrumental role of heritage, as well as its broader contributions—particularly in responding to contemporary societal needs and maintaining social sustainability. Their significance is therefore reconsidered from a social and community-building perspective.

Framing Community-Centered Use Adaptations in a Social Sustainability Perspective

It is possible to argue that the vitality of heritage depends on its ability to adapt to change—and, in a way, generate new use values in response to the changing context—while maintaining its fundamental characteristics and itself in a continuous regenerative process (Fusco Girard & Vecco, 2021). However, adapting heritage to respond to current needs can be considered not only as a means to sustain its own vitality but also as a significant tool in enhancing social sustainability.

From this perspective, Vafaie et al. (2023), in a recent study, identify aspects including but not limited to promoting attachment and a sense of place, being a practical social amenity, improving the quality of life, and enhancing social inclusion, while referring to socio-cultural factors that affect the success of adaptive reuse projects. Similarly, in these processes—as well as beyond them—the social pillar of sustainability is emphasized through social networks, infrastructure, capital, and community participation, along with various aspects such as equity, stability, and security (Bramley et al., 2006; Cuthill, 2010; Owojori et al., 2024). Simultaneously, the conservation of original ways and the continuity of life, alongside the strengthening of cultural traditions and diversity, stands out as a key theme among those highlighted (Yung et al., 2014).

In this sense, aspects of social sustainability have a direct relationship with sustainable communities—one that is fundamental to the concept itself and enables society to function as a collective entity (Dempsey et al., 2011). When considered, urban and architectural spaces are critical nodes that enable and enhance social sustainability (Lami & Mecca, 2021), and community-centered (re)use adaptations can essentially be regarded as a social practice through which places are produced and reproduced to address conflict and inequality caused by *"throwntogetherness*[1]*"* (House & Murialdo, 2023).

Based on the existing literature, this research has facilitated the contextual adaptation of the core dimensions of the social practice in question to the architectural/building scale. In this context, a six-dimensional framework, which are particularly specialized around use adaptations, can be identified. As seen in Table 1, these dimensions are as follows: a) conserving and sustaining values and uses; b) adopting an ethical framework based on the common good; c) serving as a functional social amenity; d) encouraging place attachment and

[1] Here Massey's (2005) concept, which the authors refer to, may become particularly in a context where future possibilities emerge regarding how space might be coded and how terms of connectivity might be negotiated.

cultivating communal identity; e) fostering community participation, shared connections, and development; and f) improving the overall quality of life and well-being of the community.

Table 1. Dimensions of use adaptations regarding social sustainability (Adapted by Author, 2025)

Dimension	Definition
Conserving and sustaining values and uses	Advocating for the conservation and continuation of authentic functions and uses as much as possible, and, when necessary, unveiling potential uses and values that are compatible with the fundamental heritage characteristics.
Adopting an ethical framework based on the common good	Managing decision-making and implementation processes, while also upholding and cultivating ethical standards within the framework of principles such as social justice, inclusion, and diversity.
Serving as a functional social amenity	Serving the relevant communities as a functional social amenity and sustaining use value from a community-centered perspective.
Encouraging place attachment and cultivating communal identity	Helping to improve people's sense of attachment and cultivate communal identity as expressions of social cohesion.
Fostering community participation, shared connections, and development	Providing opportunities that encourage community participation, broaden, and deepen social ties, and contribute to the development of relevant communities.
Improving the overall quality of life and well-being of the community	Contributing to the social well-being of all parties through a holistic perspective that embraces all aspects of human life and dignity.

Methods

The study adopts a twofold research methodology. First, a literature review was conducted to identify the fundamental dimensions of use adaptations related to social sustainability. This review particularly flourished around the idea of community-centeredness and eliminated other respective factors regarding maintaining heritage and its cultural significance, as well as the remaining pillars of sustainability. As a result, a six-dimensional framework at the architectural/building scale that prioritizes the contextualization of these adaptations, as elaborated in the previous section, was developed. In the next stage of the process, piers in Istanbul were selected as recent and prominent examples of such implementations. Finally, these case studies were evaluated and examined within the framework developed as part of the research.

Istanbul's Piers

Istanbul's piers have recently been subject to adaptive reuse implementations and/or use adaptations, primarily through the introduction of additional functions within existing structures. This approach appears to have been adopted across the city, particularly in examples such as the Moda, Kadıköy, Kuzguncuk, and Beşiktaş piers (See Figure 1). In these cases, in addition to their primary functions, the structures are generally complemented by amenities such as libraries, flexible work areas, and small-scale cafés that mostly cater to young people and students, but ultimately serving the broader public (See Figure 2).

Figure 1. Respectively Moda, Kadıköy, Kuzguncuk and Moda Piers (Author, 2025).

Being one of three assets located at the Anatolian side, Moda Pier was designed in the 1910s by the renowned architect of the period, Vedat Tek. The structure, whose upper floor served as an observation terrace, was designed by the architect for the Seyr-i Sefain Administration during his tenure at the Ministry of War, alongside the Haydarpaşa Pier and the (unrealized) Kadıköy Pier, and its construction benefited from the Ministry's resources (Gümüş, 2021). Similarly, today's Kadıköy Pier was constructed nearly a decade later, featuring comparable neoclassical nationalist characteristics. During this period, Kadıköy and its surroundings have gained attractiveness especially with the launch of ferry services (Akay, 2023), and these structures have played an important part in the era-specific development of

their districts. Over the years, they have experienced various losses to their original character and have been subjected to multiple restorations.

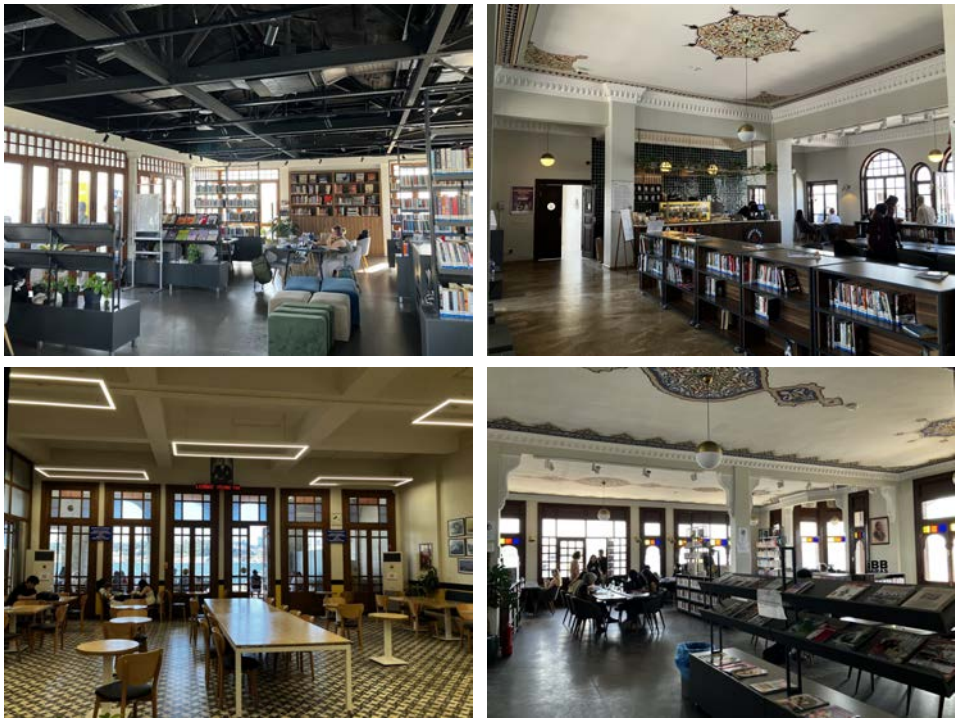

Figure 2. Interior views from newly adapted uses (Author, 2025).

Another structure built around the same period in the near vicinity is the Kuzguncuk Pier, whose architect—although commonly attributed to Ali Talat Bey—is subject to conflicting information. It is noteworthy that the upper floor was once used as a cinema and that the building is remembered as a place where the local residents first encountered urban culture (Genim, 2006). Most recently, the structure was restored by preserving its street-facing façade and reconstructing the others in accordance with the original.

On the European shore, Beşiktaş Pier was designed by Ali Talat Bey in the 1910s and stands as a prominent example of the First National Architectural Movement. Much like the previously mentioned piers, the structure whose original function included an entertainment hall on the upper floor has survived to the present day through various restorations and some changes in use (Salman, 1994).

These structures hold representative and evidential value in terms of both the city's transportation history and the maritime culture of the areas in which they were built. They also stand out for reflecting the technological capabilities and advancements of their time, as well as the emerging and relatively new everyday practices and lifestyles of the era. As distinctive

examples of particular architectural styles and as works of prominent architects of the period, these structures further reinforce their place in the city's urban memory. Moreover, their role in the provision of transport services arguably brings their use value and functional relevance to the forefront.

Use Adaptations of Istanbul's Piers: An Evaluation

The authenticity of heritage may be linked to a wide range of sources, including use and function (ICCROM et al., 1994), and conserving, and maintaining the uses that contribute to the value of that heritage remains essential. However, in cases where a change of use is proposed, the new use should be compatible with this value and should have little or no adverse effect on it (ICOMOS New Zealand, 2010). In this context, the fact that the Kadıköy and Beşiktaş piers continue to serve their original functions intensively is of particular significance. Regarding the Kuzguncuk and, especially, the Moda piers, the lower number of services indicates relatively limited continuity, despite being supported by sea taxi transportation. Although justified by reasonable causes, including low user demand, this situation still occasionally leads to questioning the priorities of use guiding the implementations. Nonetheless, it is safe to say that the newly adapted functions have enabled all structures to accommodate a wider range of uses and practices.

It is especially important because these spaces, which have been opened to the public as libraries and workspaces, are accessible to people across all segments of society. Considering their valuable locations and relationship with the city, it is evident that these structures reflect an approach aligned with fundamental principles such as social justice and inclusion while also supporting the right to the city. These adaptations gain further importance, especially given that public use in the surrounding areas has become increasingly restricted or privatized over time. However, it is still possible to argue that the decision-making and implementation processes of these use adaptations generally remain less participatory, and a general approach is adopted in determining the recommended uses for all structures.

With their adapted uses, these structures serve the relevant communities as social amenities, and their use value is sustained, if not enhanced, from a community-centered perspective. In this context, they can be considered significant gains for both the city and its residents[2]. On the other hand, a critique that can be raised here is the proposal of the same

[2] It should be noted here that the upper floor of the Kuzguncuk Pier is used by a foundation, which has partly restricted direct public use, and that the co-working space and library are affiliated with this foundation.

mixed-use scheme for all structures. An alternative approach could be to adjust these uses to district and community-specific needs, and to identify them through a more pluralistic process while maintaining the underlying principles.

On the other hand, opening up a discussion on how use adaptations enhance people's sense of attachment and cultivate communal identity can be a challenging task. This is particularly relevant for structures like the Kadıköy and Beşiktaş piers, which experience high levels of circulation. In such cases, the majority of users are likely to be visitors or passengers, and regular usage may remain relatively limited. However, in examples like Moda and Kuzguncuk, the presence of a nearby residential fabric and a more settled user profile seems more likely, despite the rapidly changing demographics in these areas. Within this framework, it could be argued that, on a small scale, this dimension of social sustainability remains a grey area, and further research on this issue is needed.

The piers, which together with other buildings in their vicinity, have enabled more frequent social gatherings, increased interaction, and communication, and contributed to the formation of a new socio-cultural environment in earlier periods (Yılmaz, 2023). It can be argued that their recent use adaptations help restore this role in the present day for structures that, over time, have largely been reduced to their transportation functions only as service facilities or have completely acquired other functions and have been opened to private use. However, the opportunities these structures can offer in this regard may still be supported through structured and purposeful participation processes. This may also contribute to the instrumentalization of heritage for the systematic development of relevant communities.

As the final topic of discussion, it is undeniable that the implemented practices have contributed to improving the overall quality of life and well-being in Istanbul. These adaptations are particularly prominent in the context of Sustainable Development Goal 11, that aims to "*make cities and human settlements inclusive, safe, resilient, and sustainable"*. With a special emphasis on the protection of cultural and natural heritage, they support the creation of a sustainable city, as well as the advancement of the multidimensional well-being of all residents of the city (See Table 2).

Table 2. Evaluation of use adaptations within the six-dimensional framework

Dimension	Evaluation
Conserving and sustaining values and uses	Kadıköy and Beşiktaş piers continue to serve their original functions. Kuzguncuk and Moda piers have relatively limited continuity. Newly adapted functions have enabled all structures to accommodate a wider range of uses and practices.
Adopting an ethical framework based on the common good	Structures are accessible to people across all segments of society. Fundamental principles such as social justice and inclusion, and the right to the city are supported. However, decision-making and implementation processes remain less participatory.
Serving as a functional social amenity	Structures serve the relevant communities as social amenities, and their use value is sustained. Uses can be adjusted to district and community-specific needs.
Encouraging place attachment and cultivating communal identity	Kadıköy and Beşiktaş piers experience high levels of circulation, and the majority of users are likely to be visitors or passengers. A more settled user profile seems more likely for Moda and Kuzguncuk. Further research is needed for a more in-depth evaluation.
Fostering community participation, shared connections, and development	Adapted uses enabled more frequent social gatherings, increased interaction, and communication, and contributed to the formation of a new socio-cultural environment. This may still be supported through structured and purposeful participation processes.
Improving the overall quality of life and well-being of the community	Implementations contributed to improving the overall quality of life and well-being. They support the creation of a sustainable city, as well as the advancement of the multidimensional well-being of all residents.

Conclusion

The piers in Istanbul, beyond serving merely as units that meet the city's transportation needs, are significant assets that provide unique insights into urban development and lifestyles of their era. Integrated with the city's distinctive topography and maritime culture, they also served as important gathering and connection points for their districts, as well as for the city more broadly. In this context, they should be regarded as inseparable from Istanbul's unique urban history and identity. Their recent use adaptations, on the other hand, have enabled these structures to serve as a means to foster social sustainability from a community-centered perspective.

One of the most significant benefits of the additional adapted uses—such as libraries, flexible working spaces, and cafés—of these structures, which continue their original functions to varying degrees, is making heritage more accessible to the public and enabling these assets to participate more actively in urban life as social amenities. The newly added functions of these structures, which once provided important spaces for social gatherings and increased interaction, are significant in terms of re-establishing this role as well as helping city dwellers to overcome *"throwntogetherness"* and ensuring sustainability on many levels.

Despite criticisms concerning the prioritization of uses, the general mixed-use scheme, and the relatively limited participatory decision-making processes, these adaptations can be regarded as valuable implementations that contribute to the city and its related communities. In this light, they can also be considered exemplary practices for the fair use and egalitarian stewardship of heritage, as well as for fostering a more liveable city where no one is left behind.

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ARCHITECTURAL ASSESSMENT AND CONSERVATION OF THE FERHAT PASHA MOSQUE

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Architectural Assessment and Conservation of the Ferhat Pasha Mosque

Abstract: The Ferhat Pasha Mosque, located in the Ferhatpaşa neighborhood of Çatalca district in Istanbul, is an Ottoman structure attributed to Mimar Sinan and dates back to the 16th century. This study documents the mosque's historical development, architectural features, and the interventions and restorations it has undergone. Exhibiting characteristics of classical Ottoman architecture, the building features a square-planned prayer hall, a central dome, a porticoed forecourt, and a single-balcony minaret. Archival records and field surveys reveal that the mosque underwent major restorations in 1968 and 1975, during which significant alterations were made to the minaret, interior decorations, forecourt, and courtyard arrangements. Today, the mosque survives as a significant element of the region's cultural heritage with many of its architectural components preserved. Moreover, by emphasizing the role of disasters as a critical factor in the deterioration of cultural heritage-a subject rarely addressed in existing sources-this study highlights the mosque's architectural and historical significance and presents a record of its documented interventions.

Keywords: Ferhat Pasha Mosque; cultural heritage; restoration; disaster risk; GIS

Introducion

The Ferhat Pasha Mosque, located in the Ferhatpaşa neighborhood of the Çatalca district in Istanbul, is a significant Ottoman monument attributed to Mimar Sinan and dates back to the 16th century. The structure comprises a square-planned prayer hall, a central dome, a porticoed forecourt, and a single-balcony minaret. Despite its architectural and historical value, the mosque has been the subject of limited scholarly attention; in particular, although it is included among Mimar Sinan's works, its architectural characteristics and historical development have not been adequately examined in existing literature. This lack of comprehensive studies underscores the importance of documenting both the architectural features of the mosque and the interventions and restorations it has undergone over time.

The aim of this study is to present the historical development, architectural characteristics, and restoration processes of the Ferhat Pasha Mosque, as well as to evaluate its significance within the cultural heritage context of the region. Furthermore, the mosque is situated in an area with a high potential exposure to natural hazards, which further emphasizes the urgency of its preservation. By addressing these aspects, the study seeks to fill a gap in the literature, provide a detailed documentation of the monument, and contribute to sustainable conservation approaches.

Literature Review

The conservation of cultural heritage, encompassing both tangible and intangible values, holds significant importance at national and international levels for ensuring their

transmission to future generations (UNIDRR, MARSH, ICCROM, ICOMOS, ICORP, & UNESCO, 2013; UNESCO, 2015). However, numerous threats challenge the preservation of cultural properties. The literature emphasizes that natural disasters (earthquakes, floods, wind, etc.), environmental conditions, misuse, inappropriate repairs, and interventions jeopardize the integrity of cultural heritage (Ahunbay, 2019; Sanpaolesi, 1972; SARAT Project, 2017–2020; Feilden, 2003). Studies on historical structures, including examples such as Hagia Sophia, the Grand Bazaar, Bam Citadel, Hasankeyf, and the Zeyrek Houses, have examined conservation approaches and revealed that improper interventions, environmental factors, and natural disasters can cause irreversible damage to historical buildings (Ahunbay, 2019; "1894 Istanbul Earthquake," 2023; Eshghi & Zaré, 2004; "Abandoned to Decay While on the UNESCO List," 2019; Uluçam & Eliüşük, 2018, as cited in Yılmaz, Sevgi Eskici, Şener, & Eliüşük, 2020).

Methods

This study aimed to document the architectural features of the Ferhat Pasha Mosque, identify the interventions it has undergone, and evaluate the environmental risks affecting its preservation. The research was conducted in two main stages.

1. Archival and Document Analysis:

Archival research was carried out using survey, restitution, and restoration projects obtained from the General Directorate of Foundations (Vakıflar Genel Müdürlüğü - VGM), the Conservation Implementation and Control Offices (Koruma Uygulama ve Denetim Büroları - KUDEB), and other relevant institutions. Maintenance and repair reports dated 1964, 1968, 1985, 1988, 1990, and 2021, as well as the restoration project prepared in 2004, were examined in detail to understand the interventions implemented over time.

2. Field Surveys and Geospatial Analysis:

On-site inspections were conducted to document the current condition of the mosque's architectural elements. In addition, a disaster risk assessment of the site was performed using Geographic Information Systems (GIS). Eight parameters-slope, aspect, elevation, precipitation, hydrological features, proximity to fault lines, soil characteristics, and land use-were considered. The Weighted Overlay method was applied using ArcGIS 10.5 software to integrate these parameters and evaluate the structural and environmental context of the mosque in a comprehensive manner.

Findings and Discussion

The Ferhat Pasha Mosque forms a cohesive complex comprising a square-planned prayer hall with a central dome (~9.20 m dia.), a single-balcony minaret, a double-arcaded portico, a primary school to the northeast, a boundary-wall fountain, and an octagonal ablution fountain. The structure is built of finely cut local limestone with lead roofing. Set above the street level on the east, the courtyard with the ablution fountain is supported by retaining walls on three sides; the ablution fountain itself is placed off-axis, shifted west of the portico.

The dome rests on pendentives and a low octagonal drum. Each façade has two symmetrically arranged windows. The south wall contains a muqarnas-decorated limestone mihrab; the wooden minbar is in the southwest corner, and a women's upper gallery occupies the north side-formerly accessed via an internal stair, now by a door from the minaret. KUDEB (2020) reports severe damage during the Balkan Wars, followed by repairs. Although decorative paintings were renewed from the 1990s onward, the original ornamentation around the mihrab, dome base, and pendentives noted by Eyice (1995) is no longer extant.

The front portico has three bays and a double arcade: the inner arcade carries three domes on four marble columns; the outer, of seven bays, has a timber roof clad in lead. Its arches are now enclosed with glazing. The minaret rises 25 m at the southwest corner; a truncated-pyramidal transition leads from the square base to a twelve-sided shaft. The balcony features muqarnas beneath, stone-paneled railings, and a lead-clad pointed spire.

The ablution fountain, located northwest of the portico, has an octagonal plan with a wooden superstructure. Later interventions replaced the roof and spouts, while the stone body has retained its original character. The courtyard fountain, at the southeast corner on the street-facing wall, is ashlar-built with a pointed-arched façade framed by a rectangle. Its tympanum bears an elongated marble slab inscribed H.1006/M.1597–98 within two cartouches. The original spout stone has been partially obscured by a reinforced concrete intervention, leaving only its upper part visible; a small pointed-arched niche survives above, and modern taps have replaced the original spouts.

The primary school stands on the enclosure wall at the northeast corner, oriented northeast–southwest. Its load-bearing walls are constructed of local limestone; the brick dome is lead-clad. The plan comprises a square classroom and a rectangular entrance section with a portico supported by three wooden posts and roofed with Marseille tiles. Restored with the mosque in 1968, it later served as a Qur'an course. Subsequent repainting has obscured the interior dome's original motifs and painted ornament. On the east and west façades, the

windows are in two tiers: lower openings with rectangular frames and relieving arches, and upper ones pointed-arched. The only surviving decorations are plaster grilles with palmette motifs on the inner surfaces of the upper-tier windows.

The burial ground surrounds the mosque on its southern, eastern, and western sides and lies between the school and the mosque, containing approximately seventy tombstones, most of which are no longer legible. KUDEB (2020) dates the graves to the 18th and 19th centuries and notes burials of Crimean khans and their families. A plaque at the entrance to the women's prayer section records the interment of the Divan poet and historian Halim Giray (1772–1823). Today, the burial ground is in a neglected state, with several tombstones piled irregularly.

Restoration History;

In the 1964 restoration, The Ali Pasha and Ferhat Pasha mosques were treated jointly to address deterioration of eaves, flat roofs, and dome lead cladding; approximately 30,210 kg of sheet lead was supplied and installed (VGM, 1964).

In the 1968 restoration, Joint works included filling floor and step gaps, cleaning mortar stains, repairing and repainting the wooden ceilings of the ablution fountain and the area in front of the Mufti's Office, renewing roofing felt in accordance with specifications, repairing blistered plaster and corners, cleaning door and window jambs, fixing roof and post cracks, resetting broken border stones of the ablution fountain, filling base cavities, and site cleanup (VGM, 1968).

In the 1985 restoration, Plaster and whitewash scraping in the portico, repainting of classical coffered ceilings, scaffolding erected on the dome, and plans made to execute painted decoration, plastering, the upper gallery, and railings following preliminary investigations (VGM, 1985).

The restoration efforts in 1988 focused on the structurally vulnerable minaret: removal of decayed material from inner steps and façades, joint grouting, fine grooved surface cleaning, installation of railings, and imitation plaster applications to ensure stability. The dome, drum, and flat roofs were also treated; moisture-prevention measures were implemented in the lower walls, rubble walls were repaired, and block concrete works were completed, all in compliance with the approved survey and specifications (VGM, 1988).

According to the 1990 restoration reports, Comprehensive interventions were carried out on both the interior and exterior: concrete block flooring and drainage around the mosque; repair and renewal of hardwood windows, plaster linings, and concrete sills; restoration and oil-painting of deteriorated coffered ceilings; dome plastering; interior floor repairs and

painting; clearing accumulated soil and debris from the cemetery; renewal and painting of the classical coffered ceiling of the ablution fountain and the portico; and reopening for worship upon completion (VGM, 1990).

In 2004, a restoration project for the Ferhat Pasha Mosque was prepared by Avunduk İnş. Tur. San. ve Tic. Ltd. Şti. and approved in 2005. The project proposed removing non-original joinery in the portico, repairing hairline cracks, reconstructing cabinet and window shutters in their original forms, renewing deteriorated or detached lead on the dome and roof, replacing the existing non-original ablution fountain with a classical-period model featuring marble columns, a timber roof, and a lead covering, and cleaning and corrosion-proofing metal elements. The planned interventions had not yet been implemented, and the mosque remained open for worship (Giray Küçük, 2017; KUDEB, 2020).

According to the 2021 reports of the General Directorate of Foundations, comprehensive restoration works were carried out at Ferhat Pasha Mosque. Reported works included renewing the lead coverings of the portico and main dome, modifying the minaret's lead cladding, removing the portico roof covering, reinforcing decayed or deformed timber elements and renewing sub-roof lead, building-wide plaster scraping and re-plastering, repairing deteriorated stones in load-bearing walls using the replacement-and-completion method, and sandblasting to remove heavy exterior soiling (VGM, 2021).

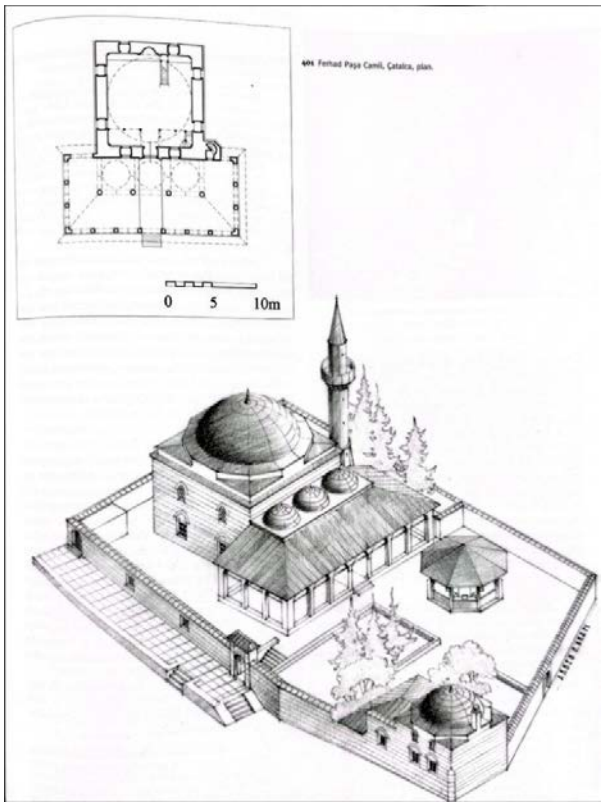

Figure 1. Ferhatpaşa Mosque plan and axonometric perspective (Necipoğlu, 2017)

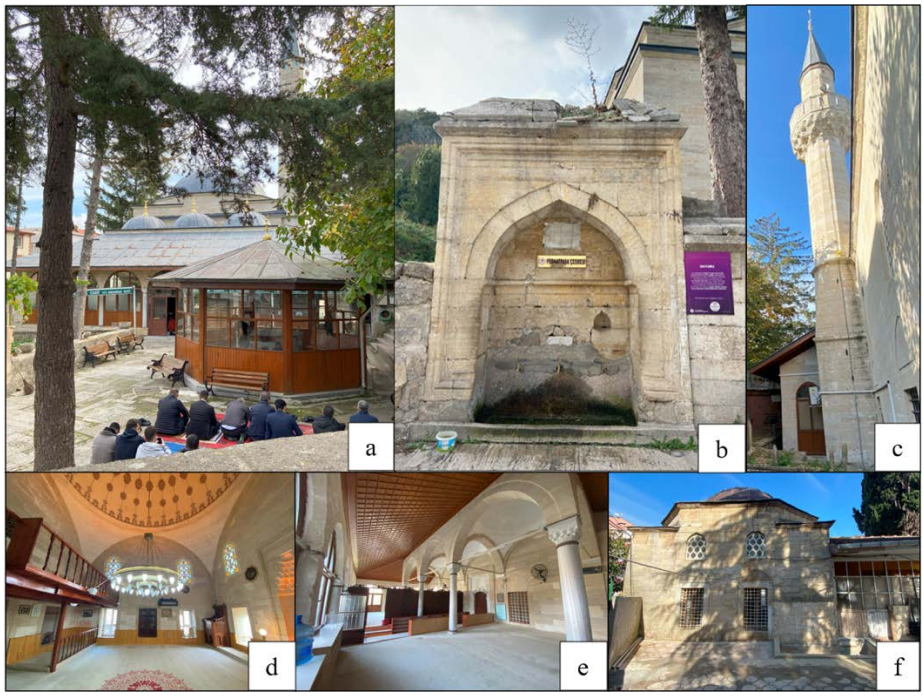

Figure 2. Ferhatpaşa Mosque (a), Fountain (b), Minaret (c), Interior details (d, e), Primary school in 2024 (f) (Handenur Özdemir, dated 01.11.2024)

The disaster risk analyses conducted in the Ferhatpaşa Neighborhood, where the Ferhat Pasha Mosque is located, reveal that the site is exposed to various threats originating from both natural and built environments. In the analyses carried out using the Geographic Information Systems (GIS)-based Weighted Overlay method, eight parameters were evaluated collectively: slope, elevation, aspect, precipitation amount, soil capability, land use, proximity to fault lines, and proximity to hydrological features. The results of these analyses indicate that the area where the Ferhat Pasha Mosque is situated falls into the medium-risk category. Specifically, 71.99% of the study area is classified as medium risk, 28% as low risk, and only 0.02% as high risk. Key factors contributing to the elevated risk potential of the site include its proximity of approximately 29,600 meters to active fault lines, an annual average precipitation of about 1,005 mm, the predominance of alluvial and non-calcareous brown soils in the surrounding area (56.44%), and its location within a residential zone. Additionally, the mosque's close proximity to a dry stream (~250 meters) and a stream-like hydrological feature (~800 meters) increases its susceptibility to flooding. When these factors are considered together, it is evident that the structure occupies a vulnerable position against both geological and meteorological hazards, with earthquake, flood, and erosion risks being particularly prominent.

According to the 2020 data from the Istanbul Metropolitan Municipality, Department of Earthquake Risk Management and Urban Improvement, Directorate of Earthquake and

Ground Investigation, a deterministic earthquake scenario projects a high number of damaged buildings and potential loss of life in the neighborhood. Ferhatpaşa Neighborhood has been identified as one of the areas with the highest vulnerability within the Çatalca district. GIS analyses further indicate that approximately 72% of the neighborhood falls within the medium-risk category, while 28% is classified as low risk; although high-risk zones are limited, they are located in close proximity to residential areas.

These findings are of critical importance not only for preserving the historical value of the structure but also within the context of regional disaster management. The study demonstrates the applicability of GIS-based disaster risk analyses in the conservation of cultural heritage structures and emphasizes the necessity of implementing risk-reducing strategies-such as regular maintenance and repairs, monitoring of environmental risks, and adopting a risk-oriented approach in urban planning. In this regard, the preservation of Ferhat Pasha Mosque is concluded to be a priority, not only for safeguarding the building itself but also for ensuring the sustainability of the surrounding cultural heritage sites.

Conclusion

This study has comprehensively documented the architectural features, historical development, and the interventions and restorations undergone by Ferhat Pasha Mosque, attributed to Mimar Sinan in the 16th century, and evaluated its current state of preservation. Archival records and on-site observations reveal that, although the mosque has retained many of its original elements, interventions carried out throughout the 20th century have altered components such as interior decorations, the minaret, and the portico. The loss of original painted ornamentation, modifications in the portico and courtyard, and the neglected state of the cemetery have increased the structure's vulnerability to both environmental and human-induced threats.

Geographic Information System (GIS)-based disaster risk analyses indicate that Ferhatpaşa Neighborhood, where Ferhat Pasha Mosque is located, falls within the medium-risk category. The analyses identified several factors contributing to the elevated risk level: its proximity to active fault lines (~29.6 km), high annual precipitation (~1,005 mm), the predominance of alluvial and calcareous-free brown soils in the surrounding area (56.44%), and its location within a densely populated residential zone. Additionally, the mosque's close proximity to water sources-approximately 250 meters from a dry stream and around 800 meters from a small river-like watercourse-further increases its susceptibility to flooding. When these

factors are considered collectively, the site is found to be vulnerable to both geological and meteorological hazards, with earthquake, flood, and erosion risks standing out as particularly significant.

The findings of this research highlight that solely architectural interventions are insufficient for the conservation of cultural heritage; environmental and geological risks must also be addressed within an integrated framework. The GIS-based multi-criteria analysis method employed in this study enables a data-driven assessment of risks, providing an applicable model for the preservation of similar cultural heritage sites. In this context, the conservation of Ferhat Pasha Mosque holds critical importance not only for transmitting a significant example of Ottoman Classical Period architecture to future generations but also for ensuring the sustainability of cultural heritage under disaster risk.

Within the scope of this study, the documentation of the architectural features of Ferhat Pasha Mosque and the assessment of risk factors in its surrounding environment provide a holistic approach to the conservation of historic structures. These findings offer a method applicable to the preservation and transmission of similar architectural works to future generations, serving as a guiding framework for planning regular maintenance and repair activities, developing preventive strategies against environmental risks, and preparing analyses to support conservation projects.

Acknowledgments

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TABRIZ BAZAAR AS A BACKBONE INVALUABLE HERITAGE SITE: LESSONS FOR GREEN ADAPTIVE REUSE

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Tabriz Bazaar as a Backbone Invaluable Heritage Site: Lessons for Green Adaptive Reuse

Abstract: Tabriz, one of the most important cities in Iran, is known for its cleanliness, pleasant atmosphere, and pioneering developments. However, the old parts of Tabriz are facing a high rate of deterioration, and the reuse of green space is essential to preserve it based on a futuristic visioning. This study emphasizes the need for a cohesive factor to unify the different elements of the city. Tabriz Bazaar, a UNESCO World Heritage Site and a key commercial center on the Silk Road, is selected as a case study for this research. This research uses a descriptive-analytical method and logical reasoning strategy to identify the capacities of Tabriz Bazaar. As a part of GRACE - Green Reuse through Adaptive Conservation and Environment-Friendly Design for MENA region, the study concludes that Tabriz Bazaar can serve as a model for environmentally friendly reuse and play an important role in the revitalization of the old city fabric. The bazaar, through covered walkways, increases interactions, making it a key factor in preserving Tabriz's heritage and economy.

Keywords: Green Adaptive Reuse, Tabriz Bazaar, MENA Region, Futuristic Visioning, WEE (Water-Energy Efficiency).

Introduction

The Iranian market, as an urban space, is a twin manifestation and crystallization of the "structural", "perceptual" and "social behavior" dimensions in space and meaning in such a space is manifested in the mutual relationships between the space and the dimensions (Sajjadzadeh and Pirbabaei, 2012).

The The presence of the world's largest roofed Bazaar within the historical context of Tabriz is a special commercial axis and the backbone of the central context and a handicraft supply center with with trans-urban and trans-regional functions (Yazdani, Deh Deh Zadeh Silabi). In fact, the Grand Bazaar of Tabriz is an outstanding example of a multifunctional and integrated urban complex (Khamachi, 1996).

Literature Review

- Mohammadi and Oliveira say:The shops ("hojres"), the "saras", the "timches" and "rastes" contribute to the sustainability of the Bazaar by creating an appropriate social and economic interaction (Mohammadi, Oliveira,2015).
- Samani and Pourjafar mentioned in their article about sustainable development indicators in Tabriz market and consider climate-based design as one of the environmental indicators (Samani, Pourjafar, 2012).

Historical background and reasons for the emergence of the bazaar and the city of Tabriz

The history of Tabriz Bazaar, like most of the historical cities of Iran, goes back to the early periods of urban planning in Iran after Islam. But due to numerous earthquakes, it is not possible to find a building with a long history in the bazaar that shows the formation of the initial core of the bazaar. What is certain is that the establishment of the Grand Mosque dates back to the Seljuk period, which coincides with the beginning of Tabriz's rapid growth and its emergence as an important city in Iran and even in a region beyond Iran at that time. In general, Tabriz's location on one of the main branches of the Silk Road and its strategic role in regional and international trade (the connecting axis between Europe and Asia, the East, and the Far East) were among the most important reasons for the formation of this city (Ministry of Housing and Urban Development, 2009).

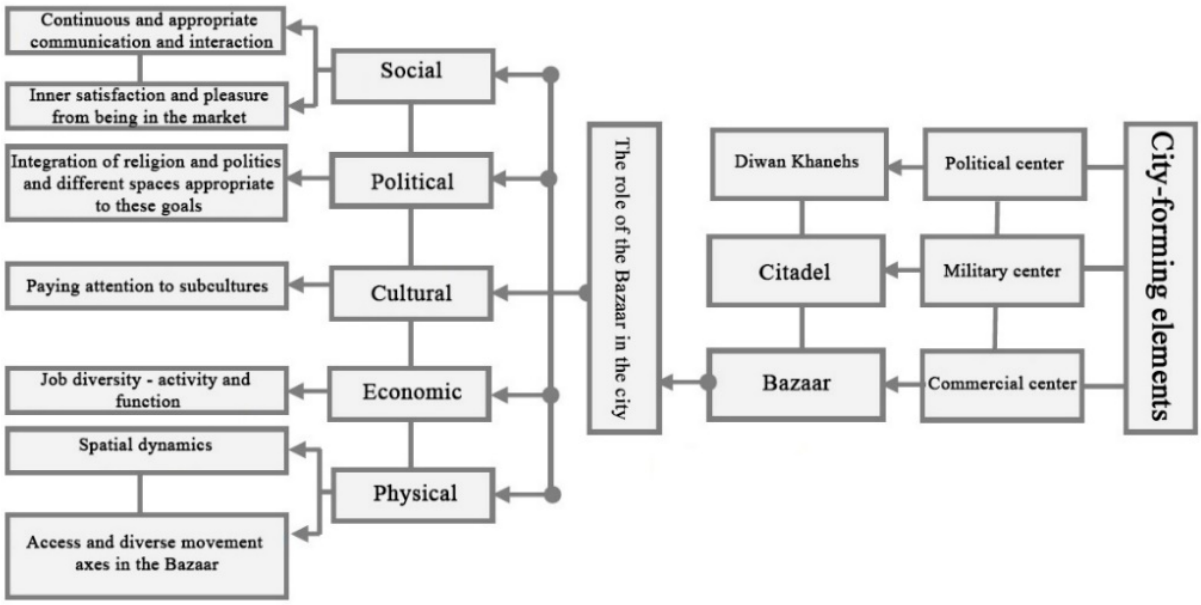

Chart 1. The role of Tabriz Bazaar in the city (Mehdinejad, NajariNabi,2018).

Before this century, Tabriz was a city that got its life force mainly from the three factors of commercial prosperity, military and political centrality, which was the result of the geographical location of this city and the connection of Iran and Asia with Russia, Ottoman and Europe (Chart 1). The physical reflection of the three factors mentioned can be seen in the city's structure in the form of a large and wealthy bazaar, extensive Divan Khans and several barracks and military centers around the central core of the city (Molaei, 2019).

How the Bazaar Was Formed and Developed

The central core of Tabriz is located within a quadrilateral, and Tabriz Bazaar is located in the center of this quadrilateral. This bazaar is bounded by Ali Qapu on the eastern side and

Jameh Mosque on the western side, and on the northern side, it encompasses parts of the north of the Mehran River, and these two parts are connected by wooden bridges along the bazaar (Samani and Pourjafar, 2010). This bazaar is a multi-axis bazaar (Tabriz Municipality website).

Tabriz Bazaar as the Core of the City Formation

The Tabriz Bazaar was located in the central part of the city, among other prominent buildings of that time. Tabriz Bazaar was located along one of the main routes that connected the Rey Gate in the southeast of the city to the Shtarban Gate and the Istanbul Gate in the northwest of the city. Two axes intersect, one of which starts from the Baghmishe Gate. They are perpendicular to the first axis. Hence, the structure of the bazaar is woven into the fabric of the city. The inside of the bazaar is connected to the outside (Taghizadeh Vahed, 2015).

Each of the chambers of the Tabriz Bazaar structure has a specific function. Before the urban fabric developments, these residential parts were occupied by merchants. And the city was divided into different areas based on the commercial activities of the residents. This type of separation is the main reason for naming the city's areas. For example, the Cheese Sellers' Quarter, the Carpet Sellers' Quarter, etc. The chambers were not only the cores of the bazaar, but also the cores of urban fabric. The Tabriz bazaar was the backbone of the city's formation (Taghizadeh Vahed, 2015). And in the meantime, important and busy streets, entrances, accesses, more productive and richer rooms have a direct impact on the establishment of guilds in the market (Hosseinzadeh Dalir, Ashna, 2011).

The connection between access, uses, and traffic, and the two-way relationship with the street, has given a new face to this part of the city and led to the emergence of vitality and happiness in this area. (see Figure 1)

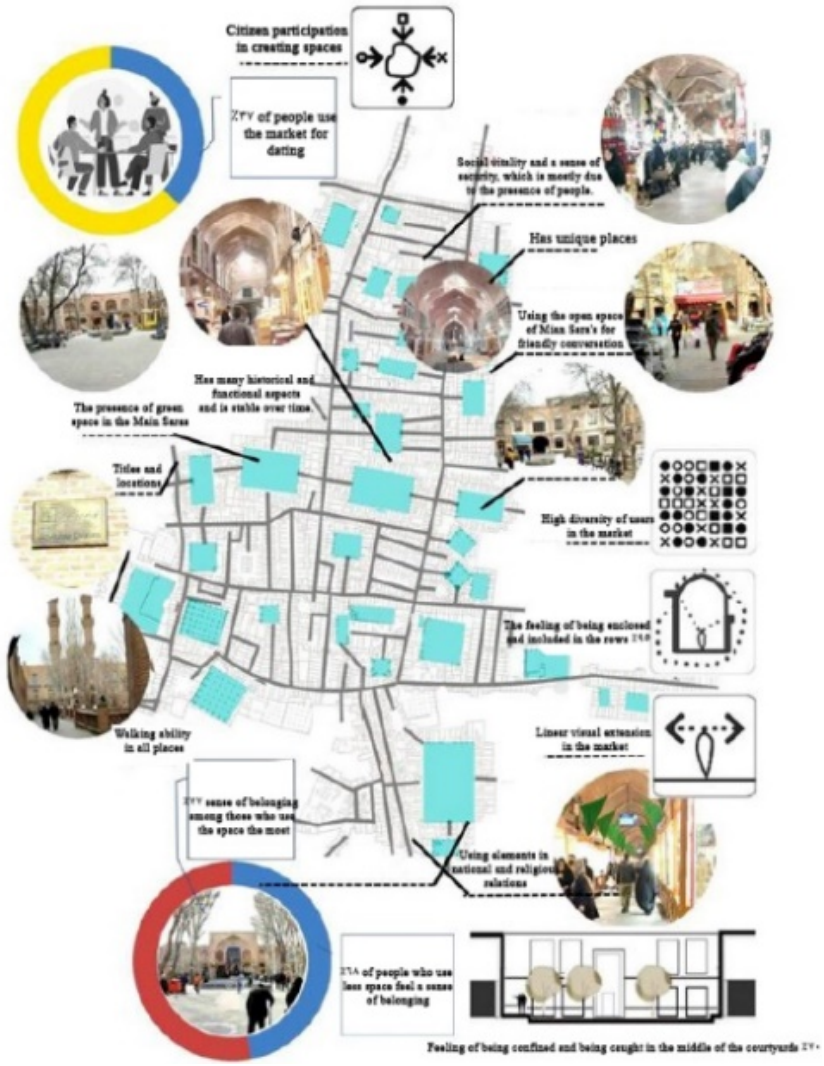

Figure 1. Analysis of the historical Bazaar of Tabriz from the aspect of usage and activities and access and connection) Hosseinikia and others,2024).

How the Bazaar is Connected to Important Buildings in Tabriz

The Bazaar of Tabriz is connected to important areas in various ways. Saheb-al-Amer Square is located in the north, and the Alishah Citadel is located in the southern part of the bazaar. On the other hand, we can mention the Mehran River, which is located on the southern side of the current square and the tomb of Saheb-al-Amer and passes through the middle of the northern and southern parts of the bazaar (Hashempour et al., 2018). (see Figure 2)

Figure 2. Important areas of the city and their communication routes to Tabriz Bazaar (Authors)

Architectural Features of Tabriz Bazaar

The main bazaar of Tabriz should be considered the largest and most comprehensive bazaar in the Islamic world. The architectural style, especially its arches and domes, is architecturally significant, and the religious centers of this section are also notable and play an important role in the spatial structure of the city. Unlike the bazaars of most cities in the eastern Islamic countries, and certainly Iran, this bazaar has a specific area with a clear boundary that has special entrance doors (Khamachi, 1996).

Tabriz Bazaar, with its unique usage pattern and variety of lively spaces, is present in the urban memory as one of the identity-building factors of the city of Tabriz, which has continued to exist with some changes over time (Ministry of Housing and Urban Development, 2009).

Acoustic Behaviour of the Bazaar

The physical characteristics of the Tabriz bazaar have caused the sound deformation to vary in different locations depending on different components. In fact, understanding the acoustic contrast along the different spaces of the Tabriz bazaar is very useful in stimulating the role of this valuable and historical place (Ghafari et al., 2012).

Investigating Sustainable Development Indicators in the Design of Tabriz Traditional Bazaar

Tabriz Bazaar is one of the traditional urban spaces that, in addition to its economic function, also has a social function and is also physically in harmony with nature (Samani and Pourjafar, 2011). Tabriz Bazaar, with its compact texture, buffer spaces, roof and walls, openings, location and direction of establishment, use of green and water elements in the design of the walls, and diverse uses that are compatible with nature, has contributed to the sustainability of the city's environment (taken from Samani and Pourjafar, 2011).

Tabriz Bazaar Potentials

The city of Tabriz has been selected as the world city of handicrafts in the field of carpet weaving and is considered the origin of one of the Iranian painting schools. It has also been selected as the tourism capital of Islamic cities in 2018. Meanwhile, the tourism industry plays an important role in the dynamism of the city's economy; Applying creative tourism dimensions in all urban areas, including the historical contexts of Tabriz, can be a very good lever for promoting this city on a global scale (Marsousi and Bagherkhani, 2011).

Considering the multiple characteristics of historical Bazaars, each part of which is a platform for the manifestation of traditional Iranian Islamic social capital, the social capital of historical Bazaars can be comprehensively studied in the following six fields:

- Cultural and religious field
- Social field
- Economic field
- Historical field
- Semantic field
- Spatial field (Samani and Pourjafar,2011).

Bazaar Factors Affecting Urban Space

In a general summary, the positive physical values of different parts of the Tabriz Bazaar, which have caused order in this urban space, can appear in the following classifications:

Existence of spatial hierarchy, Observance of arenas, Connection and combination of components, the relationship between the part and the whole, How the elements are placed in the text, Order, layout, proportion and ratio of openings, Spatial qualities such as composition, rhythm, symmetry, equilibrium, balance, Symmetry with visual unity, Observance of human scale and human centrality in spatial design, Spatial understanding and creating a clear image in the viewer's mind, creating connections and connections between urban spaces, Creating continuity and coherence in urban spaces, A balanced combination of architecture and urban planning (Yazdani, Deh Deh Zadeh,2018).

The Impact of Bazaar Sustainability on Social Welfare and Economic Growth

Given recent constructions and the lack of harmony and consistency of the materials used with the overall form of the building under study, and the lack of proper harmony between the edge of Mehran-Rood and the main body of the Bazaar and the disregard for its overall structure, solutions can be proposed for the harmony and sustainability of this building.

By implementing the following steps, a sustainable Bazaar can be created that promotes economic growth, environmental protection, and social well-being. As a result, this sustainability can have a positive impact on cultural heritage in several ways.

Preservation of historic architecture, promotion of local culture and heritage, awareness and education, cooperation with local communities and sustainable tourism (Elyasi and Yamakli, 2023).

Tabriz Bazaar Situation and Affecting Factors from the Past Until Now

With the investigations carried out, we realize that the role of Tabriz bazaar is not the same as in the past, whether in terms of architecture, society, etc. Various factors have been effective in this. In general, these factors are classified into two categories, external and internal. We will explain and examine these factors in Table 1.

Table1. Influential factors throughout history in Tabriz Bazaar

Influential factors throughout history in Tabriz Bazaar		
Internal factors	Physical	- Lack of proper lighting in the Bazaar - Inadequate electrical connections - Inadequate flooring and asphalting of the passages - Occupying the space of the Rasteh by Bazaars and problems with access and traffic - Imbalance in the shopkeepers' windows - Incorrect implementation of the horno and its improper installation and rainwater penetration inside
	Social	- Changes in different guilds - Marginalizing the Bazaar - Diminishing presence of people in the central part of the Bazaar
	Economic	- Tax collection unlike before - Increase in commercial centers around the Bazaar and loss of Bazaar customers - Economic conditions of the country - Lack of financial prosperity
	Religious	- Change in land use and loss of many jobs of interest to villagers and nomads - The fading of the business model of the past - The diminishing of the spatial sanctity of the Bazaar
	Street design	- Cutting off the extension of the Bazaar and fragmenting the Bazaar - The destruction of the surrounding neighborhoods and the wear and tear of the traditional fabric and replacement by the marginalized people - Modernization and increase in cars and lack of parking due to the large number of cars - Lack of proper transportation in the Bazaar - Heavy traffic around and around the streets of the Bazaar due to its location in the central core and the lack of proper arrangements - Construction of shopping malls and commercial complexes around the Bazaar and increasing traffic load - The loss of important Bazaar entrances due to street construction and the abandonment of many entrances
External factors	Natural disasters (floods and earthquakes)	- Weak drainage system in the Bazaar - Lack of optimal resistance of the Bazaar against major earthquakes
	Fire	- Lack of proper fire extinguishing equipment - Lack of proper access for fire trucks in case of fire - Failure of Bazaars to comply with the use of proper heating equipment in the Bazaar
	Cityscape	- Lack of visibility due to the construction of parking lots and underground passages around the Bazaar - The presence of vendors on the edge of the Bazaar entrances and the creation of an inappropriate urban landscape

Conclusion

The influential components in Tabriz architecture have a direct relationship with its climate and politics. Tabriz Bazaar has taken an important and vital step in giving meaning to the city by influencing individual perception and creating a sense of belonging due to playing with color and light, creating shadows and penumbras and guiding the audience to go to

different parts of itself and a sense of dynamism, creating a different auditory experience in its different spatial types and attracting the audience through it.

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THE PORTUGUESE CULTURAL HERITAGE. RESIDENCES AND PARKS IN SINTRA

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The Portuguese Cultural Heritage. Residences and Parks in Sintra

Abstract: The research aims to document the current state of the estates, the residences built by the nobility to spend time away from everyday city life, using photogrammetric surveys based on the Structure from Motion (SfM) method, with acquisitions both from the ground and via quadcopter drones (UAV). This image-based method has made it possible to obtain a three-dimensional representation of the elements, necessary for the graphic interpretation of the building and for accurate documentation in order to ensure sustainable accessibility to the buildings and spaces.
The case study is the results of the photogrammetric survey of Quinta de Amizade and Quinta da Ribafria, two historic estates located in Sintra, Portugal. Designed as private residences, the structures reflect the cultural values of the late 19th century, characterised by a refined fusion of architecture and nature.
The results achieved highlight the importance of knowledge of private residences in relation to the inaccessibility of spaces.

Keywords: documentation, sustainability, use, photogrammetric survey, Portugal

Introduction

The sustainability of a place is linked to knowledge of the architectural and naturalistic system where humans permanently reside, live and carry out their daily activities.
The word landscape, from the French paysage, does not refer to a well-defined object; according to anthropologist Gérard Lenclud, the term denotes “a place isolated from view, a space reconstructed from a perceptive analysis, a cut-out of the world, but a cut-out with meaning”. Landscape, therefore, is the image of the dynamic structure of the territory, and a phenomenon generated by a contemplative process, an interpretation that is expressly subjective, determined by aesthetic and emotional factors linked to the observer's state of mind.

The study of the territory of the city of Sintra has made it possible to identify numerous artefacts of architectural and historical-cultural interest, cornerstones of the symbiosis between natural and man-made landscapes. Analysing the cultural landscape by representing it according to a semiotic approach has provided a way of interpreting its constituent elements that is capable of yielding a specific and measurable amount of information traced on the territory.

Considering the landscape as a set of different and distinctive components of an environment, understood as individual units to be measured and documented, understood and protected, which “make a territory a landscape”, depicting its image meant undertaking a gnoseological investigation aimed at outlining a portrait of the area under investigation capable of clarifying the complexity of a site that over the centuries has attracted monarchs, poets and artists over the centuries.

The town of Sintra, located in central Portugal, at the western end of the Iberian Peninsula and a few kilometres from the Atlantic Ocean, fits into the historical and cultural context that characterised the 19th century. Recognised as a World Heritage Site in 1995 during the 19th session of the UNESCO World Heritage Committee held in Berlin, which led to the definition of the cultural landscape category by the organisation, Sintra is a portion of territory whose peculiarities derive from a unique symbiotic relationship between "natural and human factors", an expression of the cultural richness that has characterised this nation for centuries. Celebrated by the Portuguese playwright and poet Gil Vicente as "a garden of earthly paradise", Sintra was praised in many literary works by foreign writers such as the British Robert Southey and William Beckford, who lived in the city at the end of the 18th century and published letters and diaries about their stays, attracting other travellers.

The private residences in the Sintra area are a heritage of considerable interest for graphic investigations into the use proposed by the nobility in past centuries. These places are also relevant today because, even now, there is still the custom of the "second home", a place dedicated to leisure, often located far from the city. Perhaps, over the centuries, these structures have lost their characteristic as production buildings, as they no longer perform the ancient function of farms capable of meeting the needs of the main residence, but are intended for periods of relaxation away from the hustle and bustle of city life.

In this context, the contribution presents, as case studies, the results of the photogrammetric survey of Quinta de Amizade and Quinta da Ribafria, two historic estates located in the city of Sintra, Portugal. (Mateus, et altri, 2020)

Quinta de Amizade, also known as Villa Sassetti, was built between 1890 and 1894 in Lombard Revival style and stands along the road leading to Castle of the Moors.
Designed as a private residence, the structures reflect the cultural values of the late 19th century, characterised by a refined fusion of architecture and nature, in which the scenographic aesthetics and choice of materials interact with the environment, evoking the shapes and colours of the landscape.

Quinta da Ribafria, on the other hand, originally designed as a refuge during the epidemic that struck Lisbon in the 16th century, was transformed into a private residence, reflecting the cultural values of the 17th century in its spaces. The scenographic aesthetics and the use of different architectural styles interact harmoniously with the environment.

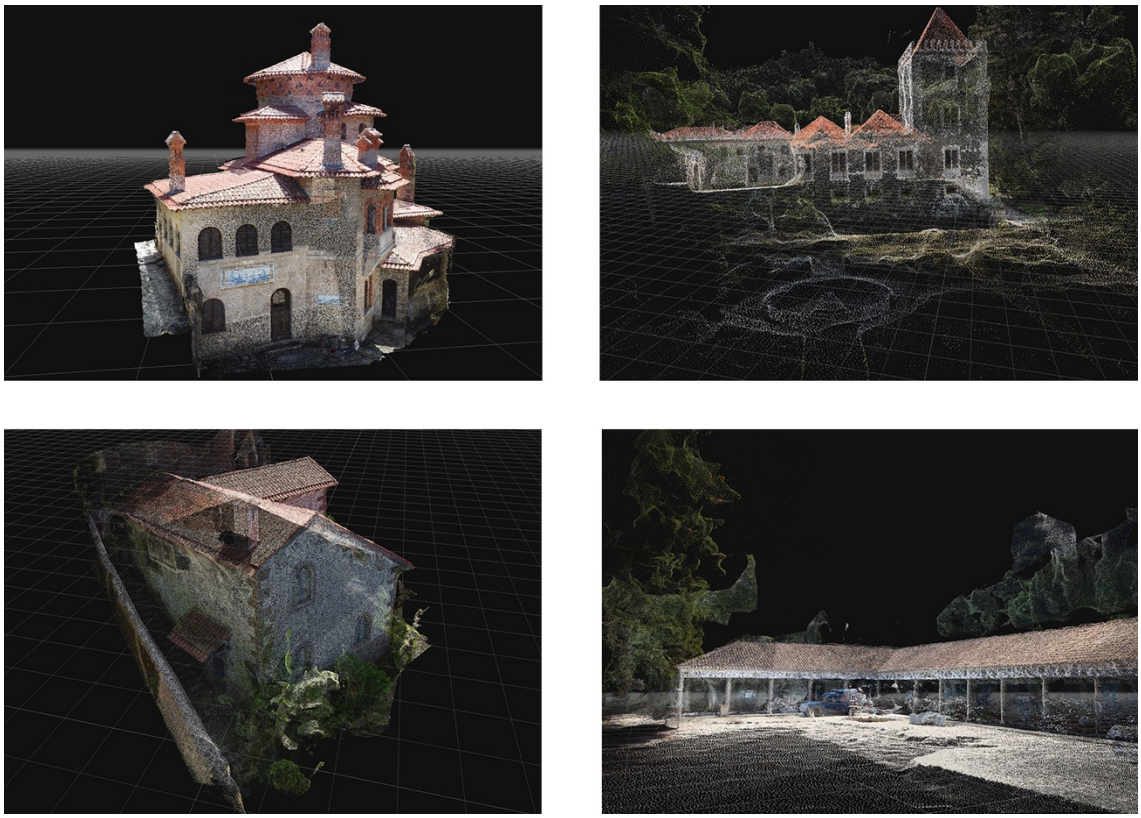

Figure 1. Point cloud from the Quinta of Sintra, subject of the research

Literature Review

The architectural and naturalistic structure of Quinta de Amizade, also known as Villa Sassetti, is a complex of buildings of considerable historical and architectural value located in the city of Sintra. Designed by architect Luigi Manini (AA. VV., 2006) between 1890 and 1894, creator of notable parks (Corniello, 2019) and gardens in the area, the villa is an example of Lombard revivalism, where tradition, modernity and nature blend harmoniously with the surrounding landscape.

The structure is located on the slopes of the Castello dos Mouros, and Villa Sassetti is part of an ambitious project by Mainini (Cordera, 2007) who, at the end of the 20th century, intended to build a series of noble residences in the Sintra area. The villa was built during a period of intense construction activity, when a new bourgeoisie was building prestigious residences for the purpose of productive estates and places of pleasure. Commissioned by entrepreneur Victor Carlos Sassetti, the structure expresses the meeting between the client's aspirations and Manini's ability to transform a cultural ideology into concrete forms in the naturalistic setting composed of a series of architectural elements in addition to the Villa.

The three-storey circular tower, asymmetrical volumes and use of local materials such as granite and terracotta create elements of considerable value, where rustic simplicity and architectural refinement coexist in a work of technique and creativity, celebrating the connection between architecture and nature. The interiors, designed for the comfort of the user and in harmony with natural light, open onto the landscape through windows and large terraces. The gardens, designed with a landscape aesthetic, follow a path through waterfalls, ponds and winding paths.

Over the years, the original Quinta de Amizade has undergone a number of transformations, including the 1894 expansion project and modifications in the 20th century. (AA. VV., 1996)

Quinta da Ribafria, on the other hand, was built in 1541 by Gaspar Gonçalves and is a fine example of Manueline civil architecture, with elements added later, such as the 17th century tower. Located on the Lourel estate, the villa is surrounded by gardens that reflect the balance between nature and architecture, a feature that links it to the romantic cultural context of Sintra.

The main building also features a cistern and a garden with a large water basin, where the facades are reflected, creating an interaction between architectural and natural elements.

Ornamental details, such as the coat of arms carved on the façade, testify to the wealth and importance of the commissioning family, while the interiors offer a fusion of structural solidity and functionality, represented by the stone vaults and arches that dominate the main rooms.

The work also examined three structures present in Quinta da Ribafria, namely the Manueline tower, the chapel in the garden and the monumental fountain. The Manueline tower, with its height of thirty metres, dominates the architectural complex as a symbol of prestige and power. The use of decorative motifs reminiscent of marine and natural elements is characteristic of the Manueline style and highlights the role of the city of Sintra as a place of exchange between nature and culture. The tower was designed to offer a view of nearby Penha Verde, another property owned by the family who owned the land.

The garden chapel, surrounded by greenery, is an intimate and evocative place of prayer. Decorated with azulejos, it offers an example of Portuguese ceramic art, celebrating sacred scenes and religious symbols in harmony with the natural environment. The monumental fountain, located in the centre of the gardens, stands out for its geometric basins and sculpted that enhance the combination of functionality and decoration.

Figure 2. The Quinta de Amizade. South elevation of the main residence.

Methods and analysis of architectures

To graphically document Quinta de Amizade and Quinta da Ribafria (AA. VV., 1990) in Sintra, photography was adopted as a tool of considerable interest, seen not only as a visual report, but also as a means of photogrammetric surveying capable of providing information for understanding the building.

Figure 3. The Quinta da Ribafria. North-west elevation of the main residence.

The research was carried out using photographic documentation, both terrestrial and aerial (Barba, 2020), to create an adequate illustrative campaign of the architectural and landscape features of the estates.

In a second phase, a survey was carried out using a drone (DJI mini 2), structuring a flight plan aimed at capturing as many details as possible of the sites and their geometric and morphological characteristics. An aspect of great interest in the survey was the design of the shots, the choice of photographic shooting points from which the measurements were taken. (Corniello, Lento, 2021)

This project took into account the actual dimensions of both the villas and the surrounding landscape, including gardens and towers, and provided for 70% image overlap and correct alignment of the collected data (Corniello, 2021). The characterisation of the shots made it possible to establish filtering procedures to reduce noise and maintain the original geometry of the architectural elements. (Corniello, 2020)

The images captured, in sufficient number for the purpose of the survey, were integrated with measurements from different points of view. Subsequently, the data collected was processed using 3D Zephyr and Agisoft Metashape software, chosen to allow a comparison between the results obtained and to select the most optimal one for graphic-geometric documentation. A key aspect of this phase was the alignment of the images using digital software, ensuring that the images overlapped by at least 70%, with a symmetrical view from two vertices towards the same shooting point. (Corniello, 2024)

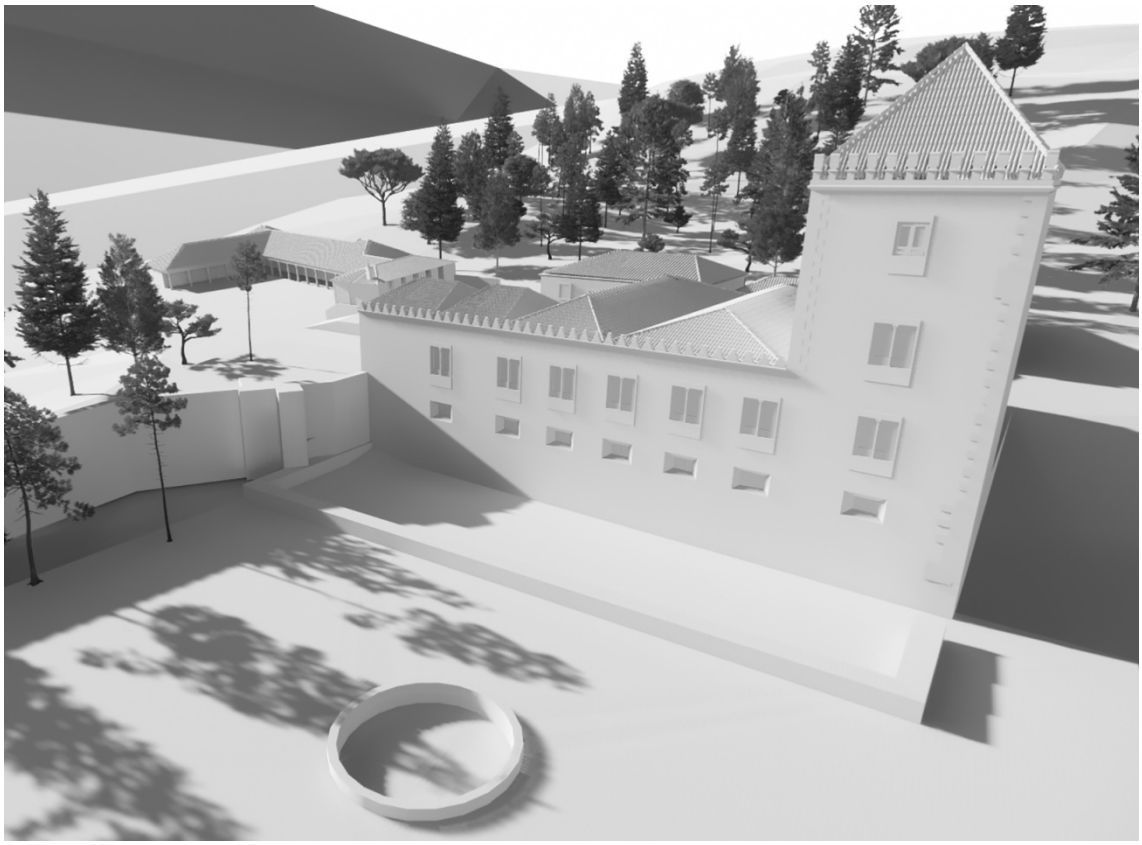

Figure 4. The Quinta da Ribafria. View of the 3D model with the residence in the foreground and the stables on the left.

This made it possible to obtain a survey while maintaining the integrity of the original configuration of the building.

The study of Quinta de Amizade and Quinta da Ribafria included surveying campaigns conducted using the Structure from Motion (SfM) photogrammetric process, using photographic acquisitions (UAV). This approach made it possible to describe the morphology and space of the architectural structures of the complex and, for Quinta de Amizade, the Sassetti pavilion, the central tower and the gardens, while for Quinta da Ribafria, the Manueline tower, the garden chapel and the monumental fountain.

Through the use of photomodelling software, dense point clouds and textured 3D meshes were generated, which were essential for processing metric, material and colorimetric information. (Amoruso, Apollonio, Remondino, 2010)

Subsequent 3D modelling made it possible to translate the architectural complexity of the Quinte into three-dimensional spatial representations that highlight the relationships between the architectural volumes and the landscape.

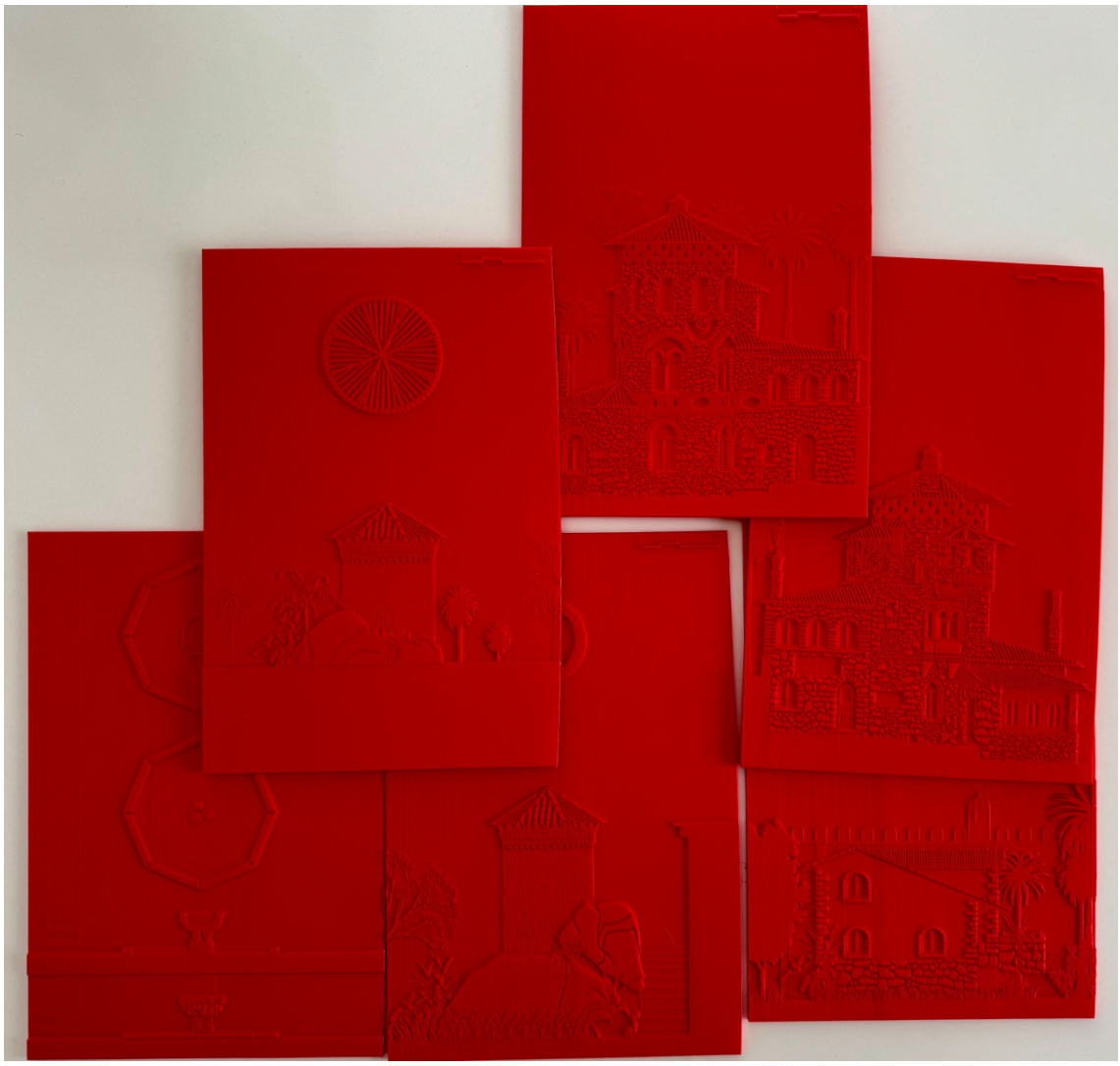

Figure 5. The Quinta de Amizade. Tactile tablets made using a 3D printer with a thickness suitable for visually impaired individuals.

As is well known, the concept of “model” is related to the term “plastic” and indicates a small-scale replica of an architectural structure. This tool, used since ancient times, serves as a means of demonstration to clarify the information gathered during the investigation phase. (Corniello, 2024) This process, understood as analysis, has enabled the creation of plastic models without material consistency, which are a valid container of information capable of providing a collection of numerical data relating to the size, shape and geometry of this heritage, managing to merge the concepts of design and vision, reality and figuration. The model, therefore, remains a tool for reflection and communication, proving particularly useful for describing complex shapes that would be difficult to represent using traditional methods of descriptive geometry.

The research lends itself to a series of activities to be carried out on site in order to broaden knowledge of the area, which is currently limited to the architectural structures in the town centre. In fact, the contribution aims to create a network of smaller residences in the town of Sintra in order to create a cultural tourist route for the promotion of holiday residences. In this context, in addition to traditional logistical activities, a number of solutions are proposed to facilitate access for people with disabilities. These include the creation of tactile tablets that allow users to experience visual sensations through touch, stimulating their imagination as they touch the texture of the masonry, the location of tree species and the beauty of the roof tiles.

Conclusion

The work, part of a broader study on the theme of second homes and holiday homes, describes two Portuguese case studies, that is the Quinta de Amizade and the Quinta da Ribafria in Sintra, seeking differences and similarities both in terms of their different locations over the centuries and their intended purpose. Currently inaccessible, the contribution aims to document the state of the sites through survey graphics and current images.

Among the possible future developments, in addition to greater knowledge of the sites through digital visions (Corniello, Lento, 2022) and interactions with interdisciplinary fields, it is possible to establish a European network of second homes where a tourist route could encourage the protection and enhancement of structures that are currently often in a state of decay and abandonment.

The contribution also aims at the sustainability of the sites through remote access, inclusiveness for people with reduced mobility and the visually impaired through a system of tactile tablets capable of describing the current state of the sites.

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RECONSTRUCTION OF COLLECTIVE MEMORY THROUGH ANTAKYA'S THREE MONUMENTAL BUILDINGS

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Reconstruction of Collective Memory through Antakya's Three Monumental Buildings

Abstract: The earthquakes that struck Kahramanmaraş in 2023 caused severe destruction in Antakya, causing loss of much of its historic urban fabric. Beyond physical damage, this destruction interrupted collective memory. In this context, the reconstruction of buildings emerges as a critical intervention method. This paper aims to examine the reconstruction of three monumental buildings in Antakya, the Parliament Building, the Greek Orthodox Church, and the Habibi Neccar Mosque, regarding spatial and socio-cultural continuity. Qualitative methods, including literature review, visual analysis, and on-site observations, assess how these interventions contribute to re-establishing urban identity. While reconstructions in Antakya's historic centre have become essential due to the scale of destruction, their effectiveness in restoring collective memory depends on the reintegration of communities and intangible heritage, emphasising the need for holistic and participatory approaches.

Keywords: earthquake, reconstruction, collective memory, Antakya.

Introduction

The earthquakes centred in Kahramanmaraş in 2023 caused destruction in 11 cities, particularly Antakya (Presidency of the Republic of Türkiye, Strategy and Budget Directorate, 2023). A large part of Antakya city centre's historical fabric was either severely damaged or destroyed. Post-disaster losses should not be considered only as the destruction of the physical setting but also as a severe disruption of collective memory and spatial and cultural continuity. In this context, the restoration or reconstruction of the city's symbolic and mnemonic monuments is as significant for social continuity as the renewal of the housing stock (Yarlıgaş, 2016).

Reconstruction, one of the most controversial conservation techniques applied when historical structures are completely demolished, is considered an 'exceptional' practice under international conservation principles in cases of permanent destruction caused by disasters or wars. Article 15 of the 1964 Venice Charter states that reconstruction can only be carried out if there is sufficient documentation, plans, photographs, materials and technical information about the original state of the cultural heritage and if it has symbolic value from a social/cultural perspective (Venice Charter, 1964, Art. 15). Accordingly, reconstruction is not only a physical reproduction but also a vital conservation method that entails ethical responsibilities and plays an essential role in rebuilding collective memory.

This paper examines three monumental buildings in Antakya that were entirely destroyed by the earthquake and underwent reconstruction recently: The Parliament Building, the Greek Orthodox Church, and the Habibi Neccar Mosque. It aims to examine how these interventions were carried out within the framework of international conservation principles

and their impact on re-establishing collective memory. Antakya was chosen as the case study area because the multi-layered destruction impacts can be observed most intensely, and buildings and sites with symbolic value for urban memory are concentrated in its city centre.

Literature Review

Reconstruction is an intervention technique that has sparked debates within conservation theories. John Ruskin (1849) argued that a building's original state should not be interfered with. According to him, destruction is a natural process of time, and rebuilding is regarded as forgery. Viollet-le-Duc (1854/1990), on the other hand, presented a different perspective, claiming that restoration is the process of returning a building to a completed state in a stylistic unity that may never have existed.

After the Second World War, the reconstruction technique was frequently employed for rising destroyed cities and strengthening their social cohesion. The Venice Charter (1964) recognises reconstruction only in "exceptional cases". This applies only when documentation is sufficient and when the preservation of cultural values is considered essential. The Nara Document on Authenticity (1994) further emphasised that authenticity is not limited to materials solely but also encompasses design, function, tradition, technique, and spirit of place. Thus, it highlights the significance of preserving intangible heritage alongside reconstructing tangible elements.

Ahunbay (1996) also underlines that reconstruction should be pursued only when supported by eligible documentation and measured drawings, and only when indispensable for preserving collective memory. In this respect, the literature defines reconstruction not merely as physical intervention but as a delicate balance between documentation, authenticity, and collective memory. As an intervention method to be applied in extraordinary situations such as sudden destruction and war, it is also favoured to prevent the loss of social attachment and offer a rapid construction technique.

Methods

This research is conducted within the framework of qualitative research methods. It is based on a literature review, analysis of existing visual and written sources, and a comparative assessment of the pre- and post-earthquake conditions of the three aforementioned buildings. Additionally, their reconstruction processes are examined through on-site observation, analysis

of visual records, and evaluation of existing documents, in accordance with international conservation documents.

Case Study

Antakya, Earthquake and Reconstruction

Antakya and its environs, among the oldest settlements of Anatolia, have been continuously inhabited since prehistoric times. Archaeological excavations have revealed findings dating to the Neolithic, Chalcolithic, and Bronze Ages, shedding light on the city's millennia-old past (Sökmen Kök & Uşma, 2022). Referred to as the "Queen of the East" (*Orientis Apicem Pulcrum*) in ancient sources, the city hosted various civilisations, including the Assyrians, Hittites, Persians, Macedonians, Egyptians, Romans, Arabs, Seljuks, Crusaders, Mamluks, and Ottomans, thus forming a multi-layered cultural heritage (Kaypak, 2010). The city came under French mandate just after World War I, Atatürk referred to the region as "Hatay" in 1936, the Hatay State was established in 1938, and it became part of the Republic of Turkiye in 1939 (Sökmen Kök & Uşma, 2022).

The earthquakes of February 6, 2023, with magnitudes of 7.7 and 7.6, followed by a 6.4 aftershock on February 20, caused destruction in nearly 90% of the city centre. A significant part of the cultural heritage was completely damaged (Aydın et.al., 2025). The Housing Development Administration (*TOKİ*) and the Ministry of Environment, Urbanisation and Climate Change took part in the process of renewing and rebuilding the housing stock. In the planning process of the historic city centre, the Turkiye Design Foundation (*Türkiye Tasarım Vakfı*) also became involved (ICOMOS Türkiye, 2024). Meetings, an important step beyond physical reconstruction toward the safeguarding of collective memory, were held with local residents and experts. In this context, it was decided that symbolic monuments, which hold significant places in urban memory, would be reconstructed (Republic of Türkiye, Ministry of Culture and Tourism, 2024).

Reconstructed Monumental Buildings: Antakya Parliament Building, Antakya Greek Orthodox Church, and Habib-i Neccar Mosque

Following the 2023 earthquake, three important monuments in the centre of Antakya, the Parliament Building, the Greek Orthodox Church, and the Habib-i Neccar Mosque, were largely destroyed (Table 1). These buildings hold great significance both architecturally and socio-culturally. They were symbolic buildings with architectural, historical and spiritual value

that reflect Antakya's multi-layered cultural identity. Their loss represents not only a physical destruction but also a rupture in collective memory. For this reason, their reconstructions are crucial for preserving the city's historical and socio-cultural continuity as well as for re-establishing a sense of belonging. The fact that these buildings were recently and extensively documented has made it possible to reconstruct them in a scientific manner. The architectural teams undertaking this work consist of experts who have previously prepared the restoration projects for these buildings, which have played a critical role in safeguarding their authenticity and heritage values. The reconstruction of these buildings is also central to ensuring historical continuity and to reviving Antakya's historic city centre. The fact that the selected buildings were constructed in different periods with different techniques, had previously undergone restoration and survey works, and were subject to repair processes at various times provides valuable data for tracking and understanding the previous interventions. A scientific committee established for the reconstruction of these three selected buildings is still carrying out the work (Anadolu Agency, 2023).

Table 1. The general information about case studies (Author, 2025)

Building	**Year of Construction**	**Interventions / Survey**	**Earthquake (2023)**	**Debris Removal**	**Expected Completion**
Parliament Building	1930s	2020 (partial consolidation and restoration)	Collapse	2023	Uncertain
Greek Orthodox Church	19th century	2021 (survey works)	Collapse	2025	Uncertain
Habib-i Neccar Mosque	7th century	2014 (restoration)	Collapse	2023	Uncertain

Antakya Parliament Building

Constructed in the 1930s, the Antakya Parliament Building emerged as a symbolic building of political history (Kayış, 2023). Completely destroyed in the earthquake, the building holds a significant role in collective memory and urban identity. Its reconstruction is vital not only in physical terms but also for reinforcing the sense of belonging. A comprehensive restoration project, prepared shortly before the earthquake, provides the necessary documentation to enable reconstruction. Given its central role in the urban memory, debris removal works began immediately after the disaster, with 85% of the stones numbered and sorted. Believing that each stone carries memory, the team has continued reconstruction efforts. Damaged structural elements are being replaced while remaining respectful to the

characteristics of the building (Ertaş, 2025). The Parliament Building's prominent role in the urban silhouette, being visible from the main urban axis and serving as a focal point, makes the preservation of its authenticity a priority within the reconstruction process. This simultaneously highlights the symbolic value of the building for both collective memory and urban identity. Although July 23, 2025, the anniversary of Hatay's unification with the Republic of Turkiye, was initially set as the target for the reconstruction's completion, the timeline has been extended due to the continuation of façade works (NTV, 2025).

Antakya Greek Orthodox Church

The Greek Orthodox Church, a 19th-century monument representing Antakya's multi-cultural character, has long served as the main place of worship for the local Christian community. The building underwent extensive restoration in 2000, and its survey and documentation were completed in 2021 (Kayış, 2023). Following the earthquakes, the World Monuments Fund designated the Greek Orthodox Church as a priority site for urgent intervention due to its central role in Antakya's collective memory. Within the scope of an internationally supported program, the institution has undertaken emergency stabilisation, documentation, and geotechnical investigations to lay the groundwork for future conservation (WMF, n.d.). The church was completely destroyed by the earthquake, and it was placed under reconstruction with the support of the Cultural Heritage Conservation Board and the World Monuments Fund (WMF, 2023). The existence of a recent survey before the earthquake provides essential documentation for the rebuilding process. Debris removal and sorting have only recently been completed, and a detailed report covering the building and its surroundings has been shared with the WMF. According to this report, ground studies have begun, although the reconstruction project itself has not yet been approved (Gül, 2025). Despite its collapse, the Greek Orthodox Church is perceived as having preserved its spirit of place. In February 2023, following the earthquakes, Christmas celebrations were held among the debris, symbolising the importance of sustaining the church's spirit for both the local people and the church community, even in its physical absence (Gül, 2023).

Antakya Habibi Neccar Mosque

As one of the earliest examples of Islamic architecture in Anatolia, the mosque was originally built in the 7th century. Having undergone various repairs over time, it holds historical significance as a symbol of the city's religious and cultural continuity. Named after

Habib-i Neccar, who is revered in Abrahamic religions for his sacrifice and devotion, the mosque functioned not only as a place of worship but also as a symbolic monument reflecting Antakya's multi-faith and multi-cultural character (Özkaya, Payaslı & Eraslan, 2022). Completely destroyed in the earthquakes of February 6, 2023, the structure represents not only a significant physical loss but also a rupture in the local community's spiritual and cultural memory. Its reconstruction is therefore of critical importance for safeguarding the site's multi-layered meaning (TMMOB, 2023). The reconstruction project is being carried out under the leadership of Konya Metropolitan Municipality, in collaboration with the General Directorate of Foundations and the Ministry of Culture and Tourism (Konya Metropolitan Municipality, n.d.). Currently, the on-site reconstruction work has been completed. Following interventions such as the rebuilding of walls, windows, and the fountain's roof, the mosque's newly crafted wooden dome has been placed in its original location (Konya Metropolitan Municipality, n.d.).

Findings and Discussion

The Parliament Building, the Greek Orthodox Church, and the Habib-i Neccar Mosque were decided to be reconstructed due to their historical and architectural values, tangible and intangible authenticity, symbolic significance in urban memory, and the comprehensive documentation works carried out prior to the earthquake. These buildings embody both differences and similarities in historical, functional, and cultural terms. Their cultural significance, authenticity, reconstruction approaches and earlier interventions and surveys are comparatively presented in Table 2. For the continuity of urban memory, it is necessary to develop a multi-dimensional perspective that ensures the holistic preservation of buildings in relation to their urban and intangible attributes. Beyond addressing physical destruction, the reconstruction of these buildings carries significance not merely as a conservation practice but as a means of re-establishing cultural continuity.

The pace of on-site work differs across the cases. While debris removal at the Orthodox Church has only recently been completed, the rough construction stages of the Parliament Building and the Habib-i Neccar Mosque are nearly finished. Despite the close proximity of these monuments and the passage of two and a half years since the earthquake, the processes remain incomplete, and the gaps left in the urban silhouette pose challenges for the spatial and social memory of Antakya's residents and those connected to the city. The reconstruction of these structures plays a vital role not only through their physical presence but also in the revival

of Antakya, which has suffered severe social breakdown and significant outmigration in the aftermath of the earthquake.

Table 2. The evaluation of reconstruction processes of case studies (Author, 2025)

Building	**Function**	**Last Intervention**	**Documentation Method**	**Status of Reconstruction**	**Authenticity**	**Cultural Significance**
Parliament Building	Political–public building	Restoration (2020)	Survey drawings, archival documents, photographic documentation, material analysis	Reconstruction process ongoing since 2023	Material/ construction technique/	Landmark on the city's main axis, city symbol, place of collective memory
Greek Orthodox Church	Religious building	Survey (2021)	Survey drawings, photographic documentation	Debris removal and sorting started in 2025 /Reconstruction project not yet approved	Not yet assessed	Spiritual bond for the community, place of collective memory
Habib-i Neccar Mosque	Religious building	Restoration (2014)	Survey drawings, archival documents, material analyses, photographic documentation	Reconstruction process ongoing since 2023	Design/ Functional	Spiritual bond for the community, place of collective memory

Conclusion

This paper examines the reconstruction processes of the Parliament Building, the Greek Orthodox Church, and the Habib-i Neccar Mosque, which were severely damaged in Antakya during the earthquakes of February 6 and 20, 2023. The analysis focuses on their historical, socio-cultural and symbolic values, as well as the methods of preserving authenticity. Yet, since their reconstructions are still not completed and social life has not fully recovered, their impact on collective memory cannot be fully evaluated in this research. Future studies should therefore address these aspects once the interventions are finalised. Furthermore, whether conservation efforts limited to single buildings can ensure a holistic urban memory preservation strategy remains debatable.

The earthquakes caused extensive destruction in Antakya's historic fabric. Although debris removal began immediately, shortcomings and negligence led to the loss of civil architecture that might have been saved through restoration. While reconstruction is not the only method for the preservation of the built environment, in Antakya's historic centre, where destruction reached 90%, it has become a crucial tool for safeguarding symbolic buildings. However, preserving the multi-layered urban environment depends not only on rebuilding

physically but also on the return of local communities to sustain intangible heritage and everyday practices.

Maintaining collective memory requires preparing memory maps and interviews, producing publications that transmit intangible heritage to future generations, and reintegrating the historic fabric with new design. In this sense, the reconstruction of only symbolic buildings may prove insufficient to encompass all attributes of collective memory, underlining the need for more comprehensive and participatory approaches.

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BEYOND ALL LIMITS 2025: 3rd International Conference on Sustainability in Architecture, Planning, and Design, 16-17 October 2025, Ankara, Türkiye

CASERTAVECCHIA AS A LABORATORY OF SUSTAINABILITY: DOCUMENTATION, RESILIENCE AND INCLUSIVE ACCESSIBILITY OF CULTURAL HERITAGE

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Casertavecchia as a Laboratory of Sustainability: Documentation, Resilience and Inclusive Accessibility of Cultural Heritage

Abstract: Minor historic centres represent a crucial component of Italy's cultural heritage, yet they are often marginalized in enhancement processes and remain highly vulnerable to natural risks. The medieval village of Casertavecchia (CE), a significant example of cultural heritage in Southern Italy, exhibits a complex historical stratification that raises major conservation challenges and calls for sustainable strategies of protection and use. This paper, developed within the framework of the GeNeSis project – GestioNE del rischio SISmico per la valorizzazione turistica del Mezzogiorno – presents an integrated methodological approach combining architectural survey, typological-structural analysis, and advanced digital tools. The creation of a multi-layered information corpus and the development of an immersive virtual tour have enabled the documentation of the urban fabric while promoting inclusive accessibility. The results highlight how systematic knowledge can support seismic risk mitigation while simultaneously fostering digital, inclusive, and sustainable practices of heritage fruition, consistent with broader objectives of resilience and cultural innovation.
Keywords: Accessibility, Casertavecchia, Seismic Risk Mitigation, Sustainable Conservation

Introduction

The safeguarding and enhancement of minor historic centres represent one of the most complex and urgent challenges in the contemporary field of cultural heritage research and conservation, closely linked to the international objectives of sustainability and resilience [MiBACT, 2017]. These settlements, characterised by multi-millennial historical stratification and a distinctive territorial identity, constitute a heritage of inestimable value. However, their preservation is often undermined by processes of marginalisation, structural vulnerability, and accessibility limitations. The limited attention devoted to such contexts, together with chronic shortages of dedicated resources, has frequently resulted in progressive deterioration, making it imperative to develop innovative knowledge and protection strategies grounded in multidisciplinary approaches and integrated methodologies.

Within this framework, Casertavecchia emerges as an emblematic case: a medieval village of considerable historical relevance that preserves a significant architectural heritage, requiring systematic documentation and enhancement strategies informed by sustainability criteria. Among its most notable landmarks are the Cathedral of San Michele Arcangelo, the Torre dei Falchi, and the Church of the Annunziata, which, together with the peculiar Norman-period urban organisation, enrich the historical and cultural identity of the village (Fig. 1) [D'Onofrio, 1993]. The conservation and valorisation of built heritage today rely on consolidated technologies capable of overcoming the limitations of traditional methodologies and integrating with innovative digital tools. The integration of direct and digital architectural survey enables the acquisition of multi-level data, essential for understanding the conservation

state of buildings and planning interventions compatible with their historical and artistic value [Cirillo & Iaderosa, 2024].

Figure 1. Views of Casertavecchia's built fabric and architectural landmarks: top left, aerial view with the Church of the Annunziata; bottom left, urban frontage along road Annunziata; centre, drum of the Cathedral of San Michele Arcangelo; right, the cathedral's bell tower (aerial shots by M. Cicala).

The synergic relationship between geometric survey, material characterisation, and structural diagnostics produces a comprehensive knowledge framework, functional to the definition of conservation strategies based on principles of minimal invasiveness and contextual coherence [Cicala, Iovane, 2024]. At the same time, the digitalisation of cultural heritage represents a strategic resource for dissemination, inclusive fruition, and the promotion of immersive experiences capable of broadening accessibility to historic villages.

In this perspective, the contribution is framed within the *GeNeSis* research project – *GestioNE del rischio SISmico per la valorizzazione turistica del Mezzogiorno* (funded under PON MIUR – D.D. no. 1735 of 13/07/2017), which involves ten universities and fourteen industrial partners, and addresses issues of knowledge and enhancement of Southern Italy's historic centres, with particular attention to seismic risk mitigation. Within the disciplinary domain of Drawing, the aim is to establish a knowledge process for the village as an indispensable action for the safeguarding, enhancement, and sustainable fruition of cultural heritage. The adopted approach seeks to ensure inclusive and diversified access, promoting a conscious and resilient conservation of historic-architectural heritage.

In this framework, the study presents the first outcomes of the *GeNeSis* project, focused on the integrated acquisition of architectural and urban data of Casertavecchia through advanced survey methodologies. The systematised knowledge, restituted through consolidated

practices of surveying and graphic representation, provides a critical foundation for the future planning of safety measures, tourist-cultural enhancement, and inclusive digital fruition.

Reading Historic Urban Fabrics through Building Frontages: Towards Sustainable Heritage Strategies

The Historic villages of Southern Italy represent a settlement system of considerable interest for the disciplinary field of Drawing, as they embody the expression and organisation of urban and architectural forms developed through processes of contextual adaptation, cultural stratification, and the transmission of constructive knowledge. Despite their extraordinary historical and morphological value, such settlements are often disadvantaged by conditions of marginality and inaccessibility, which compromise their full enjoyment and enhancement.

Within this framework, attention is focused on Casertavecchia, considered within a broader reflection on the territory of the historic province of Terra di Lavoro, referred to by the ancients as *Campania felix* [Tescione, 1965], which represented a fundamental reference for the settlement and constructive configuration of Southern Italian villages. This geographical area, already outlined by the Lombard Principality of Capua and later formalised during the Norman-Swabian period, has for centuries been a space of cultural stratification, characterised by resilient settlement systems, typological-morphological continuity, and close interrelations among landscape, architecture, and socio-economic organisation [Natale et al., 2003]. The structural permanence and material coherence observable in historic villages of the area, such as Teano, Alife, and Sant'Agata de' Goti, provide a significant methodological reference today, in which architectural and urban survey is no longer conceived merely as a descriptive tool, but as a critical device for the stratigraphic interpretation of historicised landscapes. In this context, the notion of a historical-territorial matrix emerges as a fundamental interpretative key for understanding the widespread urban heritage and the settlement logics of minor historic centres.

The concept of landscape and cultural continuity that unites these minor centres is reflected in their building fabric: the repetition of housing modules aggregated along secondary road axes; the prevalent use of Campanian grey tuff and limestone; and recurrent architectural solutions, such as stone arches, lowered arched windows, and carved cornerstones, which define the typological coherence of the built environment.

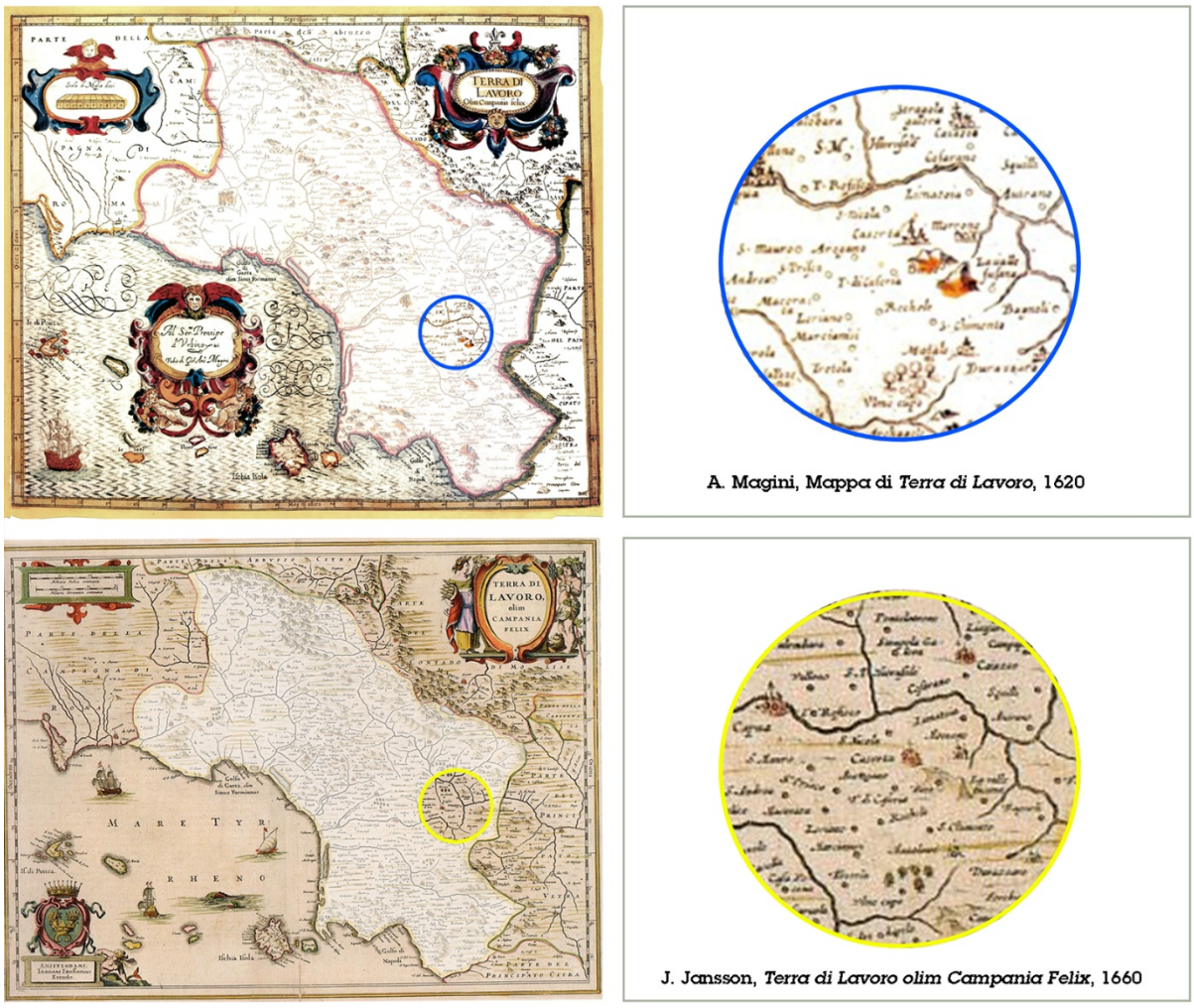

Figure 2. Top: Map of Terra di Lavoro by A. Magini (1620); bottom: *Terra di Lavoro olim Campania Felix* by J. Jansson (1660). Right: enlargements of the respective maps with details of the Caserta area (elaborations by M. Cicala).

Casertavecchia, included in the historic province of Terra di Lavoro (Fig. 2), was selected as a case study within the research project not only for its typological relevance and density of architectural evidence, but also for its "demonstrative" potential within a programme of industrial research and experimental development in the fields of conservation, digitalisation, and valorisation of Southern Italy's cultural heritage. The project, structured on multiple levels of analysis, involves the use of integrated methodologies for the knowledge, survey, and monitoring of historic architecture, with particular attention to seismic risk mitigation and the promotion of tourism through interactive digital tools, including the GeNeSis platform (similar to a remotely accessible web-GIS).

The "old Caserta" [Laracca Ronghi, 1888], registered as a hamlet of the municipality of Caserta and once described as "illustrious and flourishing" [Laracca Ronghi, 1888], rises about 401 metres above sea level on the slopes of Mount *dé Tifati* [Vultaggio, 1993], approximately

10 km from the "new Caserta" [Tescione, 1965]. Its origins are documented at least as early as 861 A.D., when the Benedictine monk Erchemperto mentioned it as *Casahirta*, meaning "village located on high ground," from which the toponym is derived [Busino, 2015].

Subsequently, in the fourteenth century (specifically in 1310), the village, which had previously belonged to the Angevins, was ceded to the Catalan nobleman Diego La Rath (later della Ratta) and was later transferred to the Acquaviva family. La Rath relocated his residence to the plain, in the area now occupied by the urban centre of Caserta [Spinelli, 2003]. This event, which contributed to the depopulation and further isolation of the village, already situated in a morphologically impervious position, paradoxically led to the preservation of its medieval urban layout. The settlement remained organised along street axes adapted to the hilly topography and punctuated by significant architectural landmarks (Fig. 3). Such permanence can be observed in the design drawings prepared for the urban restoration plan commissioned in 1954 from R. Pane and E. De Felice, which, however, was never implemented or funded [Serraglio, 2021].

Figure 3. View of Caserta by G.B. Pacichelli (1703), engraved in *Il Regno di Napoli in prospettiva*. Right: enlargement of the section depicting Casertavecchia, located on a hill and characterised by the city walls and the cathedral.

Thus, the urban structure of the village, still legible in its original configuration, is organised along road networks that conform to the hilly morphology of the site. A sequence of public spaces and architectural backdrops defines a continuous building fabric, predominantly composed of terraced or linear housing units, generally two or three storeys high, often characterised by simple planimetric schemes and aggregations formed through juxtaposition.

The building aggregates are arranged around the site's architectural landmarks, primarily the rectangular Piazza Vescovado, at the eastern end of which stands the Cathedral of San Michele Arcangelo. Constructed between 1113 and 1153, the cathedral combines the Siculo-Muslim style with elements of Apulian and Benedictine Romanesque architecture

[Tescione, 1995]. To the left of its façade rises the bell tower (32 m), completed in 1234 under Frederick II, distinguished by its intertwined and bichromatic decorative motifs that recall Islamic influences [Zerlenga et al., 2022]. Beyond the right flank of the cathedral stands the small Church of the Annunziata, a Gothic building dating from the late thirteenth century. On the eastern side, not far from the cathedral, lies the medieval castle (9th century), whose cylindrical tower dates back to the Swabian period [Busino, 2015].

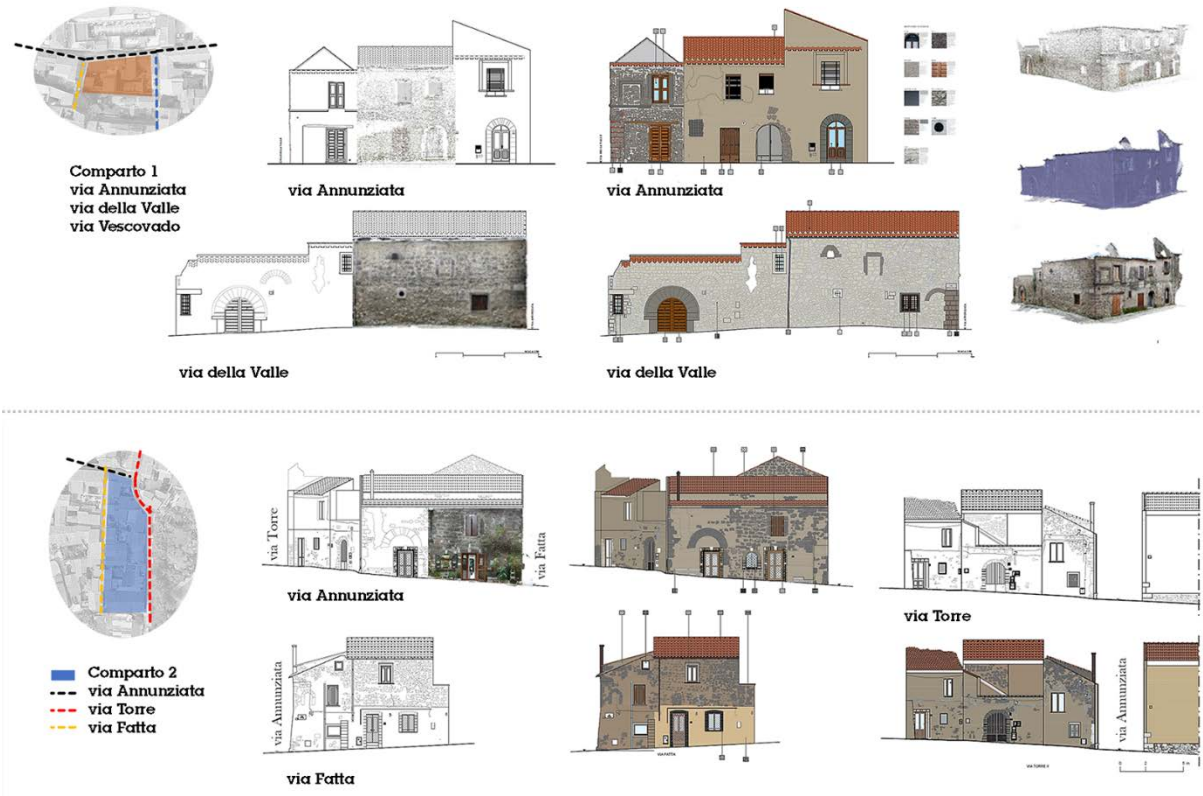

Figure 4. Building sectors of Casertavecchia: multidimensional surveys of the urban façades along Annunziata Road, Della Valle Road, Torre Road, and Fatta Road, with photographic restitutions and orthophotos. Model processing and survey drawings by M. Cicala.

In light of the historical, morphological, and typological considerations outlined above, the analysis carried out has made it possible not only to document the main architectural landmarks but, more importantly, to interpret the residential fabric through the study of the building frontages [Zerlenga, 2009], regarded as key indicators of settlement and construction dynamics. Although both components have been surveyed and documented, this contribution focuses specifically on the building frontages, recognised as strategic elements for understanding the transformations of the urban fabric over time. The first outcomes of the survey, accessibility, and enhancement activities conducted in Casertavecchia, discussed in the following section, provide a detailed representation of the built fabric, highlighting the

typological coherence, material continuity, and aggregative logics that characterise the historical morphogenesis of the village (Fig. 4).

Integrated Survey and Digital Documentation for Sustainable and Inclusive Heritage Strategies

The systematic knowledge of minor historic centres represents an indispensable prerequisite for the activation of effective strategies of safeguarding, valorisation, and accessible fruition of cultural heritage. Within this framework lies the phase of architectural survey and digital documentation conducted on Casertavecchia as part of the GeNeSis research project, aimed at constructing a multi-layered information corpus to support practices of inclusive conservation and sustainable territorial development. The investigation began with a territorial framework study, developed using GIS systems, designed to decipher settlement dynamics and to create a geo-referenced database for subsequent morphological and typological analysis (Fig. 5).

The identification of building sectors of interest was based on a systematic reading of the urban fabric, aimed at selecting morphologically coherent aggregates representative of traditional building practices. In this analytical phase, two sample sectors were selected along Via dell'Annunziata, the village's main axis, marked by pronounced typological and material continuity. Here, an "architectural sector" is understood as a portion of historicised urban fabric which, due to typological homogeneity, constructional coherence, and consolidated distributive relations, constitutes an autonomous and legible morphological unit. These units represent the privileged level of investigation for reconstructing, through survey, the settlement logics, morphogenesis of building aggregates, and persistence of material matrices within the historic built environment.

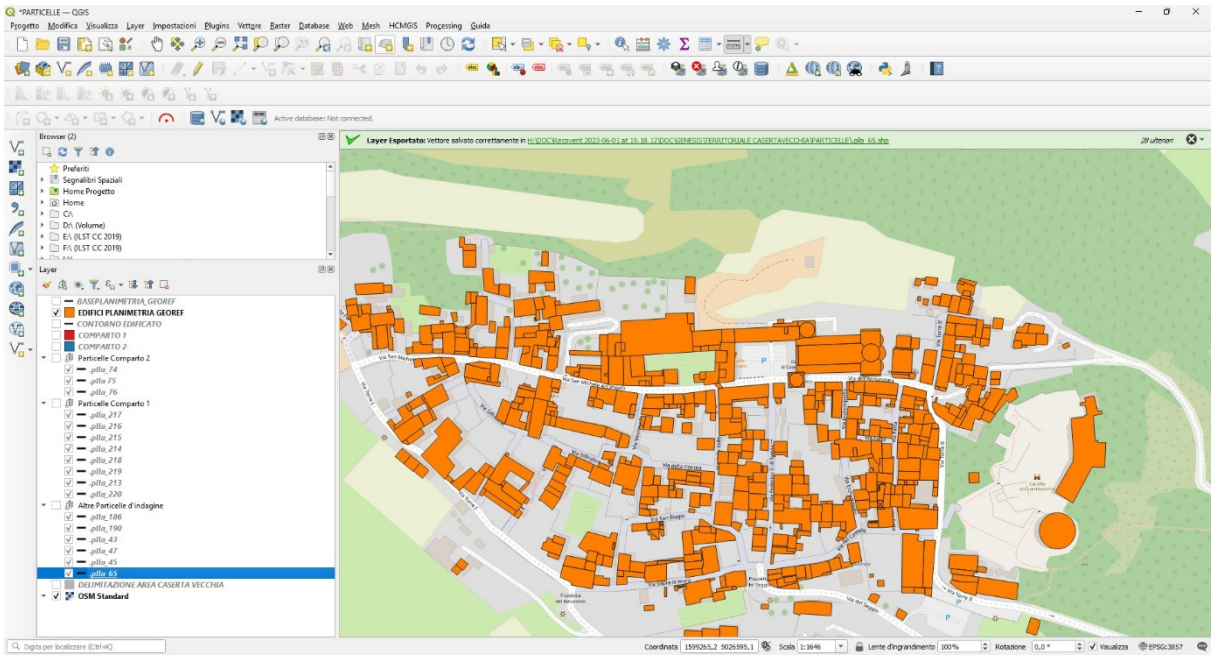

Figure 5. Fig. 5. GIS framework of Casertavecchia's historic centre with study area delimitation, georeferencing from aerial orthomosaic, and identification of surveyed building sectors (elaborations by M. Cicala).

Subsequently, the architectural survey was organised through an integrated methodological approach, in which traditional techniques of manual measurement and graphic restitution were combined with advanced digital acquisition procedures, including terrestrial and aerial photogrammetry with UAVs and Structure from Motion (SfM) processing [Galasso & La Placa, 2020]. Careful data processing enabled the production of high-resolution orthophotos, textured 3D models, and dense point clouds, delivering a high-definition representation of the building fabric [Bianchini, 2014], suitable to support morphological, typological, and conservation

The selected building sectors are characterised by a compact and continuous fabric, composed of terraced or linear housing units developed over two or three storeys, with heights varying between six and ten metres. Load-bearing walls are built in Campanian grey tuff, a widely used local material, while details such as cornices, jambs, quoins, and stringcourses are in limestone, ensuring material coherence and chromatic uniformity across the urban layout. The façades, characterised by a sober and balanced composition, display openings distributed according to modular rhythms and strict alignments, reflecting a consolidated vernacular settlement logic, the result of building practices sedimented and transmitted over time. The morphological analysis highlighted the repetition of distributive solutions, the modularity of building units, and the systematic use of characteristic elements of local building traditions,

such as stone lintels, moulded cornices, and vertical openings. These elements collectively delineate a stratified and coherent framework of the built environment, the expression of a historical process of architectural stratification and consolidation of vernacular construction practices.

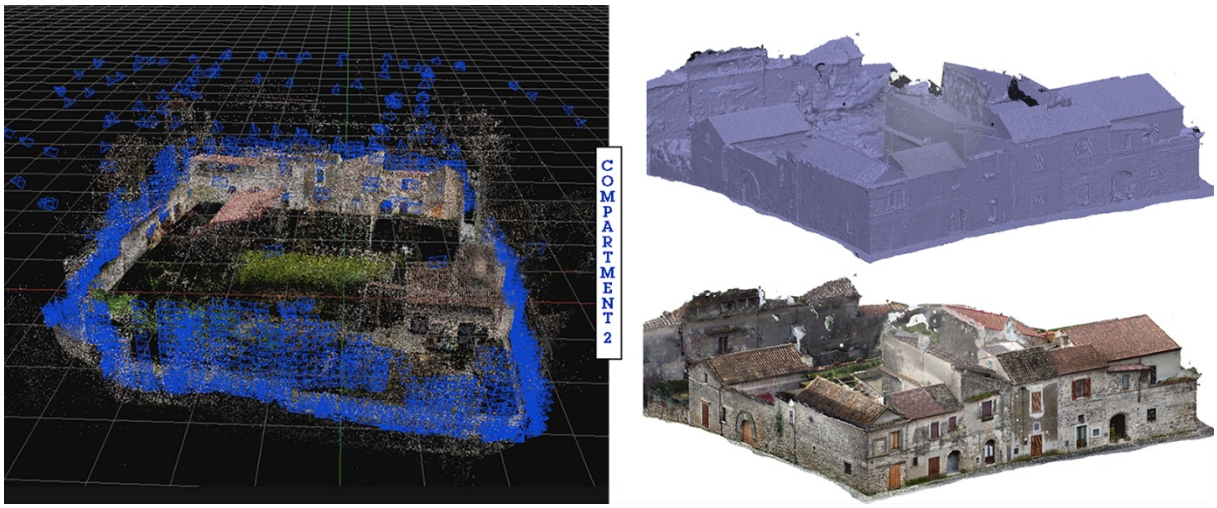

Figure 6. 3D modelling workflow of architectural sector 2 using 3DF Zephyr: generation of dense point cloud, triangular mesh, and textured model from calibrated terrestrial photogrammetric datasets (data acquisition and processing by M. Cicala).

The data collected were organised into a series of multi-level records, urban, sectoral, and building sheets, elaborated according to a shared methodological protocol within the GeNeSis project (Fig. 7). These records, documenting dimensional, material, typological, and conservation characteristics, constitute an operational archive of fundamental importance for the integrated management of historic heritage. They feed into the structural, historical, acoustic, and conservation analyses foreseen by the project, serving as an indispensable knowledge base for the planning of future restoration, conservation, and enhancement interventions. The entire information corpus is currently being implemented within the GeNeSis digital platform, structured on a multi-level architecture designed to allow interrogation, management, and dynamic visualisation of data related to minor historic centres. Still under development, the platform is configured as a strategic tool for the programmed management and accessible valorisation of heritage, making data interoperable and available to public authorities, technical operators, researchers, and local communities. In parallel, an immersive virtual tour of the village was developed, built through 360° panoramic acquisitions and geo-referenced 3D models.

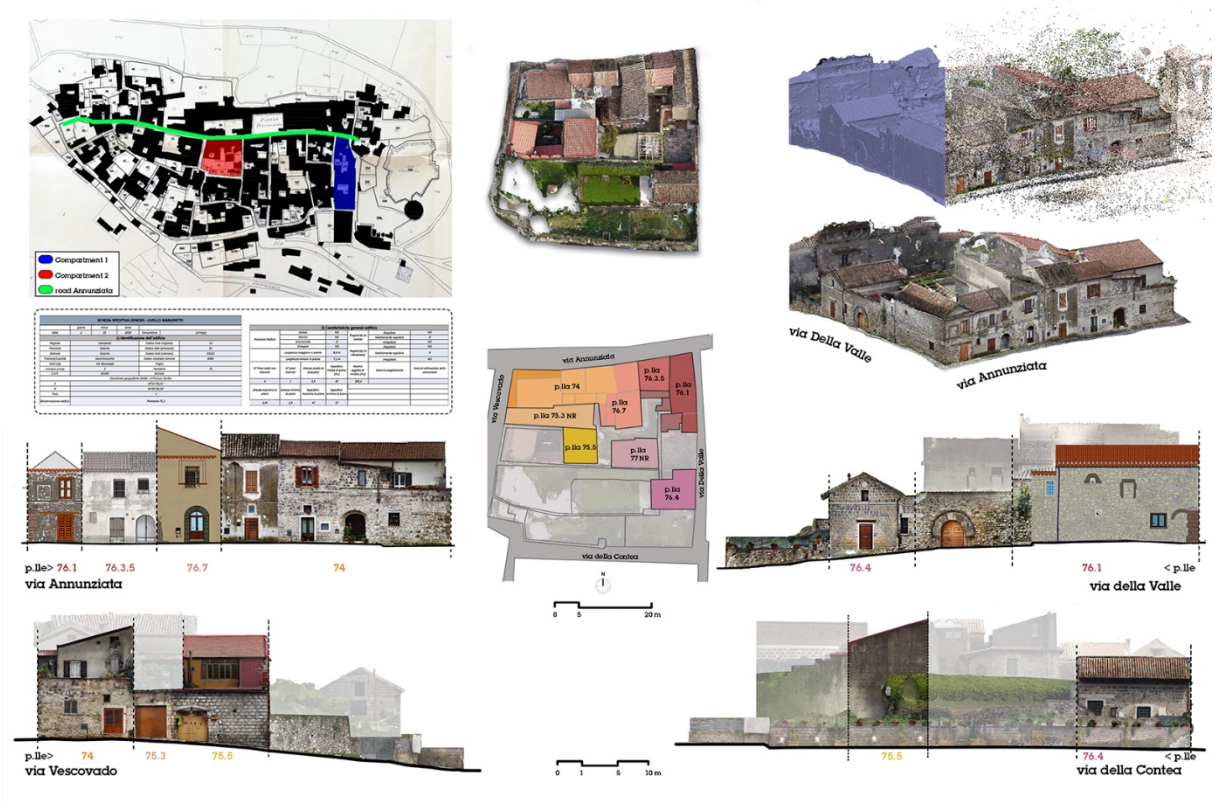

Figure 7. Architectural survey of building sector 1 in Casertavecchia: investigation methodology. Top left: sector identification and detail of aerial orthomosaic; centre: plan reconstruction with parcel mapping; right: 3D models from aerial surveys; bottom: elevation studies with orthophotos and architectural/material surveys of façades along Annunziata and Della Valle Roads (acquisition, processing, and graphic composition by M. Cicala).

The virtual tour created using the Lapentor platform [Zerlenga et al., 2023], integrates graphic and descriptive contents derived from the architectural survey, allowing external users to navigate interactively through the studied building sectors and offering differentiated access to architectural, material, and conservation data (Figs. 8-9). Along the exploratory path, thematic hotspots provide insights into traditional building techniques and historical transformations of the surveyed urban fabric.

This immersive restitution, based on digital tools, though already consolidated, is configured as a design device for cognitive and sensorial accessibility (sight and hearing), capable of overcoming physical and cultural barriers and promoting participatory and inclusive heritage enjoyment [Meloni, 2023]. In this perspective, architectural drawing, no longer understood merely as a descriptive instrument but as a critical-operative device, assumes the role of a design mediator, able to generate new forms of interaction between historic heritage and contemporary communities.

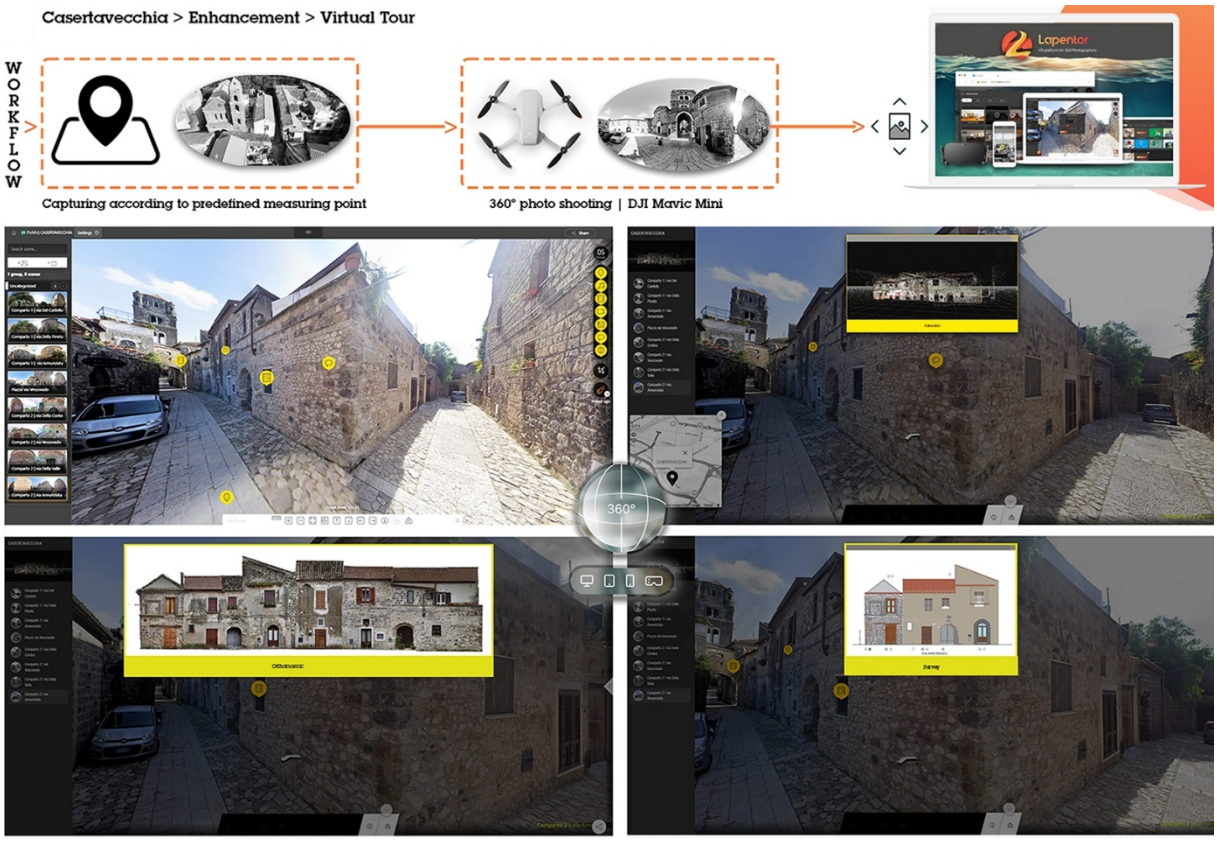

Figure 8. Interactive documentation with workflow and views of the virtual tour of the building frontage on Annunziata Road. Top left: interface with geolocated observation points; bottom left: immersive view with integrated orthomosaic; top right: 3D photogrammetric model; bottom right: graphic restitution of façades (virtual tour development and graphic processing by M. Cicala).

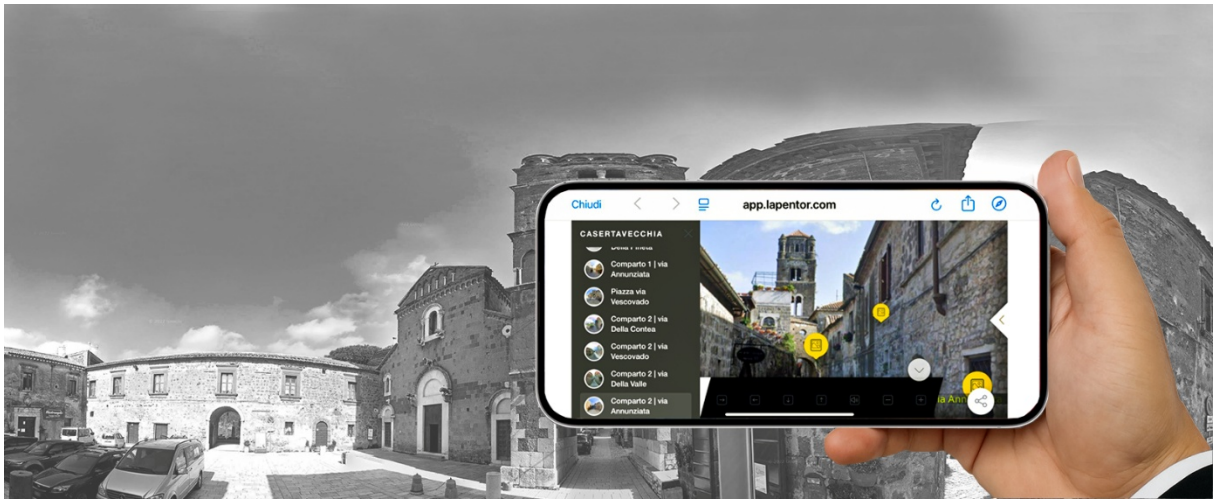

Figure 9. Interface of the Casertavecchia virtual tour created with Lapentor, enabling interactive navigation of surveyed sectors and access to geo-referenced digital contents (by M. Cicala).

Conclusion

The documentation activities carried out in Casertavecchia confirm how the disciplinary field of drawing and architectural surveying, conceived not only as a descriptive tool but also as a critical and operative medium, can play a decisive role in fostering cognitive accessibility, spatial inclusion, and resilience in minor historic contexts. The integration of different operational methodologies has enabled the construction of a multi-layered knowledge framework of the village, functional not only to safeguarding and conservation, but also to the promotion of participatory and sustainable forms of heritage fruition. Looking ahead, the research foresees the implementation of geo-referenced exploratory routes aimed at the valorisation of the most significant and historicised architectural elements of the urban fabric, particularly in sectors not yet systematically surveyed. New data will be acquired through low-cost open-source applications, such as Polycam and Scaniverse, which will also allow augmented reality visualisation, with the goal of integrating and expanding the existing knowledge corpus in a perspective of widespread accessibility, digital sustainability, and immersive interaction (Fig. 10). The proposed tourist routes, based on simplified three-dimensional models enriched with multi-layered narrative contents, will be designed to promote a capillary and inclusive fruition of the village, making heritage understandable and accessible to a heterogeneous and global audience. Through the design of thematic itineraries supported by digital tools, the experience of the urban space will be enhanced by hybrid practices, capable of integrating physical and virtual dimensions and contributing to the development of resilient and culturally aware communities. In conclusion, within this framework, Casertavecchia stands out as as a living laboratory for the elaboration of innovative heritage valorisation practices, oriented towards cultural accessibility, sustainability, and the construction of participatory narratives in the processes of heritage knowledge and safeguarding.

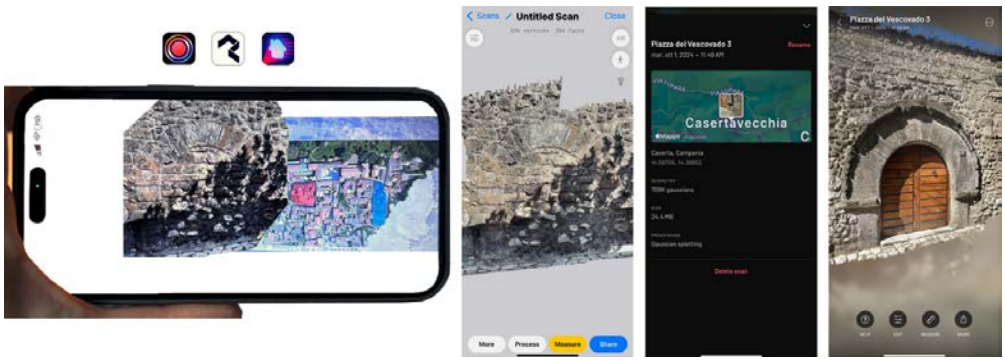

Figure 10. AR acquisition and visualisation workflow in Casertavecchia: left, LiDAR scan with Polycam; centre and right, 3D modelling and AR visualisation of the portal in Piazza del Vescovado using Scaniverse and 3dScannerArchitecture (by M. Cicala).

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CULTURAL HERITAGE DOCUMENTATION. THE COMPLEX OF SANTA MARIA DELLA VITA IN NAPLES (ITALY)

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Cultural Heritage Documentation. The complex of Santa Maria della Vita in Naples (Italy)

Abstract: This study explores the architectural complex of Santa Maria della Vita in the city of Naples and aims to investigate the workflow carried out so far, through the critical analysis of historical sources and drawings, in order to evaluate the different architectural stages of the monastic complex up to the current configuration, and to gain a new insight of the inner disappeared sacred space through the digital relocation of some of the work of art which were originally placed inside the church. The study is part of broader funded research focused on creating new access pathways to the city's often inaccessible religious heritage, and trying to establish a common workflow of knowledge, usability and accessibility for these architectural complexes within the city of Naples.

Keywords: documentation; accessibility; Santa Maria della Vita.

Introduction. Santa Maria della Vita between the current context and the past cultural relevance within the city of Naples

The monastic complex of Santa Maria della Vita is located in an area that has long been regarded as peripheral, lying outside the city's ancient walls, once known as Borgo dei Vergini, an area historically dedicated to the management of the deceased due to the presence of numerous catacombs and cemeteries. Despite its initial marginal location, the complex's proximity to both the Church of Santa Maria della Sanità and the Cimitero delle Fontanelle (i.e. inside the so-called "Fontalle Path", today also known as the "Miglio Sacro"), combined with the historical importance of the Carmelite order that founded the church, gives it considerable cultural and historical significance (Fig. 1). However, following the suppression of the Carmelite order during the French occupation in the early 19th century, the memory of this site has gradually faded, leaving the church in a state of complete abandonment and conservation distress. Nowadays, the monastery is used by an association called La Tenda, which hosts the homeless inside the spaces of the monastery, and led the church to be used as a deposit. For these reasons, the interior space of the church is in a state of total abandonment and deterioration, and over the years the internal decorative apparatuses and artworks have been removed from their original positions. This absence has led to a complete disjunction between the interior space of the church and its previous liturgical meanings (Fig. 2). Consequently, the first part of the research relied on historical and archival sources to assess the possible configurations of the various architectural developments of the complex. The second phase, using the same historical sources, sought to conduct a survey of several movable artworks originally housed within the sacred space, which, following the suppression of the order, were dispersed across various cultural institutions within the urban fabric.

Figure 1. The central position of the church of Santa Maria della Vita between the church of Santa Maria della Sanità (point n. 1) and the Fontanelle cemetery (point n. 3).

Figure 2. The current situation of the monastic insula of Santa Maria della Vita, together with some details of the abandoned liturgical inner space.

Sources and drawings for the critical interpretation of the different architectural stages

The critical-historical research carried out about the history of Santa Maria della Vita and its diverse architectural states has been taken up by some authors of the historical guides of the City of Naples, a corpus which is able to describe cultic paths and provide information about the complex historical events of relevant buildings. From this first analysis, the historical information on the foundation and evolution of the monastic complex has been deepened by consulting some archival sources of the state archive of Naples (Fig. 3). All written sources agree that at the date of foundation of the convent - i.e. 1577 - in the place where it now stands there was already a first chapel or shrine dedicated to the cult of Saint Vitus: mixing the name of the Saint with the concept of Life (Vita, in italian), and wanting to dedicate the site to the cult of the Virgin Mary, the carmelites gave the name of Santa Maria della Vita (literally, Saint Mary of Life) to this church. According to the written sources, the analysis of some historical cartography (Lafrèry, 1566; and Hongenberg, 1572) in the area of Santa Maria della Vita appear to support the hypothesis of a small architectural pre-existence in the area where the Church was founded in 1577. It also seems that the church of Santa Maria della Vita, founded from

1577, was completed in the span of twenty years thus consisting in a single environment with six side chapels, and that the first chapel dedicated to San Vito was completely abandoned by the cult (Fig. 4).

Figure 3. On the left, the corpus of historical city guides from the 17th up to the 19th century analyzed; on the right: the front pages of some of the archival sources about the monastery of Santa Maria della Vita found inside the State archive of Naples, within the fund *Corporazioni Religiose Soppresse*.

Figure 4. Two historical cartographies of the city of Naples, from Lafrery (on the left, 1566), and from Hongenberg (on the right, 1572): the details in the red circle show the area where che monastery of Santa Maria della Vita was founded and built.

However, this first architectural layout had a short life: the archive sources state that the so-called 'second church' had to be realized in the first half of the 17th century under the guidance of Father Jovene. How the 'second church' was configured is testified by some cartographic sources, such as the famous Veduta Baratta dated 1629, in which the facade of the

church of Santa Maria della Vita appears: in the view, the church was not to have any dome (although there seems to be a bell tower on the left, no longer existing), and therefore the apse area must still have small dimensions, the main corpse to be a single nave without transept. Another map evidence can give some indication on the plan of the church in this intermediate stage: it is the copy of a drawing dating back in 1660. In the lower right corner of the plant the Church of Santa Maria della Vita appears, in the form of a sketch, as a single nave environment with a modest apse area, without dome or transept (Fig. 5).

Figure 5. On the top: the Veduta Baratta, dating back 1629, where the facade of Santa Maria della Vita appears; on the bottom: the map of Donato Gallarano, *plan of the Stella district of the city of Naples,* 1718 (based on the drawing of the plan by Francesco Venosa in 1660), where a sketch of the layout of Santa Maria della Vita appears.

However, the archive sources state that from the 'second church' a new one was built in the late 17th century. In this case, the numerous drawings found at the archive allow us to make a critical reading of the expansion of the 17th century. The starting point is the drawing by Luc'Antonio de Natale which is attached to an agreement between the convent of Santa Maria della Vita and that of Santa Maria della Sanità. In anticipation of the expansion desired by the Carmelites, which had to necessarily include the removal of the tufa ridge behind the church, owned by the Dominicans from the Sanità, the two sides agreed that the Dominicans gave up "415 steps of land behind Santa Maria della Vita". In this sense, the drawing of the de Natale, of which there is an identical copy, defines the project of enlargement and dismantling

of the tufa cost actually carried out in the last part of the 17th century, with the realization of a large transept surmounted by a dome.

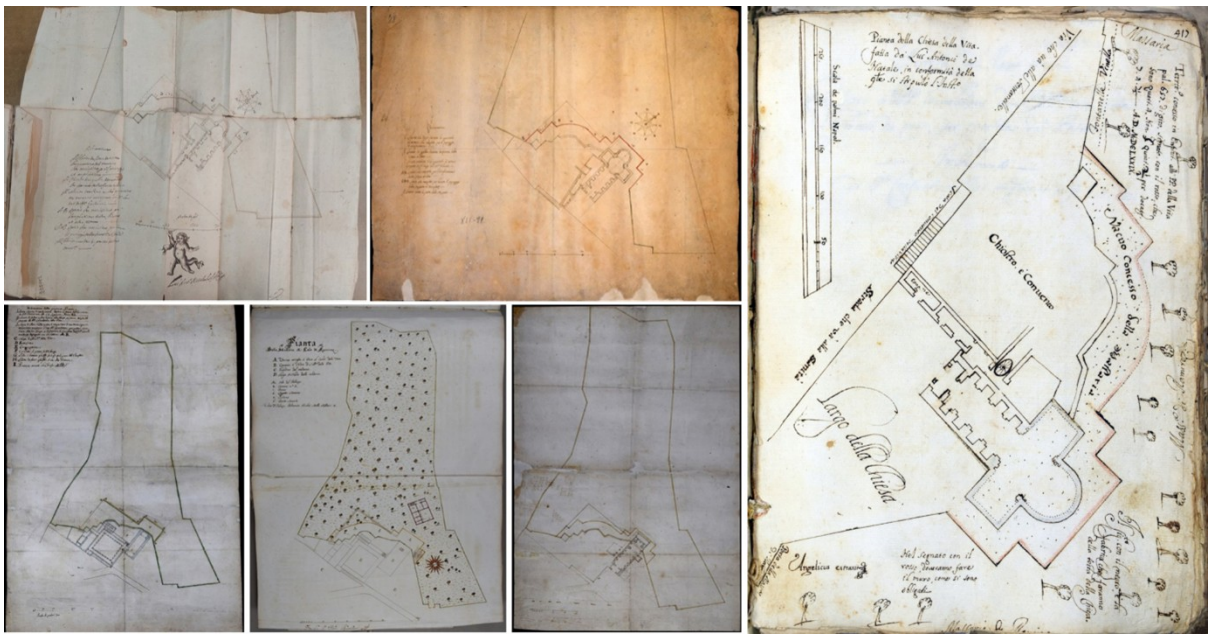

Figure 6. The corpus of archive drawings analysed to find the layout of the so-called ‘third church’. On the top, we can see the two drawings by De Natale; on the bottom, the three drawings of Majorino (the first two are ‘reliefs’ of the ‘second church’, and the third one seems to be a project idea for the ‘third church’, never realised in favour of the project of De Natale. The drawing on the right is in fact a copy of De Natale realised by Majorino, as the caption on the upper part of the drawing clearly states.

In contrast to this first group of drawings, other drawings by the dominican friar Majorino where found. In the first drawing, Majorino represents the church of Santa Maria della Vita with a single nave plant rather elongated with small entrance atrium and presbyterial area of rectangular shape, and he provides the large area of tuff to be removed behind the church. The same slightly revised outcrop forecast appears in the second drawing. The last drawing presents a different architectural system: the church is configured as a single environment but with an internal subdivision with side chapels as described in the design drawings of the de Natale.

Therefore, it seems reasonable to assume that the first drawings of Majorino constitute 'reliefs' of the state of fact of the ‘second church’, of which it can be confirmed the configuration to single nave without dome nor transept. Still, following this logical line, the third drawing of Majorinowould be a first project idea related to the excavation and expansion of the church, never fully realized, in favor of the de Natale project, which is followed for the shape of the apse area, from the transept to the course of the stripping line (Fig. 6).

In this sense, the last drawing of Majorino (which is a copy of De Natale) and the two drawings of De Natale are the trace of how the late 17th century extension had to be configured: with minor changes, this architectural layout was maintained up to the early 19th century, when the monastic order was suppressed by the new French government and the monastic complex survived thanks to other - commercial and social - uses (Fig. 7).

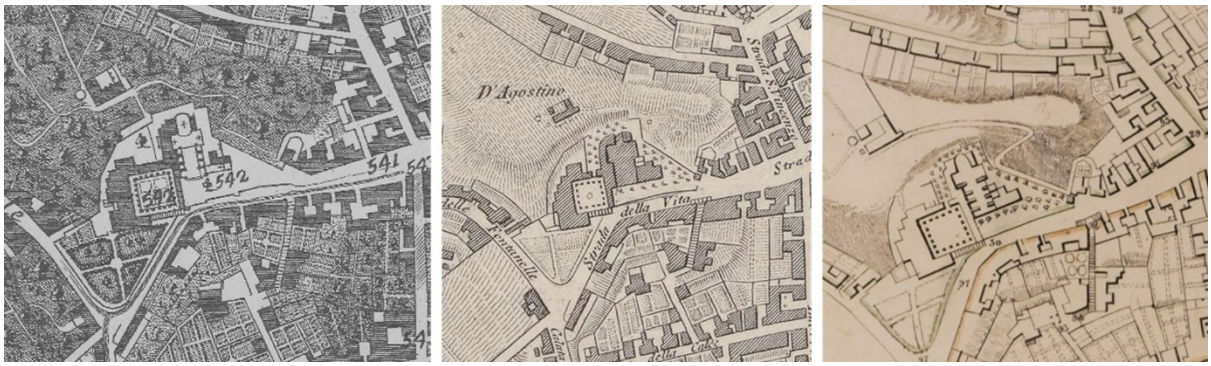

Figure 7. Some details representing the plan of Santa Maria della Vita after the suppression of the monastic order, from the left: Map of the city of Naples by Duca di Noja (1775); Plan of the City of Naples by Real Officio Topografico (1826); Plan of the Quartiere Stella (1830 ca.).

The adopted method, which combines a philological analysis of historical sources with a critical graphic representation, has made it possible to outline not only the original architectural layout of the complex but also its subsequent transformations in relation to the cultural and geographical context. This approach has revealed the site's high spatial and functional complexity, characterized by interconnections between the cloister, the chapel, and the church, demonstrating an architectural organization designed to enhance the sacredness of the spaces while ensuring an efficient liturgical distribution.

The inner sacred space: 'new' critical-historical research to 'reconstitute' it

Other than the evaluation of the main architectural changes up to the late 17th century, the critical-historical research was aimed at finding the artworks and decorations which were originally placed inside the church, following the belief that the theme of 'elements of architecture', seen in its broadest sense, finds reference in the elements that realize an architecture at different scales, from the capital to the masonry, and therefore, in the specific case of the sacred complex, both in its geometric spatial conformations and in the distribution and entity of the mobile decorative apparatuses.

In this sense, one of the tourist guides of the city helped us to identify the very first painting: in fact, the guide from Carlo Celano (1692), which was then modified and enlarged with other details by Giovan Battista Chiarini (1860), confirms the cultural relevance of the

church by descripting some of the major artworks contained inside the main space. Above the different details within the description of the church, Chiarini cites one precise artworks, described as "una magnifica tela di S. Sebastiano bersagliato, ancora semivivo, cui una pietosa giovane donna sta a medicare con penna intinta nel balsamo una ferita di freccia al braccio sinistro, mentre un'altra in piedi tiene il vasello del balsamo nelle mani. Le due principali figure sono bellissime, e soprattutto il S. Sebastiano è meravigliosamente illuminato in un grande scuro per l'ombra dell'albero che gli va alla faccia ed al petto, dove il rimanente del torso in iscorcio e gli arti inferiori sono trattati con una vivezza ed industria di colorito che risaltano quasi dal quadro. Non ci è riuscito sapere l'autore di sì pregevole lavoro" (Celano 1860, p. 347). From this passage, comparing the visual details with other paintings inside the ICCD national catalogue, the canvas painting by Paolo De Matteis representing Saint Sebastian assisted by Saint Irene was identified, as it is now conserved inside the Donnaregina Museum in Naples. From this first identification, the study of the sources found inside the Donnaregina museum permitted another identification, i.e. the panel painting representing the Virgin Mary with Saint John the Baptist and Saint Francis, by the flemish painter Dirck Hendricksz Centen (who moved to Naples and renamed himself Teodoro D'Errico, thus creating several paintings for neapolitan churches, mixing the South italian style with some of the flemish characteristics). Other than that, some unpublished documents found in the Soprintendenza of the city of Naples have allowed the recognition of two other paintings signed by Sebastiano Conca, representing respectively the Sacred Heart of Jesus and the Vision of Mary Magdalene.

Once found the four paintings, and in order to reconstitute, at a digital level, the inner sacred space of the church, photogrammetric surveys have been carried out on the paintings, to be placed inside the 3D model of the church (Fig. 8). The current 'reconstruction' situation we are dealing with, at the same time, is not completed yet: two paintings already have a definite position within the church, while two others have yet to be digitally relocated. Even if it seems impossible, to date, to find and reconstitute all the internal apparatus, exactly as it was in the late 19th century or in any case before the suppression of the church due to the French domination, this analysis of the sources and drawings shows how the historical approach can dialogue with digital relief in order to realize a model which is both explorable by common users and historically correct, complete of the liturgical apparatuses, in which the space of the sacred is finally reconstituted (Fig. 9).

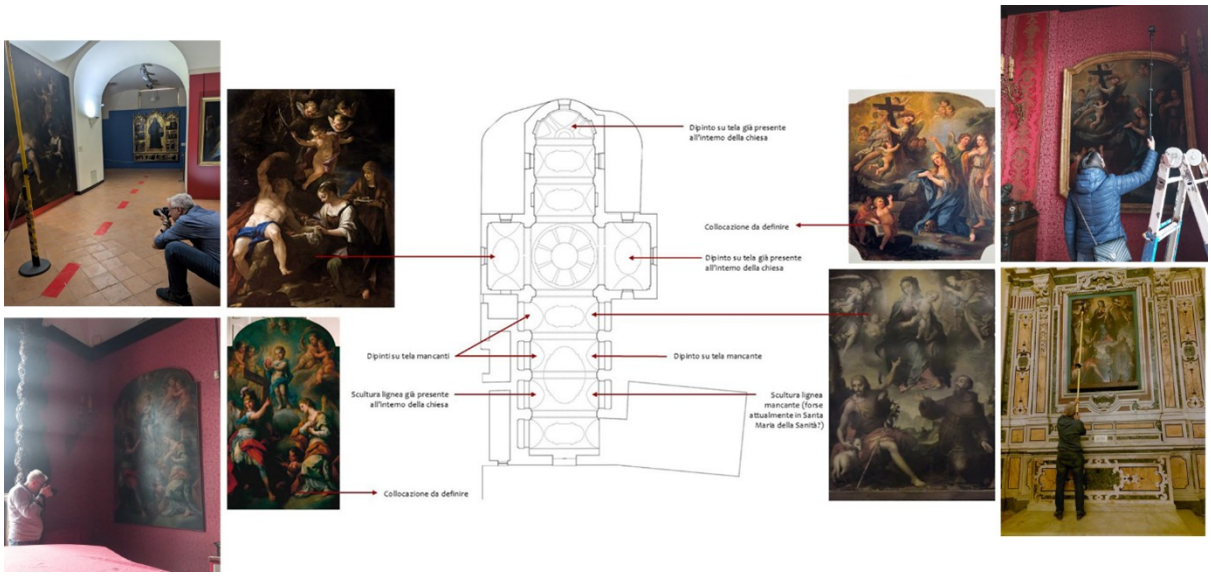

Figure 8. The current layout of the church together with the position of some artworks, which have been documented through the photogrammetric technique.

Figure 9. One of the side chapels, as it is nowadays thanks to the digital survey (on the left); and with the artwork by Teodoro D'Errico digitally located as it was in the historical sources.

Conclusions

Based on a critical and interpretative analysis, which is not without certain aspects that are difficult to comprehend, of the historical guides related to the city of Naples, along with visual and cartographic testimonies and in conjunction with unpublished resources from the State Archive of Naples –data that are all essential for a detailed description of the city's cultual system– it has been possible to propose a hypothesis regarding the constructive evolution of the complex and to provide a partial iconographic reconstruction of the liturgical environment, as it appeared to the writers and intellectuals who, in the nineteenth century, walked the streets of the Sanità district. This period, marked by French domination and the construction of the grand

Sanità bridge, led to the progressive urban and socio-cultural marginalization of the Sanità valley, generating a disconnection between the complex's previous historical values and the state of neglect in which it currently resides. The reconstruction of the decorative interior of the church of Santa Maria della Vita, made possible through current digital tools, can therefore offer renewed accessibility to the building. This accessibility, understood as a cognitive operation, represents a preliminary step for the future development of the project and the strategies aimed at the 'expanded usability' (both physical and digital) of the architectural heritage under study.

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POST- DISASTER SUSTAINABILITY OF INTANGIBLE CULTURAL HERITAGE: A SPATIAL AND SOCIO-CULTURAL EVALUATION OF ANTAKYA LONG BAZAAR

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Post- Disaster Sustainability of Intangible Cultural Heritage: A Spatial and Socio-Cultural Evaluation of Antakya Long Bazaar

Abstract: This research investigates the post-disaster sustainability of intangible cultural heritage through Antakya Long Bazaar, severely damaged in the February 6 and 20, 2023 earthquakes. Historically, the bazaar has been a site of collective identity and social continuity beyond trade. The study aims to assess the potential for revitalization within the framework of cultural heritage management and urban resilience. The research is based on a holistic qualitative approach, including short-term on-site observations, official planning documents, and reports. The findings suggest that sustainable recovery cannot be limited to physical restoration alone; socio-cultural practices and local production must be integrated into participatory governance. The "Re:START" project in Christchurch and the post-2015 heritage restoration in Bhaktapur demonstrate the importance of cultural continuity in resilience, and the Antakya Long Bazaar has the potential to become a model for heritage management.

Keywords: intangible cultural heritage, post-disaster recovery, urban resilience, Antakya Long Bazaar, cultural sustainability

Introduction

Intangible cultural heritage is a rich field of value, encompassing rituals, gastronomy, handicrafts, and traditional marketplaces, transmitting the collective identity, lifestyle, and social ties of societies across generations. UNESCO's 2003 Convention for the Safeguarding of the Intangible Cultural Heritage emphasizes not only the protection of this heritage but also its preservation in line with sustainable development goals (UNESCO, 2003). In this context, historical bazaars serve not only as economic hubs but also as vital spaces preserving local culture, social interaction, and community resilience, especially during disasters.

Historical bazaars in Türkiye such as Istanbul Grand Bazaar, Izmir Kemeralti Bazaar, Gaziantep Coppersmiths' Bazaar, Mardin, Bursa and Konya bazaars sustain trade, craftsmanship, and cultural identity. Their resilience shows that post-disaster reconstruction must ensure not only physical restoration but also socio-cultural continuity. In this context, Pelling (2011) emphasizes the criticality of the concept of resilience for post-disaster transformation, stating: Healey (2006) emphasizes the importance of participatory planning and governance processes for legitimacy. Fainstein (2010) argues that justice and inclusiveness are essential dimensions in reconstruction processes; Smith (2006) demonstrates that cultural heritage is not merely an object to be protected but an active part of social identity and collective memory.

Long Bazaar in Antakya has long symbolized regional trade, gastronomy, and multicultural life. The February 2023 earthquakes severely damaged its structure, disrupting commerce and

cultural continuity, while post-disaster reconstruction raised broader challenges including heritage sustainability, social participation, and urban resilience.

This study aims to assess the potential for revitalizing Long Bazaar during the post-disaster reconstruction process from a cultural heritage management and sustainability perspective. The research is based on local and national press reports, social media content, and visual archival materials. short-term on-site observations, municipal reports and UNESCO records. This method analyses the bazaar's historical continuity, economic and social functions, and post-disaster spatial use. The study also utilizes two successful international examples to strengthen its findings: the "Re:START" temporary bazaar established after the 2011 earthquake in Christchurch (New Zealand), and the revitalization of heritage and tourism by preserving traditional construction techniques with local craftsmen after the 2015 earthquake in Bhaktapur (Nepal).

These examples demonstrate that revitalizing Antakya Long Bazaar requires more than physical restoration; holistic approaches addressing socio-cultural activities, local production, gastronomy, spatial quality, and community participation are essential, making it a potential model for sustainable post-disaster heritage and historic commercial space management.

Literature Review

The primary international framework for the protection of intangible cultural heritage is UNESCO's 2003 Convention for the Safeguarding of the Intangible Cultural Heritage. This convention emphasizes not only the protection of cultural heritage but also its preservation by integrating it with sustainable development. Similarly, the Sendai Framework for Disaster Risk Reduction, adopted by the UNDRR in 2015, identifies the preservation of cultural values as an integral component of social resilience in post-disaster reconstruction processes. ICOMOS's 2017 Guide highlights the protection of both tangible and intangible heritage, alongside community participation, within disaster risk management. It frames post-disaster heritage protection not merely as restoration but as vital for sustaining identity, belonging, and resilience.

The protection of cultural heritage in Türkiye is primarily carried out within the framework of Law No. 2863 on the Protection of Cultural and Natural Assets. This law regulates the identification, registration, protection, and restoration processes of cultural

heritage, with the Conservation Oriented Zoning Plan being the most fundamental planning tool in this process. These plans aim to not only preserve the physical fabric of areas of historical and cultural significance but also ensure the continuity of social and economic functions. However, the declaration of the Antakya Historic City Center as a "risky area" under Law No. 6306 on the Transformation of Areas at Disaster Risk following the February 6, 2023 earthquakes marked a significant turning point in the institutional framework. With this decision, the area, including the Antakya Long Bazaar, came under the ex officio approval authority of the Ministry of Environment, Urbanization and Climate Change. Thus, conservation processes transitioned from a municipality-conservation board axis to a governance model dominated by centralized governance.

At the local level, the revitalization of the Long Bazaar, led by Hatay Metropolitan Municipality and Antakya Municipality, and supported by tradesmen's unions, professional chambers, the Chamber of Urban Planners of the Union of Chambers of Turkish Engineers and Architects, and the Ancient Antakya Friends Platform, demonstrates the importance of a holistic approach between participatory, heritage-focused approaches and centralized, risk-focused national practices.

The fact that both the author and the approving authority of the plans prepared in the post-earthquake period were the same institution raises debates about ethics and transparency in the planning literature. Campbell and Marshall (2002) and Flyvbjerg (2002) emphasize that conflicts of interest undermine the legitimacy of planning, while Healey (2006) emphasizes that transparent, participatory, and deliberative processes are critical to overcoming such problems. In this context, the example of Antakya Long Bazaar serves as a laboratory that should be questioned not only in terms of the post-disaster reconstruction process but also in terms of planning ethics and governance.

Methods

As shown in Figure 1, Hatay is a province located in the south of Türkiye, on the eastern Mediterranean coast, sharing a border with Syria. Antakya, the central district of Hatay, holds administrative, cultural, and economic significance for the province. Antakya, located on the fertile Asi (Orontes) River and Amik Plain, sustains its commercial and cultural functions through the 3 km-long Long Bazaar, whose narrow streets and diverse trades preserve collective memory.

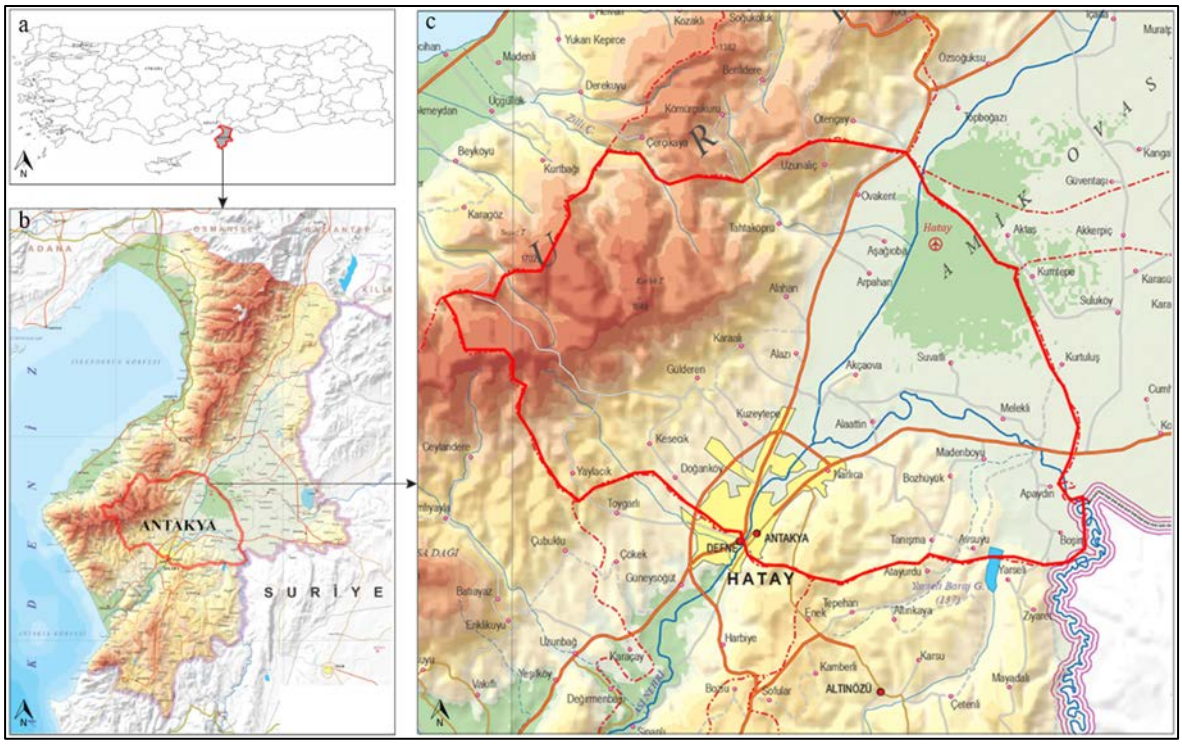

Figure 1. (a) Location of Hatay in Türkiye, (b) Location of Antakya in Hatay, (c) Antakya

The study consists of three main stages. In the first stage, the historical and commercial functions of Antakya were examined through a literature review, with particular attention to the role of the Long Bazaar. The second stage focused on the historical development and transformation of the Long Bazaar, drawing on local and national press reports, social media content, and visual archival materials. Within the framework of the 1/1000 Scale Conservation-Oriented Zoning Plan Revision, the bazaar was evaluated, and the changes that emerged following the 2023 earthquakes, along with the current conditions, were analysed. In this stage, field observations and interviews were conducted to assess current conditions. Subsequently, the Long Bazaar's post-earthquake state was holistically evaluated and based on the collected data, an assessment was made regarding the preservation of Antakya's cultural heritage and commercial sustainability.

Historical Process

Founded in 300 BC by Seleucus I Nicator, Antakya was shaped by various civilizations—including the Roman, Byzantine, Umayyad, Crusader, Mamluk, Seljuk, and Ottoman (see Figure 2)—and became a major cultural and commercial hub of the Eastern Mediterranean. Strategically located at the crossroads of the Spice, Silk, and King's Roads (see

Figure 3), its vitality was sustained by the agora, coinage, and the Roman Colonnaded Street, supported by the Orontes River and fertile Amik Plain (Çekmecelioğlu, 2016); Üçeçam Karagel & Karagel, 2014; Ferhad, 2001; Turgut, 1986;). Antakya, an economic hub during the Ottoman era, maintained its vitality through agriculture and trade, and following Mustafa Kemal Atatürk's emphasis on Hatay's importance, the province was officially incorporated into Türkiye in 1939 (Gündüz, Gökhan, Hatipoğlu, Bahadır, 2013).

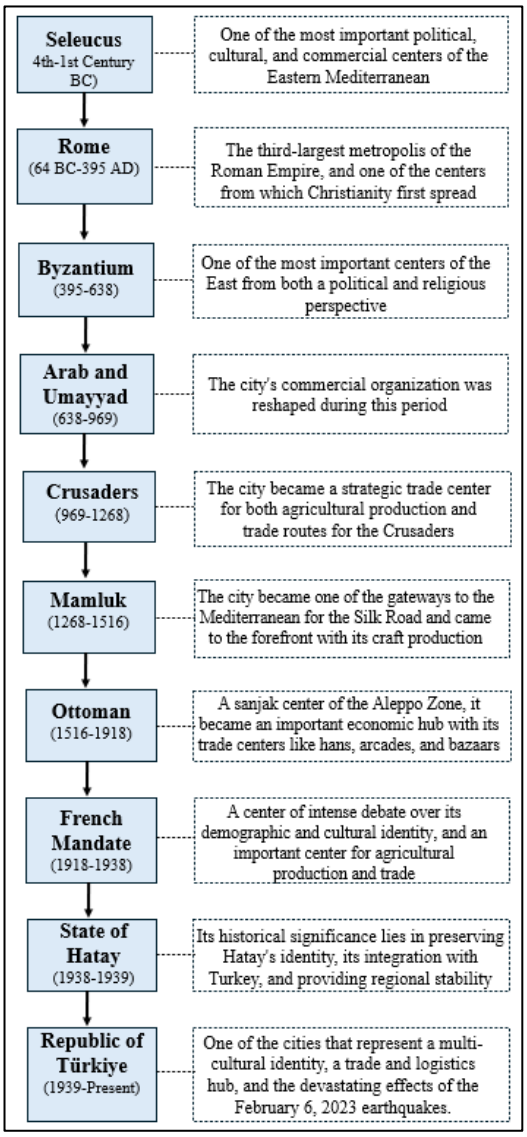

Figure 2. Historical development of Hatay

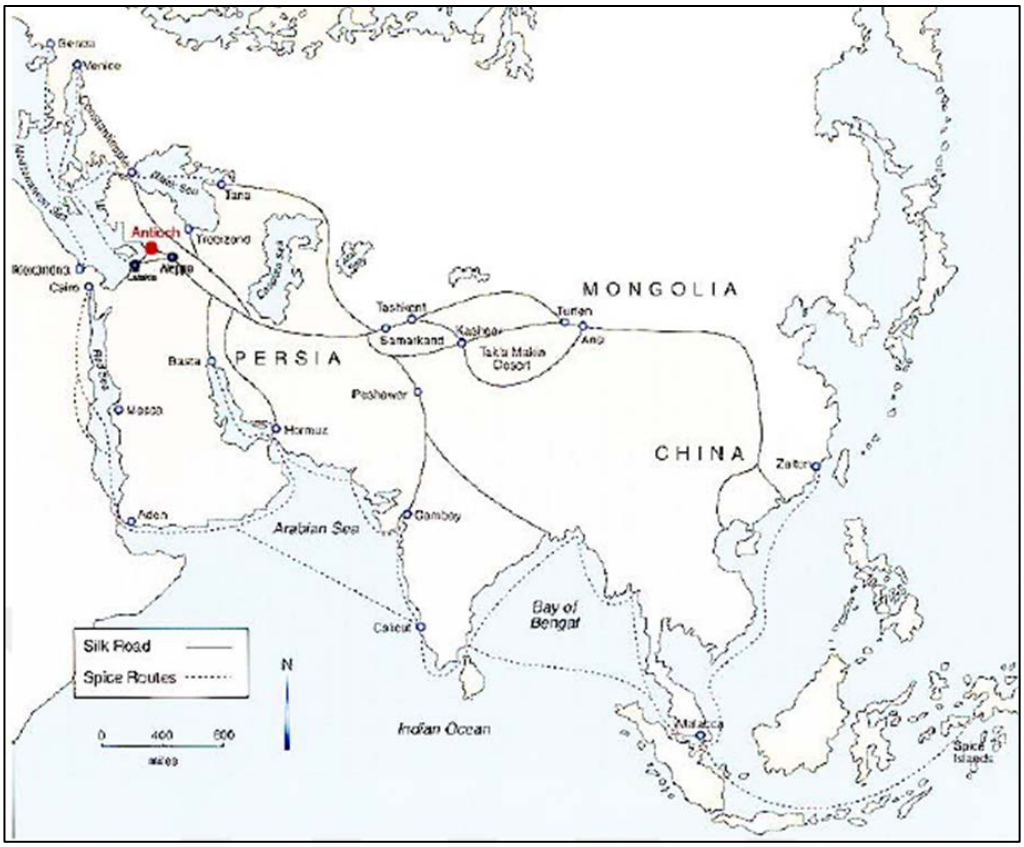

Figure 3. Historical trade routes (Çekmecelioğlu, 2016)

Antakya Long Bazaar

Located in Antakya, Long Bazaar has become one of the most important symbols of the city's historical commercial role, surviving to this day. Commercial activities that flourished during the Roman, Seljuk, and Ottoman periods strengthened a bazaar-centered economic structure within Antakya's urban fabric (Çekmecelioğlu, 2016). Throughout history, Long Bazaar was central to trade, though globalization and modern retail later reduced traditional artisans, while local food and craft trades persisted. As shown in Figure 4, Long Bazaar maintained its original architectural character and traditional commercial activities in the 1950s, while by 2017 the effects of modernization had begun to emerge. Following the significant damage caused by the February 2023 earthquakes, restoration efforts are currently ongoing, focusing on the preservation of its historical and cultural values and the reinstatement of its functional role.

Figure 4. Historical development of Antakya Long Bazaar (a) 1950s[1], (b) 2017[2], (c) after the 2023 earthquakes[3], (d) restoration works[4]

An examination of activities in Antakya Long Bazaar in the 1930s reveals a concentration of traditional, production-based crafts (see Figure 5). Carpenters, joiners, knifemakers, windrowers, cart builders, wickerworkers, cloth-printing and felting makers, rug weavers, tailors, fez pattern makers, tinsmiths, jewelers, saddlers, blacksmiths, stonemasons,

[1] Retrieved August 20, 2025, from https://www.facebook.com/hataytube/photos/nostalji-saati-antakya-uzun%C3%A7ar%C5%9F%C4%B1-1950lerhatay-antakyanostalji/2356343294390523/

[2] Retrieved August 20, 2025, from https://earth.google.com

[3] Retrieved August 20, 2025, from https://www.ntv.com.tr/galeri/turkiye/depremin-yiktigi-tarihi-uzun-carsi-hayata-donuyor,AXWoC3dvG0ePr153bUoVow/SPM17H9pSkC0lyIgpCJvgA

[4] Retrieved August 20, 2025, from https://csb.gov.tr/tarihi-uzun-carsi-da-asrin-felaketinin-izleri-siliniyor-bakanlik-faaliyetleri-40376

bricklayers, potters, and many other professions demonstrate the diversity of craft activities that met the social and economic needs of the period (Asarcıklı, 1989).

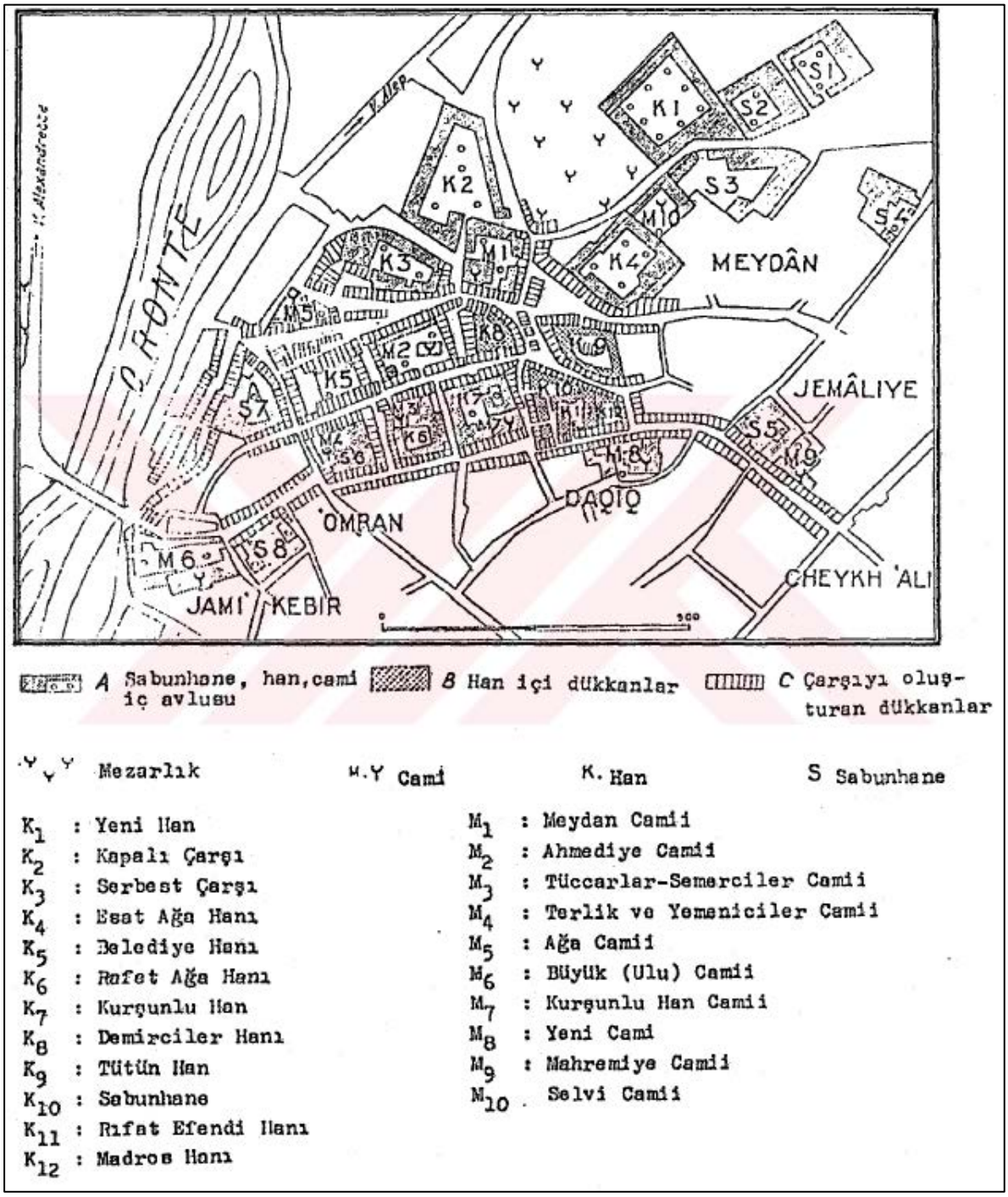

Figure 5. The bazaars of Antakya in 1935 (Asarcıklı, 1989)

However, by 2016, a change was observed in the trades in the Long Bazaar. Craftspeople such as windrowers, cloth makers, fez pattern makers, blacksmiths, millers, ice makers, and other such crafts, as well as their associated venues, had disappeared by 2016 (see

Figure 6). Instead, shops selling ready-made clothes, jewellery, draperies, glassware, white goods, and electronics have become prominent. Craftspeople such as wickerworkers, saddle makers, coppersmiths, felt makers, and tinsmiths continue to exist on a smaller scale (Çekmecelioğlu, 2016; Güngördü, 2016). Before the earthquake, traditional food and dessert production, such as kunefe, sweets, and hummus, was a key sector preserving cultural continuity in Long Bazaar. Goods in the bazaar were traditionally produced and sold on-site, with open demonstrations attracting customers; over time, it shifted from a production-focused hub to a trade and consumption centre, reflecting modernization and globalization while threatening its intangible cultural heritage and historic identity.

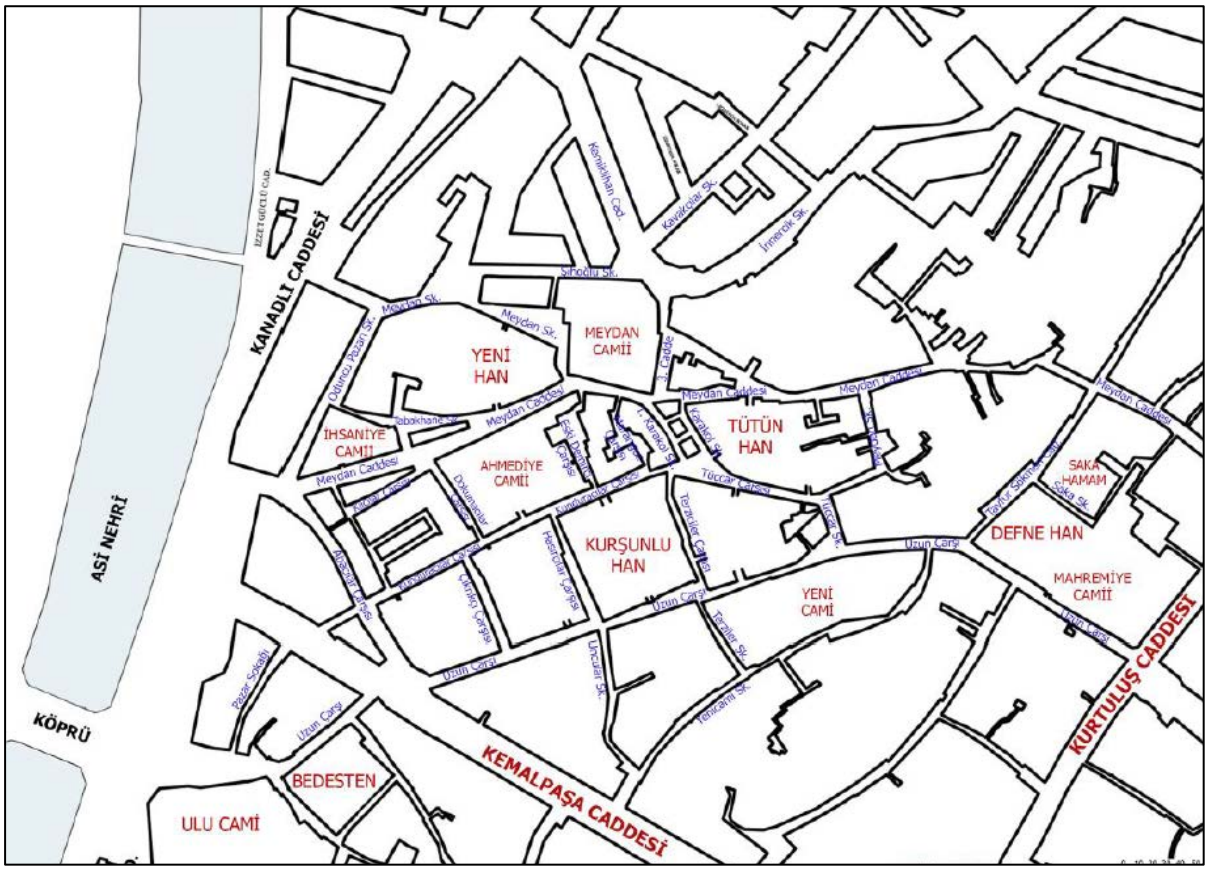

Figure 6. The bazaars of Antakya in 2016 (Çekmecelioğlu, 2016).

Already undergoing transformation, Long Bazaar was severely damaged by the February 2023 earthquakes, destroying many shops and disrupting traditional trades. Within the scope of post-earthquake intervention efforts coordinated by the Housing Development Administration of Türkiye (TOKİ), a phased process was implemented, including repair, structural strengthening, and the temporary relocation of tradespeople (MoEUCC, 2024; TACDAM, 2023). As shown in Figure 7, Long Bazaar was relocated to a prefabricated area

near the former Palladium Shopping Mall. The relocation following the earthquake disrupted traditional crafts, commerce, and spatial continuity, underlining the need for post-disaster planning that preserves both tangible and intangible cultural heritage.

Figure 7. The historical location and reconstruction area of Antakya Long Bazaar

The revised Conservation Oriented Master and Implementation Zoning Plans for Antakya's Historic City Centre, approved under Presidential Decree No. 1 and Law No. 6306, were announced on June 11, 2024 (ICOMOS Türkiye, 2023). The plan (see Figure 8) seeks to preserve Antakya's multi-layered fabric and historical continuity by reorganizing the post-earthquake urban layout and transportation, while prioritizing the protection of heritage assets, the restoration of historic bazaars like Long Bazaar, and the safeguarding of traditional functions and cultural heritage alongside urban life and trade.

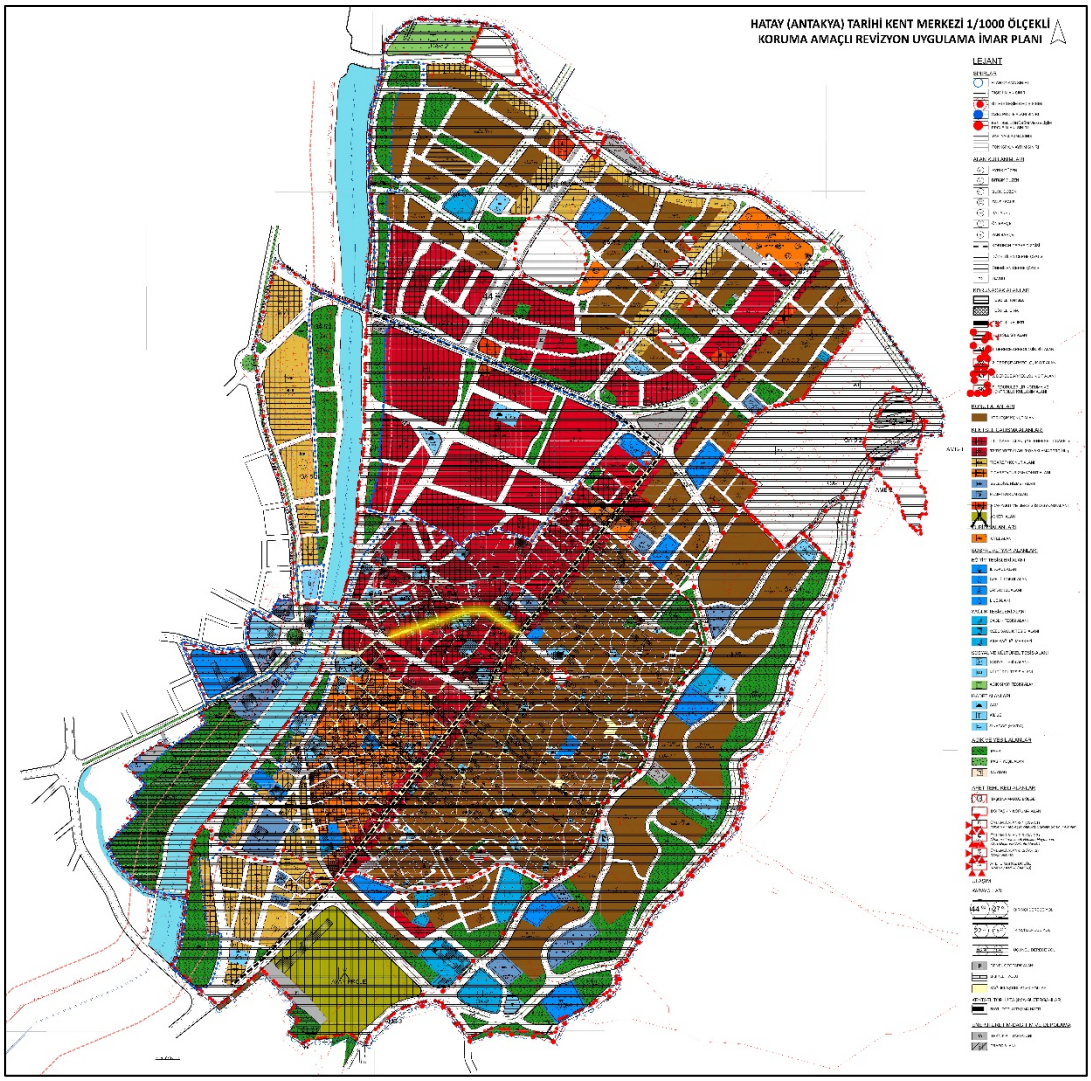

Figure 8. 1/1000 Revised Conservation-Oriented Zoning Plan

Following the 2023 earthquake, the Antakya Historical City Centre was declared a high-risk area under Presidential Decree No. 7033 (04.04.2023), and post-disaster planning authority was assigned to the Ministry of Culture and Tourism with coordination by the Turkish Design Foundation (ICOMOS Türkiye, 2023). Legal and ethical concerns regarding overlapping approval roles emphasize the need for transparency and adherence to conservation and urban planning principles. Revisions of the Master (1/5000) and Implementation (1/1000) Conservation Oriented Zoning Plans should be integrated with regional and higher-level plans, considering urban-rural landscapes, population, infrastructure, and historic centres like Long Bazaar. Post-earthquake challenges reveal traditional planning's limits, emphasizing the need for holistic, participatory, interdisciplinary, and evidence-based approaches.

Conclusion

The February 2023 earthquakes caused significant destruction in the Antakya Historical City Centre and Long Bazaar, necessitating the relocation of the bazaar to temporary sites in some areas. This disrupted spatial integrity, disrupted traditional trade and production practices, and diminished social interaction. This process revealed the inadequacy of existing established planning approaches and highlighted the need for more sensitive, participatory, and holistic planning and process management in post-disaster processes. Preserving post-disaster cultural heritage requires a long-term, scientific, multidisciplinary, multidimensional, and multi-stakeholder approach.

On the other hand, the Revised Conservation Oriented Zoning Plan is marked by significant shortcomings, including the absence of a holistic framework, the presence of institutional ambiguities, and the lack of solutions concerning property ownership. These issues highlight the necessity of a highly sensitive approach. In this regard, it is essential to establish integration of Long Bazaar with the city as a whole, taking into consideration its social, cultural, and economic dimensions.

Long Bazaar, as both an economic hub and a meeting place for diverse ethnic and religious groups, embodies Antakya's multicultural identity and urban heritage. The 2023 earthquakes, however, have disrupted its spatial continuity, traditional crafts, and trade practices. Preserving its historic fabric, supporting its commercial and social functions, and sustaining its cultural identity are thus essential in the planning process. In this regard, Long Bazaar should be approached not merely as a marketplace but as an urban heritage site that reflects historical continuity, cultural diversity, and spatial identity, with international cases offering valuable models for Antakya's reconstruction. Examples from Christchurch and Bhaktapur illustrate that temporary or post-disaster interventions can support not only economic recovery but also social and cultural resilience.

Prefabricated bazaars in Hatay have only partially realized their potential. Integrating traditional craftsmanship into Long Bazaar's reconstruction can preserve spatial authenticity, support local employment, strengthen social ownership, and ensure sustainability through holistic restoration combining local knowledge, participation, and design quality. On the positive side, one confectioner, Şahap Fansa, remarked that *"It is a very beautiful place. I think this has become the most beautiful bazaar of Antakya. Moreover, there are no parking problems.* Similarly, Mehmet Haşim Ertürk noted, *"90 % of the bazaar's original shopkeepers have relocated…. This is now the Uzun Bazaar. We welcome everyone."* Yet not all responses

were positive. A member of a CHP delegation quoted a shopkeeper's frustration, saying: *"There's dust and disorder everywhere—touch anyone, and you'll hear a hundred complaints."*[5]

The Re:START container bazaar in Christchurch (2011) demonstrated that temporary markets can go beyond restoring commerce by also fostering social memory, cultural activities, and urban vitality. In contrast, the functional but limited prefabricated bazaars in Antakya highlight the need for more participatory, aesthetic, and multifunctional temporary spaces to sustain both trade and cultural continuity.

The post-2015 Bhaktapur restoration shows how integrating local craftsmen and traditional techniques can preserve cultural identity while generating employment. Applying this model to Antakya Long Bazaar would revitalize its stone, wood, and masonry traditions, transfer economic benefits to the community, and sustain artisanal knowledge, gastronomy, and cultural practices. Together with the Christchurch case, it offers a sustainable framework that combines socio-cultural continuity with spatial restoration. Mehmet Hançer Gündüz, a local shopkeeper, emphasized the cultural memory of the bazaar: *"Every stone and street of the Long Bazaar held our memories. We were very saddened to leave, but we hope the bazaar will soon recover, and we will return again."*[6] This testimony underlines that sustainable recovery in Antakya cannot be achieved through physical reconstruction alone but must also safeguard the lived memories and cultural identity of the community.

[5] Retrieved August 28, 2025, from https://www.aksiyon.com.tr/hatay-da-tarihi-uzun-carsi-esnafi-yeni-prefabrik-carsida-isbasi-yapti-184477?utm_source=chatgpt.com

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CLIMATE CHANGE ADAPTATION: CURRENT STATUS IN TURKIYE

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Climate Change Adaptation: Current Status in Turkiye

Abstract: This study aims to assess Turkiye's climate change adaptation policies in the context of the built environment, focusing specifically on the transformations envisioned within the framework of the 2021–2030 National Climate Change Adaptation Strategy and Action Plan and the current Climate Law. The 2030 Action Plan identifies priorities for mitigating climate risks in cities, including expanding energy-efficient and low-carbon building standards, strengthening and renovating existing building stock, reducing the urban heat island effect, integrating green and blue infrastructure, developing circular economy practices in the construction sector, and increasing public-private partnerships. The study identifies the opportunities and risks Turkiye faces in the built environment, considering current strategies and upcoming legislative regulations, highlighting the need to transition from short-term protective measures to long-term systemic adaptation.

Keywords: 2030 Action plan, Climate change, Climate adaptation.

Introduction

In Turkiye, strategies aligned with the European Green Deal are being developed to combat climate change, and the Climate Law is expected to enter into force. It is anticipated that this law will lead to significant changes in the built environment in terms of energy efficiency, carbon neutrality targets, and sustainable construction principles. Furthermore, the renovation of existing building stock, energy performance certificates, renewable energy integration, and design decisions based on life cycle assessment will become mandatory in the coming period. This study aims to examine the impacts of the 2030 Action Plan and the Climate Law on the built environment and discuss the necessary measures. This will both determine the scope of the strategies to be implemented at the national level and create a guiding framework for sector stakeholders. The study will focus specifically on energy-efficient design, carbon reduction, renewal strategies, and resilient urbanization policies.

Literature Review

In Turkiye, strategies for climate change adaptation and mitigation in the built environment have become an increasing focus of both academic and practical interest in recent years. Studies on the energy efficiency and carbon intensity of the existing building stock indicate that older buildings (Aksoy, 2020; Yılmaz, 2024). Design and strengthening strategies are emphasized to enable existing buildings to adapt to climate change, while historic buildings are noted to require special protection and adaptation measures (Akköse, 2019; Halıcı, 2023). National strategy analyses conducted by Demir and Yılmaz (2014) and the Ministry of Environment and Urbanization (MoEU, 2011, 2021) demonstrate that Turkey has developed

comprehensive climate change adaptation plans for the 2021–2030 period. These plans aim to enhance urban resilience based on principles of energy efficiency, low-carbon construction, and circular economy.

International frameworks, including the Paris Agreement, the European Green Deal, and IPCC reports, emphasize the vulnerability of urban areas to climate-related risks and recommend the integration of resilience and zero-carbon solutions (European Commission, 2019;2020; IPCC, 2021, 2022). Energy efficiency and low-carbon building technologies play a critical role in new building design. While opportunities exist in Turkiye for green building certifications and sustainable material use, there are gaps in standardization and enforcement in practice (Bal & Tekin, 2020; Güner & Arslan, 2021). Building renovation and energy demand simulations highlight the importance of optimizing building performance under different climate scenarios (Kaya, 2022; Gök & Tokuç, 2025).

The urban heat island (UHI) effect directly influences microclimate conditions, increasing thermal discomfort and energy demand (Kindap et al., 2012; Kırkık Aydemir, Kazancı Altınok & Ünsal, 2023; Sakar & Çalışkan, 2019). Parametric modeling and spatial strategies emerge as effective tools for reducing UHI intensity and promoting climate-sensitive planning (Kabisch et al., 2017; Nesshöver et al., 2017). The roles of local governments, the private sector, and civil society in climate adaptation processes are frequently emphasized in the literature. Multi-actor governance enhances the effectiveness of policy implementation and addresses the limitations of centralized approaches in national strategies (Bulkeley & Betsill, 2013; Klein, Juhola & Landauer, 2017; Özer & Demirtaş, 2022; Yıldız, 2021).

At the building scale, risk assessments and adaptation methodologies contribute to the development of systematic adaptation strategies by identifying hazards such as heat waves, floods, and heavy rainfall (Sarıcıoğlu & Ayçam, 2021). The protection of cultural heritage buildings highlights the necessity of integrating adaptation policies with sustainability and resilience objectives (Halıcı, 2023). Overall, the literature indicates a shift from reactive risk reduction approaches toward proactive, systemic strategies that integrate energy efficiency, low-carbon design, and climate-sensitive urban planning (Shi et al., 2016; Ürge-Vorsatz et al., 2018).

To achieve Turkiye's 2030 climate targets, critical measures include renovating the existing building stock, improving energy efficiency, using low-carbon materials, strengthening multi-actor governance mechanisms, and integrating nature-based solutions. Within this framework, there is strong alignment between policy documents, draft legislation, and

academic studies; however, gaps in implementation capacity and standardization remain key areas requiring attention.

Methods

This study evaluates Turkiye's National Climate Change Adaptation Strategy and Action Plan (2021–2030) and the draft Climate Law from the perspective of the built environment. Conducted using a qualitative approach, the research involved three main stages. First, a document analysis was performed on the official texts of the Action Plan and the draft Climate Law, systematically classifying provisions directly affecting the built environment, including energy efficiency, net-zero carbons targets, urban resilience, material circularity, and renovation policies. Second, a thematic analysis was conducted, organizing findings under five key themes: energy efficiency and net-zero carbon buildings; renewal and resilience of the existing building stock; circular economy and sustainable material use; reduction of urban climate risks, such as heat islands, floods, and disaster hazards; and governance, stakeholder participation, and capacity building. Finally, a comparative assessment was undertaken, comparing Turkiye's 2030 targets with the EU Green Deal and IPCC global adaptation frameworks to identify current strengths, weaknesses, and priority measures for the built environment. This integrated approach not only highlights strategic objectives but also concretises the regulatory measures anticipated under the Climate Law, providing a comprehensive framework for assessing adaptation and mitigation efforts in Turkiye's built environment.

Findings and Discussion

The integrated approach of the study's findings are scrutinised around the research questions listed below:

- "Within the Strategic Framework, What Are the Priority Goals of the 2021–2030 National Climate Change Adaptation Strategy and Action Plan for the Built Environment?"
- "How Does the Draft Climate Law Complement or Strengthen These Goals?"
- "What Regulations Do the 2030 Action Plan and Climate Law Foresee Regarding the Renewal of the Existing Building Stock and the Enhancement of Climate Resilience?"
- "What Gaps and Opportunities Exist Regarding New Building Standards (Energy Efficiency, Zero Carbon, Sustainable Material Use)?"

- "In Which Areas Does Progress Remain Necessary in the Built Environment?"
- "What Role Do Local Governments, the Private Sector, and Civil Society Play in Implementing the 2030 Action Plan and Climate Law?"
- "What Risks and Opportunities Does Turkiye's Existing Built Environment Face in Terms of Climate Adaptation and Mitigation Goals?"
- "What Priority Measures Should Be Taken on the Path to 2030?"

"Within the Strategic Framework, What Are the Priority Goals of the 2021–2030 National Climate Change Adaptation Strategy and Action Plan for the Built Environment?"

Within the framework of the 2021–2030 National Climate Change Adaptation Strategy and Action Plan, the priority goals for the built environment are structured around climate adaptation, risk reduction, and the support of sustainable urbanization. Key priorities include enhancing energy efficiency and resilience through the retrofitting and renewal of the existing building stock, implementing nearly zero-energy building (NZEB) standards, updating energy performance regulations, and promoting the use of low-carbon materials. In conclusion, the plan aims to holistically address energy efficiency, disaster resilience, integration of green and blue infrastructure, and awareness-raising strategies, thereby strengthening both adaptation and risk management within the built environment.

"How Does the Climate Law Complement or Strengthen These Goals?"

The Climate Law reinforces the built environment targets established in the 2021–2030 National Climate Change Adaptation Strategy and Action Plan at both legal and institutional levels. The law provides a legal basis for adaptation measures related to energy efficiency, carbon emission reduction, and sustainable material use, while supporting mandatory requirements such as building permits and energy performance certificates. The law grants local authorities and building owners the authority to assess climate risks and develop adaptation plans, thereby facilitating the establishment of standards that enhance the resilience of the built environment against hazards such as floods, extreme heat, and heavy rainfall. Monitoring and inspection mechanisms allow the performance of these measures to be evaluated, while obligations for data collection and transparency increase the effectiveness of adaptation strategies.

"What Regulations Do the 2030 Action Plan and Climate Law Foresee Regarding the Renewal of the Existing Building Stock and the Enhancement of Climate Resilience?"

The 2030 National Climate Change Adaptation Action Plan and the Climate Law envisage comprehensive regulations aimed at increasing the climate adaptation capacity of the existing building stock and promoting sustainable transformation. Within this framework, key objectives include improving energy efficiency in both existing and new buildings, encouraging the integration of renewable energy, enhancing structural resilience and disaster resistance, promoting the use of low-carbon materials, and incorporating climate risk considerations into urban planning.

Structural reinforcement and material renewal programs will be implemented to mitigate climate risks such as extreme heat, flooding, heavy rainfall, and wind, with technical guidelines and standards provided for ensuring the safety of older buildings in high-risk areas. In conclusion, the Action Plan and Climate Law offer a comprehensive approach aimed at making the existing building stock both sustainable and resilient to climate risks, simultaneously reinforcing renovation and adaptation processes through energy efficiency, structural resilience, material quality, and financial support mechanism

"What Gaps and Opportunities Exist Regarding New Building Standards (Energy Efficiency, Zero Carbon, Sustainable Material Use)?"

Key focuses include improving energy efficiency, promoting renewable energy use in existing and new buildings, strengthening structural resilience and disaster resistance, integrating green and blue infrastructure, and incorporating climate risks into urban planning. Opportunities lie in low-carbon design, life cycle assessment (LCA), and green certification programs, which can reduce environmental impacts and enhance sustainability. For existing building stock, the Action Plan and the law support energy efficiency, renewable energy integration, structural reinforcement, safe-building programs in risk-prone areas, low-carbon material use, disaster resilience, and urban transformation projects, with financial and data collection mechanisms enhancing implementation. For new buildings, energy efficiency, zero-carbon, and sustainable material standards offer significant opportunities, although regulatory gaps and limited monitoring restrict full application. Integrated standards, performance monitoring, and sustainable material supply chains are critical steps to strengthen Turkiye's climate goals in the built environment

"In Which Areas Does Progress Remain Necessary in the Built Environment?"

Turkiye's 2030 National Climate Change Action Plan aligns broadly with the EU Green Deal and global climate policies (IPCC, UNFCCC) but has limitations in implementation and enforcement mechanisms. Advancing energy efficiency practices, carbon neutrality, low-carbon design, sustainable material use, disaster resilience, and policy integration in the built environment is critical. Accelerating energy transition, expanding low-carbon technologies, strengthening resilience measures, and establishing transparent monitoring mechanisms are fundamental to fully aligning Turkiye's 2030 targets with EU and global climate policies. Improvements in energy efficiency, carbon neutrality, sustainable materials, disaster resilience, and policy integration will enhance both national and international climate alignment, creating a sustainable adaptation framework.

"What Role Do Local Governments, the Private Sector, and Civil Society Play in Implementing the 2030 Action Plan and Climate Law?"

The 2030 National Climate Change Adaptation Plan and the Climate Law are implemented through a multi-actor governance model involving active participation from local governments, the private sector, and civil society. Local governments are responsible for applying policy objectives in urban planning, building inspection, and disaster risk management, while monitoring and reporting mechanisms ensure alignment with national targets. Civil society organizations play a critical role in awareness-raising, education, and community engagement, enhancing adaptation capacity through policy development and monitoring. Overall, this multi-actor governance model enhances both the effectiveness and sustainability of policy implementation, contributing significantly to Turkiye's 2030 climate targets.

"What Risks and Opportunities Does Turkiye's Existing Built Environment Face in Terms of Climate Adaptation and Mitigation Goals?"

Turkiye's existing built environment presents both significant risks and opportunities regarding climate adaptation and mitigation. Most existing buildings have low energy efficiency and limited resilience to climate hazards such as extreme heat, floods, and heavy rainfall. The widespread use of carbon-intensive materials such as concrete and steel further increases the sector's carbon footprint. Gaps in monitoring and enforcement, along with limited coordination among local governments, the private sector, and civil society, hinder effective

policy implementation on the ground. In this context, a holistic approach to build environment strategies is critical for reducing existing risks and developing a sustainable, climate-resilient building stock.

"What Priority Measures Should Be Taken on the Path to 2030?"

Renovating and strengthening the existing building stock, particularly buildings with low energy performance and high vulnerability to climate risks, is critical to enhancing adaptation and mitigation capacity. For new buildings, expanding standards for energy efficiency, zero carbon, and sustainable material use, along with mandatory life cycle assessments and carbon footprint calculations, is essential. Monitoring, inspection, and data-driven decision-making systems should systematically track building energy performance, carbon emissions, and resilience to climate risks. This integrated approach, combining energy efficiency, climate resilience, low-carbon materials, and multi-actor governance, provides a critical roadmap for achieving Turkiye's 2030 climate targets and strengthening the climate adaptation capacity of the built environment.

Conclusion

This study aimed to evaluate Turkiye's built environment considering climate adaptation and mitigation objectives, based on the 2021–2030 National Climate Change Adaptation Strategy and Action Plan and the Climate Law. The findings indicate that policy documents provide a holistic framework through measures including enhancing energy efficiency, reducing carbon emissions, promoting sustainable material use, strengthening the existing building stock, defining new building standards, and implementing multi-actor governance mechanisms.

The existing building stock exhibits low energy performance, limited climate resilience, and reliance on carbon-intensive materials, while gaps in monitoring restrict adaptation capacity. However, building renovation and strengthening programs, low-carbon materials, energy efficiency investments, and community awareness initiatives offer significant potential to turn these risks into opportunities.

Local governments, the private sector, and civil society play key roles in implementation, monitoring, investment, and awareness-raising through multi-actor governance, ensuring effective policy enforcement on the ground. To achieve Turkiye's 2030 climate targets, it is necessary to strengthen the existing building stock, tighten new building

standards, accelerate energy transition, promote low-carbon materials and technologies, and establish monitoring and inspection systems. This holistic and integrated approach aligns with literature-recommended sustainable and climate-resilient built environment strategies, emphasizing the critical importance of simultaneously implementing adaptation- and mitigation-focused measures.

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SUSTAINABLE REGENERATION OF PUBLIC BUILT HERITAGE FOR CLIMATE NEUTRALITY, RESILIENCE AND SOCIAL VALUE.

A COMPARATIVE ASSESSMENT OF FOUR GOOD PRACTICES

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Sustainable Regeneration of Public Built Heritage for Climate Neutrality, Resilience and Social Value. A Comparative Assessment of Four Good Practices

Abstract: Cities, responsible for a significant share of greenhouse gas emissions and pressure on urban ecosystems, provide a strategic field for implementing climate mitigation and adaptation policies. The sustainable regeneration of dismissed public built heritage represents an opportunity for climate neutrality, resilience and social value creation. This contribution compares four European good practices of sustainable regeneration in compact cities (Bordeaux, Paris, Oslo, Ghent), focusing on three Green City axes: 'energy transition', 'functional mixite and proximity', and 'urban greening, green and grey CO_2 subtraction'. A set of qualitative and quantitative indicators, derived from international protocols and guidelines, has been defined to compare the effectiveness of the strategies adopted in terms of emissions reduction, improvement of energy efficiency, accessibility and environmental quality. The results highlight how the adaptive reuse of brownfield sites can be a replicable practice, while recognising the need to refine the framework of indicators towards a more quantitative approach and to integrate social aspects more strongly into the assessment.

Keywords: sustainable regeneration; dismissed built heritage; climate neutrality; climate resilience; social value

Introduction: cities and the challenges of climate change

Cities bear primary responsibility for increasing environmental pressures through extensive natural resource extraction and pollutant discharge, with consequent implications for public safety and health (ISTAT, 2020). Consequently, sustainable regeneration of the urban built environment toward climate mitigation and adaptation is imperative, aligned with European objectives outlined in the 2030 Climate Target Plan (EC, 2020) and the 'Fit for 55' legislative package (EC, 2021), benefiting urban communities.

In this perspective, to reach climate neutrality, decarbonising and strengthening the efficiency and resilience of the energy sector, while reducing dependency on external actors, remain top EU priorities, as evidenced by the adoption of the REPowerEU Plan, the Energy Union and Clean Energy for All Europeans packages (EC, 2025). Moreover, as the transport sector is responsible for about one quarter of Europe's GHG emissions - the majority of which (73% in 2022) comes from road transport (EC, 2025) -, it is essential to valorise the proximity dimension by enhancing functional mix and services, thus discouraging vehicular mobility while increasing the quality and provision of urban functions and spaces for citizens.

The city, at the same time, is a focal point for closing the significant gap in the adoption of climate change adaptation measures. In this view, urban communities have a crucial role in the cyclic climate adaptation process (Tucci et al., 2024), which should rely on "an active citizen participation, effective information, as well as a constant dialogue with different stakeholder groups" (Green City Network, 2019, p.10). To increase climate resilience, as well as to meet

the EU targets regarding urban ecosystems, to increase CO_2 subtraction and environmental comfort, finally, it is necessary to increase urban tree coverage (EC, 2025), in order to achieve compliance with legal standards (EC, 2024).

State of the art and research aims

Sustainable regeneration of abandoned public built heritage complexes in urban settings represents, with respect to all these intertwined objectives, a strategic opportunity to pursue urban climate mitigation and adaptation while simultaneously achieving multiple social benefits. Research through simulation studies has established that achieving climate neutrality within compact urban environments depends on population density, land use diversity, and public transport development, all of which contribute to carbon intensity reduction (Fan et al., 2025). The rehabilitation of abandoned complexes provides significant potential for reducing both operational emissions and land consumption by promoting density and functional mix, while enabling communities to recognize the historical and social heritage value, seeing such sites as opportunities to foster social connectivity, stability and cohesion (Rossitti et al., 2025).

In orienting the technological-environmental design for regeneration and refunctionalization of public built heritage, this research adopts the framework of the six Green City axes (Tucci & Altamura, 2023), the 'strategic axes' on which urban interventions must operate to prevent and reduce climate-altering emissions while simultaneously contributing to decoupling economic growth from resource consumption and improving citizens' quality of life: 'energy transition', 'bioclimatic responsiveness', 'functional mixité and proximity', 'resource circularity and self-sufficiency', 'sustainable mobility', 'urban greening, green and grey CO_2 subtraction'. Within this framework, this contribution specifically aims to identify indicators that enable measurement of environmental and social benefits achievable through design strategies particularly related to the 'energy transition', 'functional mixité and proximity', and 'urban greening, green and grey CO_2 subtraction' axes, selected as primary intervention axes for abandoned public heritage regeneration. Specifically, this contribution, through systematic analysis of four case studies of abandoned urban complexes undergoing sustainable regeneration, aims to develop a set of quali-quantitative indicators and parameters enabling comparative assessment of strategy effectiveness from both environmental perspectives and from the standpoint of social value creation.

Research methodology

The research activity was conducted using a methodology involving several steps, some already completed and others currently under development.

The first step constructed a reference framework through literature review, which enabled refinement of research objectives.

The second step involved collecting case studies of regeneration and refunctionalization interventions of abandoned public built heritage sites in urban areas, selected based on various criteria: diversity of original functions (primarily former industrial, military, or healthcare sites); adoption of design strategies related to the 'energy transition' axis, particularly substantial integration of renewable energy sources; adoption of design strategies related to the 'functional mixité and proximity' axis, specifically attention to functional mix definition aligned with the "15-minute city" model, accessibility and social inclusion, generating social value from refunctionalization of dismissed built heritage; use of urban greening solutions to promote CO_2 storage and climate adaptation, aligned with the 'urban greening, green and grey CO_2 subtraction' axis. Simultaneous compliance with all these criteria, capable of ensuring strong CO_2 emission reduction toward climate neutrality, led to selecting twenty case studies.

The third step involved analysing case studies, identifying recurring design strategies, and formulating a framework associating them individually to each of the three reference axes. Strategies include promoting energy efficiency, using renewable sources, employing bioclimatic systems, promoting urban regeneration processes and soil conservation, increasing ecological quality of mobility systems, recovering natural resources and recycling them.

The fourth step involved further filtering case studies to identify four considered most emblematic for the richness of adopted strategies across all three reference axes. Additional motivation for this choice relates to the quantity of available information for quali-quantitative evaluation of intervention results.

The fifth step involved defining, based on strategies, a set of qualitatively and quantitatively measurable indicators and parameters, derived from consulting protocols and guidelines for evaluating environmental quality of buildings, public spaces, and neighbourhoods, recalibrated for the research scope. Specifically, parameters on building performance regarding renewable sources, bioclimatic devices, and intelligent monitoring systems consulted LEED protocols (2024); parameters aimed at evaluating demographic composition and quantity of services reference the UN-HABITAT public space toolkit (2020), as well as those related to accessibility, also inspired by BREEAM protocol requirements

(2012); urban greening parameters partially refer to all three aforementioned sources. The indicators and parameters set therefore derives from a synthesis of the cited sources, reformulated for the implementation in the case study analysis, due to partial data availability.

The sixth step was measuring identified parameters for each case study, and the seventh was the comparative assessment of the results obtained between the four good practices to identify strategies and associated design solutions that achieved better performance while ensuring greater benefits in terms of decarbonization, increased climate resilience, and social value creation. The last two steps, regarding quantitative indicators, are still in progress.

Findings and discussion

Among the case studies examined, four stood out as good practice in the regeneration and reuse of dismissed sites, of industrial or military origin, focused both on social inclusiveness and accessibility and on climate mitigation and adaptation objectives (Table 1). All cases are characterised by a strong correspondence to the three reference axes, and in particular to the 'functional mixite and proximity' axis, through a very rich and differentiated functional programme capable of contributing simultaneously to the optimised use of energy, the reduction of citizens' travel, thanks to a varied offer of services and spaces, and social mix, promoting cultural and shared activities (Figure 1).

Table 1. Summary chart of case studies' main features.

Case study	**Case 1** Darwin-Ecosystem Project	**Case 2** Oasis écologique de la Halle Pajol	**Case 3** Vulkan area	**Case 4** Leopolds-Kazerne
Localization	Bordeaux, France	Parigi, France	Oslo, Norway	Ghent, Belgium
Urban setting	Historic-industrial	Historic	Contemporary	Historic
Original function	Military barracks	Warehouse and railway hangar	Industrial complex with mechanical plants	Military barracks
Design year	2006	2007	2004	2016
Realization year	2010-2013	2010-2014	2011-2014	2019-today
Architect	Virginie Gravière e Olivier Martin, Pier Schneider	JAP - Jourda Architectes Paris	LPO Arkitekter	Sergison Bates Architects
Site extension	22.000 mq	11.800 mq	16.500 mq	20.000 mq
Type of transformation	Regeneration	Regeneration	Regeneration + new construction	Regeneration + new construction

The first case study is the Darwin-Ecosystem Project in Bordeaux, located on the Garonne River's right bank within a 35-hectare ZAC (Zone d'Aménagement Concerté)

developing an entire eco-district. The project involved adaptive reuse of former Magasins Généraux in the northern "Caserne Niel", a former military site covering 22,000 m² (Fiche de Projet Des Quartiers Durables, 2019). The intervention adopts energy sobriety measures, utilizing 100% renewable electricity from photovoltaic and geothermal systems, and low-tech design enhancing natural ventilation and lighting through spatial arrangement. User awareness is promoted through a digital interface measuring energy efficiency and an artistic installation visualizing energy use. The intervention fosters social inclusion and proximity through functional articulation and accessibility via convenient public transport and soft mobility. From an urban greening perspective, the project involved removing over 1,800 m² of asphalt for green spaces, enhancing biodiversity and implementing urban agriculture projects grouped around the ZAUÉ (Zone d'Agriculture Urbaine Expérimentale) scheme, launched through DARWIN endowment funds and partners. Water recovery is enabled by rainwater collection tanks.

The second case study is the Oasis écologique de la Halle Pajol in Paris, involving redevelopment of old railway warehouses near Gare de l'Est on an 11,800 m² site. The intervention brought social and cultural vitality to the neighborhood, improving quality of life and promoting eco-sustainable architecture awareness. The intervention focused on passive solutions for energy demand reduction: the mixed wood and concrete structure and 47 cm thick wooden envelope ensure high thermal inertia and excellent thermal and acoustic insulation. Additionally, integrated plant systems contribute to greywater heat recovery, reducing energy input for heating and hot water production, while the ventilation system recovers heat from extracted air, reducing energy demand for heating and cooling. During summer, air cooling is provided by geothermal systems with underground ducts (Vivian, 2024). Renewable energy production is provided by a 3,500 m² photovoltaic system integrated into the sheds, whose annual energy production meets the building's needs, while surplus energy is sold to Electricité de France (Vivian, 2024). User awareness is emphasized through an electronic panel on the library façade indicating CO_2 emissions saved. The functional program includes a hostel and commercial and cultural activities (Vivian, 2024). The area hosts the Rosa Luxemburg Garden, a 9,500 m² garden for all user groups along the railway extending from north and penetrating beneath the Halle, where socialization is encouraged as part of the green space is reserved for community gardens (Landezine, 2016). Climate resilience objectives are achieved through substantial depaving operations, green area creation, and a rainwater collection system with tanks to feed irrigation and reduce water consumption (Vivian, 2024).

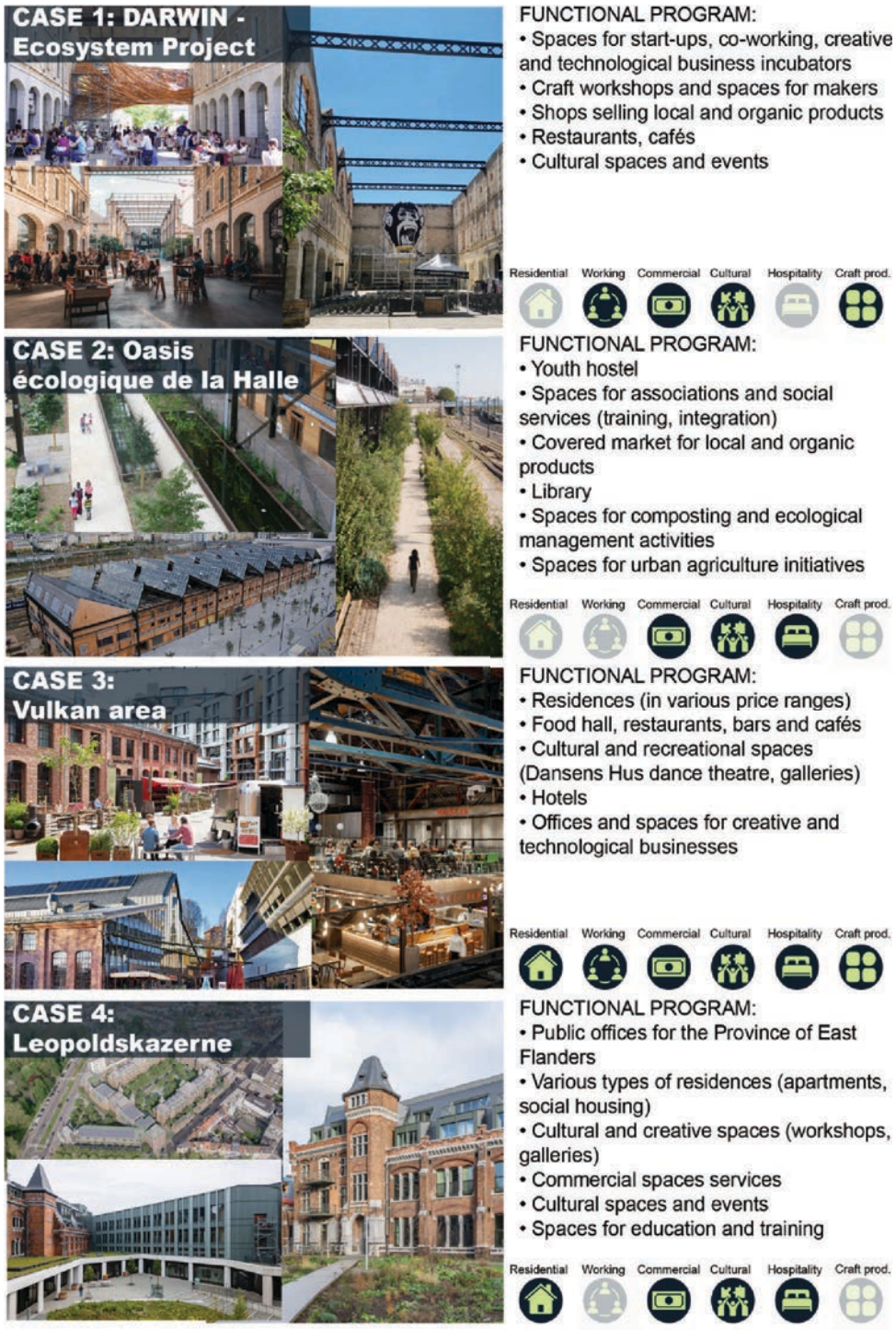

Figure 1. Images and new functional programs of case studies

The third case study is the Vulkan area, a 16,500 m² site north of Oslo's centre along the Akerselva River. The project opens views toward the river through a "cut" in one industrial building (Rote, 2017) and adopts eco-sustainable design based on cultural, resource, and energy sharing values. The district is energy self-sufficient through a local energy plant equipped with 300-meter-deep geothermal wells providing thermal energy for heating, cooling and domestic

hot water (LPO Arkitekter, 2011). Energy efficiency solutions include energy recovery from food market refrigerators and elevators, innovative insulation materials for building envelope and passive solutions optimizing natural lighting (skylights, large glazed façades, shading systems). The functions chosen for the complex refunctionalization were subject to citizen consultation, through temporary activities insertion for "testing" before final design decisions. The area offers a food hall – the Mathallen, with local product stores emphasizing cultural and economic value –, offices of an environmental organization and a sports training school. Vulkan area is accessible through connections to local public transport and bicycle path along the river's ecological corridor. It also hosts the country's largest electric car charging station (Vulkan Oslo, n.d.). Proximity to river and surrounding parks confers ecological character emphasized by buildings' green roof.

The fourth case study is Leopoldskazern in Ghent, a mixed-use military barracks redevelopment (20,000 m²). The intervention, achieving BREEAM Excellent certification for neighbourhood development and BREEAM Very Good New Construction for Provincial House conversion and expansion (Sergison Bates Architects, n.d.), integrates into the city's historic fabric, transforming the area into flexible, open, and accessible infrastructure. The designers achieved remarkably low energy efficiency levels: 70% of required energy is renewable and generated on-site using geothermal energy, heat pumps, and photovoltaic panels. For the remaining 30%, 100% green energy is purchased (PMV, n.d.), making the building CO_2 neutral. The Provincial House, the project's focal point comprising various community functions, in integrated by hotels and housing. The buildings offer approximately 34,500 m² of highly flexible spaces, allowing evolution according to future needs and functions (PMV, n.d.). The area is well connected to public transport and station, while a car-free surface approach was adopted with underground parking and bicycle stalls, promoting active mobility and reducing vehicular emissions. Among climate resilience solutions, the project depaved 9,500 m² into green spaces: Paradeplein is the new neighbourhood park built above underground parking (B2Ai, n.d.) through intensive green roof.

The systematic analysis of the case studies allowed mapping twenty-three design strategies referred to the three chosen Green Cities axes (Table 2). Furthermore, Figure 2 shows the results of the comparative assessment of the four examined case studies, compared through indicators and parameters identified for the reference axes.

Table 2. Identification of a framework of strategies associated with the four case studies.

Axes	ID	Strategies	Case 1	Case 2	Case 3	Case 4
Energy transition	ET1	Increased energy efficiency and reduced consumption by buildings	x	x	x	x
	ET2	Use of passive bioclimatic solutions	x	x	x	x
	ET3	Use of materials that meet thermal insulation requirements according to the climate zone to reduce energy consumption	x	x	x	x
	ET4	Implementation of intelligent automated systems for managing and monitoring energy performance Use of	x			
	ET5	Smart Grids that integrates systems for optimising energy use and reducing production requirements (recovery and storage)	x	x	x	
	ET6	Integration of renewable energy into the design of services in public areas (lighting)	x	x	x	x
	ET7	Use of green solutions on roofs to improve thermal inertia and insulation			x	x
Functional mixite and proximity	FM1	Densification of urban fabrics, giving identity to places	x	x	x	x
	FM2	"Hybridisation" of mono-functional areas through the introduction of a mix of functions, activities and uses	x	x	x	x
	FM3	Regeneration of disused urban spaces through formal transformation or a change in their intended use Upgrading	x	x	x	x
	FM4	and reuse of building stock to respond to new housing needs, first and foremost for social housing			x	x
	FM5	Redevelopment and reuse of building stock to meet new economic activities Provision of necessary services within a 15-minute walking radius	x	x	x	x
	FM6	Promotion of active mobility (walking and cycling) through the expansion of cycle and pedestrian networks	x	x	x	x
	FM7		x	x	x	x
	FM8	Promotion of the use of public transport	x	x	x	x
	FM9	Promotion of mobility sharing through advanced technology, including ITC and ITS systems			x	
Urban greening, green and grey, CO_2 subtraction	UG1	Regeneration to limit the consumption of soil	x	x	x	x
	UG2	Adaptation to urban heat islands		x		x
	UG3	Adaptation to intense precipitation, storms, pluvial flooding		x	x	x
	UG4	Increase in green areas to boost CO_2 storage		x	x	x
	UG5	Promotion/optimisation of ecological corridors and green belts based on the characteristics of the context and biodiversity	x		x	
	UG6	Collection and reuse of grey-water and rainwater resources in buildings and open spaces		x	x	x
	UG7	Limitation of water consumption and promotion of its effective and efficient use in buildings and open spaces	x x	x	x	x

Axes	Strategies	Indicators	Parameters	Case 1	Case 2	Case 3	Case 4
Energy transition	ET1,ET6	Use of energy from renewable sources	Percentage of energy requirements covered by renewable sources	100%	100%	100%	100%
			Amount of primary and electrical energy required to cover the total requirements of the project	80.000 kWh/y	400.000 kWh/y	N.A.	N.A.
	ET2, ET3, ET7	Adoption of bioclimatic devices	Type of bioclimatic devices present	natural ventilation + buffer space	heat recovery + geothermal	natural lighting	natural lighting
			Formal adaptation of the building to exploit natural ventilation	●	●	N.A.	N.A.
			Use of materials in the building envelope capable of reducing energy demand	●	●	●	●
			Presence of green roofing to reduce energy demand	○	○	○	○
	ET5	Reduction of CO2 emissions	Ratio between energy consumption from non-fossil and fossil sources	100%	100%	100%	100%
			Use of ICT and IoT systems to reduce energy consumption	●	●	N.A.	N.A.
	ET4	User awareness	Presence of devices for monitoring energy consumption to make users more aware and responsible	●	●	○	○
			Organisation of meetings to educate users about energy efficiency	●	○	○	○
Functional mixité and proximity	FM4, FM5	Cultural change	Population size in the municipality area	265.328 (2022)	185.825 (2020)	62.423 (2020)	263.703 (2021)
			Average age of the population within the municipality area	20-30y	30-45y	30-40y	20-30y
	FM1, FM2, FM3, FM4, FM5	Presence of diversified services in the area	Mq of space dedicated to services (public and private) compared to the total mq	100%	56%	68%	50%
			Flexible building design	●	○	●	●
	FM6, FM7, FM8, FM9	Accessibility: ease of reaching the area and related services	Distance from the nearest public transport stop	70m	5m	180m	80m
			Presence of parking spaces dedicated to electric vehicles	○	○	●	●
			Presence of parking spaces dedicated to bicycles	●	●	●	●
			Presence of clear and distinct pedestrian routes to reach the area	●	●	●	●
			Presence of crossings on a typical route (> crossings, > connectivity)	○	○	●	●
Urban greening, green and grey, CO2 subtraction	UG1, UG4, UG5	Presence of green areas	Percentage of ground surfaces covered with natural grass compared to paved outdoor areas	23%	84%	0%	58%
			Presence of green roof	○	○	●	●
			Presence of areas subject to depaving	●	●	○	●
	UG3, UG6, UG7	Resilience of outdoor spaces	Presence of NBS devices for managing extreme weather events	○	●	○	N.A.
			Presence of water retention systems	○	●	○	●
			Presence of rainwater recovery systems	●	●	●	●
			Presence of grey water recovery systems	○	●	○	N.A.
	UG2	Thermo-hygrometric comfort of outdoor spaces	Presence of special paving with heat island reduction effect	○	N.A.	○	●
			Presence of outdoor public spaces covered by shade during the hottest hours of the day	●	●	○	●

Figure 2. Comparison of case studies based on selected indicators and relative parameters.

All four cases demonstrate virtuosity in employing entirely renewable energy and bioclimatic solutions – especially Bordeaux's low-tech technological design – that drastically limit CO_2 emissions. Case studies exhibit urban hybridization through varied functional programs creating inclusive neighbourhoods. Municipal population parameters show different user catchments depending on administrative boundaries. Average age (20-45 years) justifies residential, co-working and event functions. Quality of life attention, evidenced by prevalent public and private services versus residential/hospitality functions, social cohesion, empowerment (emphasized in DARWIN and Halle Pajol) and accessibility confirms architecture's role as an instrument of equity and civic regeneration. Service densification encourages active mobility beyond addressing social needs, while public transport within 200 meters facilitates access avoiding vehicular movement and pollution. Paris and Ghent interventions are distinguished by green surface quantities relative to open public spaces (84% and 58% respectively). These cases demonstrate outdoor thermo-hygrometric comfort improvement and environmental quality through tree planting enabling pollutant storage and rainwater capture, reducing consumption and associated CO_2 emissions.

Conclusion and next steps

The examined case studies demonstrate how adaptive reuse of abandoned industrial or military complexes, leveraging their extensive spaces, enables conversion into multifunctional urban hubs oriented to climate mitigation and adaptation as well as to community engagement. This process returns dismissed built heritage to communities, creating attractive poles while reducing climate-altering emissions and enhancing resilience and social value.

A key research limitation involved partial availability of quantitative data from case studies, necessitating simplification of literature-derived parameters. This also prevented a complete assessment of intervention emission profiles and CO_2 sequestration capacity achieved through urban greening strategies, due to insufficient detail on plantings and species. The predominantly qualitative indicator set enabled comparative evaluation of case studies. However, to utilize it as a design guidance tool for future projects, research will proceed by integrating quantitative parameters based on real data, collected from case study designers and/or field surveys.

For quantifying the decarbonization contribution of the design strategies adopted in case studies, research next steps will include applying integrated estimation methodologies, addressing both embodied and operational carbon such as: one focusing on emissions from

water consumption (Romano et al., 2023); one considering the benefits of an optimized use of urban intermediate spaces (Tucci et al., 2025); one evaluating emissions embodied in existing building material stock and new materials (Luciano et al., 2023). This enhanced emission assessment would consolidate the framework, making it more effective in supporting future sustainable regeneration projects. Finally, an important research perspective involves identifying additional indicators usable by designers to quantify social benefits of design choices, maximizing social value produced in the interventions.

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SMALL OPEN SPACES AS URBAN CLIMATIC REFUGES: THE NETWORKING APPROACH

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Small Open Spaces as Urban *Climatic Refuges*: The Networking Approach

Abstract: European climate change adaptation policies have identified settlement systems as a critical area on which to act to increase their resilience to risks generated in particular by heat waves, extreme rainfall, and drought phenomena (MiTE, 2021). This paper, arguing about the term "extreme" in the climate change debate, discusses how the definition of "extreme" weather is shifting, challenging traditional conceptions and prompting a re-evaluation of urban resilience strategies and design approaches. Through the environmental design methodology and tools, the study highlights the potential of climate-adaptive design principles, such as flexibility, inclusivity, and sustainability, to convert small open spaces into a resilient urban network to face urban environmental challenges.
The research investigates how the *networking approach* can transform them into an adaptive spaces system in which people can find climate refugees, conceived as cool islands, improving urban resilience and reducing energy poverty.

Keywords: small open spaces, urban networks, cool islands, environmental design, inclusive approach

Introduction

Over half the worldwide population lives in cities, and this increases people's need for open space in urban areas to compensate for the physical and psychological impacts of being disconnected from nature, a necessity amplified by the urban challenges of designing for climate change adaptation and mitigation as well as habitat conservation (Thorne et al., 2020). Although the positive impact of urban open spaces on our health and well-being is evident, it is also necessary to confront the negative consequences of climate change. The data on the maximum temperatures reached in recent years in many cities around the world show an unprecedentedly high upward trend. Adding to the people's sense of discomfort are the numerous urban heat islands that cause temperatures to rise by up to 7 °C, transforming open urban spaces into places that are difficult to enjoy and live in (Medina et al., 2025).

Following this premise, the research group experiments with the "micro and interconnected" formula (Frettoloso et al., 2024), optimising existing spaces to provide ecosystem services. In particular, the researchers interpret the density as an opportunity to create open spaces on a human scale, favouring the necessary conditions for environmental improvement as well as for mending the built environment. This is to ensure that urban open spaces constitute a cool area infrastructure at the service of the city, answering to "extreme" weather conditions and allowing an inclusive access to well-being conditions. The consequences of extreme heat are, in fact, dangerous, both in relation to the high temperatures that can cause various short-term physical ailments and in relation to the effects of the UHI that trap pollution and reduce air quality. These effects also pose health risks in the long term, causing increased energy demand and inconvenience, especially to the most fragile groups. On

a larger scale, this also means increasing the ecological footprint of the cities in which we live (JRC, 2024).

Literature review: adaptive urban strategies

Climate change is currently one of the challenges that increasingly affects urban areas, with profound and complex repercussions on all our lives. Identifying strategies to mitigate the consequences of extreme events and reduce the human footprint on the climate is a fundamental action for protecting urban areas and promoting their climate adaptation.

Energy choices that promote the limitation of fossil fuel use and the use of renewable sources have proven very useful in combating climate change. An equally effective tool, but unfortunately little explored so far, is the co-benefits policies (win-win strategies), which mitigate climate change and simultaneously prevent disease, bringing significant benefits to the population's health (ARS Toscana, 2024).

In this regard, *"to rapidly adapt cities to the growing impacts of climate change, the open space system can play important functions as climate regulators and accelerators of sustainable urban development*" (Gargiulo & Zucaro, 2023). This statement formed the basis of the study presented by the authors, who provided a methodology for classifying open spaces according to their physical characteristics and their contribution to climate vulnerability, dividing them in relation to the costs required for adaptation and the benefits they bring. They concluded that it is necessary to update the rules for transforming areas using new criteria for the resilience requirements that cities are required to meet.

"In the context of climate change, adapting a city's open spaces to heat waves and extreme heat is crucial for mitigating the Urban Heat Island effect and ensuring the wellbeing of its inhabitants. However, the heat adaptation potential of open spaces varies within a city" (Villaverde et al., 2024). This statement is particularly significant as it refers to a study whose authors developed an objective and replicable method for classifying urban areas based on the adaptability of their open spaces and their potential for improving heat waves. They used a clustering approach that employs indicators suited to each type of urban fabric. They also validated the methodology through a case study that demonstrated the validity of obtaining meaningful information on the potential for heat adaptation in open spaces. In particular, the method can be very effective in helping local policymakers identify open spaces that can accommodate adaptation solutions. Furthermore, as it is replicable, the method can also be used

in other cities, contributing to a broader exploration of the potential for adaptation to climate change.

As part of the identification of adaptation strategies, final considerations are also provided regarding the potential offered by small urban green spaces. Urban green spaces are currently recognised as playing an important role in mitigating urban heat, especially in relation to the current intensification of heatwaves. The same cannot be said for small urban open spaces, which are not known to have this function, mainly due to their fragmented distribution. A recent study, on the other hand, has provided very interesting results in terms of the potential of small urban green spaces to play a crucial role in urban thermal mitigation and in providing ecological potential to improve the efficiency of urban cooling towards sustainable cities (Xu et al., 2025).

Methods: the networking approach

This research examines the potential of open space design as a technological system in dense urban contexts to address critical environmental challenges. Today, not only in traditionally hot world cities, but also in central and northern Europe, there is a real need to combat the high temperatures and the heat island effect for different purposes. First, bringing life back to the streets and making spaces frequently used in the past more appealing again to local citizens (Medina et al., 2025). Second, creating climatic refuges in which comfort and well-being are accessible for all, according to an inclusive design approach to limit the energetic poverty (Martini, 2019).

The need for a systemic approach to this issue is closely linked to the necessity to reconnect buildings, people, and the city with nature by working on the street system, buildings, and interstitial micro-spaces to ensure functional continuity and provide ecosystem services. Interesting national and international research project experiences confirm the need to operate according to adaptive logics centred on punctual and widespread actions whose technological-environmental contribution manifests in individual solutions' capillarity.

Sharing the importance of working on integrated and complex approaches capable of holding together spatial, environmental, and socio-economic dimensions, and centred on multi-scale, the research group explores the performance features linked to the key role that open spaces can assume within the urban network in managing technological and environmental issues. Inclusive and accessible spatial habitats, the urban open spaces can be interpreted as hybrid interfaces in which new balances between natural and artificial systems can reduce

climate vulnerabilities. Following this logic, the research group will deepen methodological and design aspects intended at an operative code aiming at identifying meta-design layouts, based on the “micro and interconnected” formula, to trace trajectories that are not always coplanar, often starting from the re-naturalisation of buildings and then arriving at the open space. This is to provide a "dynamic" prefiguration tool of the possible choices that can be implemented to increase the knowledge and awareness of the good practices and the related advantages in technological, environmental, and socio-economic terms.

By the nomenclature adopted at international level, the methodological approach envisages intervention according to three different typologies green and blue (nature-based solutions that employ the multiple services provided by natural ecosystems to improve resilience and adaptive capacity); grey interventions (infrastructural/technological solutions, aimed at making buildings, infrastructures, networks, territories, more resilient to climate change); soft adaptive capacity building measures (social and management measures that can change behaviour and lifestyles, contributing to improving adaptive capacity and raising awareness on climate change issues) (Ispra, 2023). The green actions, classifiably in two main groups (a first, which regards urban and peri-urban forestation, tree fences, urban gardens and orchards, and a second group of climate building as green and ventilated roofs and walls, shading structures, solar shading, etc.) represent strategic action priorities that address the specific challenges and leverage the city's strengths for their ability both in terms of mitigation as well as adaptation and for their potential to provide a wide range of environmental, social and economic benefits (IPCC, 2022).

Remembering that the presence of green does not guarantee an increase in quality, it is above all the level of connection between the different green areas and the type of vegetation present that gives this parameter significance, also from a climatic perspective. In Europe, interesting urban-scale projects are working precisely on the introduction of green actions as a potential climate refuge, paying attention also to the level of connection between such spaces, according to a strongly systemic approach. “*Acknowledging the limited impact that punctual greening intervention could have in fighting climate change, and particularly heatwaves, Torino has joined a replication process to recreate proGIreg solutions within and beyond the metropolitan area*” (Iodice et al., 2024), transforming an area which symbolised the industrialisation of Northern Italy into a thriving green district by developing an extended system of nature-based solutions.

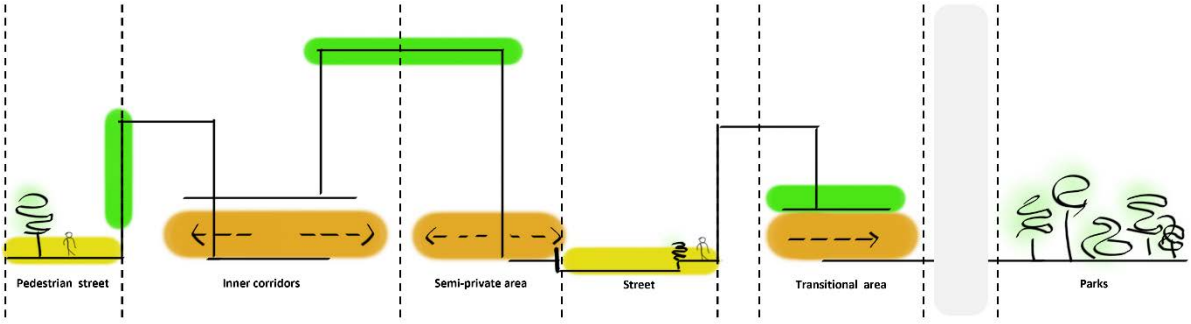

Figure 1. Building fruitive and environmental links in the urban context (C. Frettoloso, 2024).

Recalibrating the "Extreme" through a Networked Resilience Paradigm

The primary takeaway of this research is that the prevailing understanding of "extreme" weather occurrences, particularly in mainstream urban planning, is fundamentally inconsistent with current climatological realities. Although advanced academic discourse has begun to incorporate non-stationarity, the recognition that past climate conditions are not reliable indicators of the future (Milly et al., 2008), operational frameworks often remain rooted in a crisis-response model. Traditionally, "extreme" signified an infrequent divergence from a stable standard, an aberration to be endured (Seneviratne et al., 2021). However, the heightened frequency, duration, and intensity of heatwaves, recognised as a direct result of shifted statistical distributions in a warming climate (IPCC, 2022), necessitate a re-evaluation of these phenomena as persistent components of a new urban climate norm. This semantic and climatic shift reveals a crucial problem in traditional approaches: static, defensive resilience solutions developed for one-time events are fundamentally unprepared for continuous, constant climatic pressure.

This recalibration demands shifting from isolated, periodic interventions to a framework of continuous, systemic adaptability. Our findings demonstrate that the "micro and interconnected" concept provides a solid foundation for this transition. The core mechanism of this approach is that thermal resilience emerges from the intentional integration of individual spaces rather than being an essential attribute of those spaces. A single cool island's capacity is restricted by its spatial reach, which might result in crowding during peak stress. A network, on the other hand, produces synergistic effects: it gives several, close-by refuge options, cools connecting corridors to allow for secure movement (Gillner et al., 2015), and improves ecological connectedness, hence improving the overall health and cooling capacity of the urban forest. This transforms the urban fabric from a collection of vulnerable points into a resilient, responsive system.

However, the sheer presence of a network does not ensure equitable outcomes. The well-documented socio-spatial disparities in heat vulnerability, where historically marginalised neighbourhoods face higher temperatures due to the urban heat island effect and have fewer adaptive resources (Harlan et al., 2006), imply that a networked approach may unintentionally perpetuate existing inequalities if not consciously designed to address them. As a result, spatial equality principles must be expressly incorporated into the network's design. This necessitates employing vulnerability mapping, which synthesises data on socioeconomic vulnerability, health indicators, existing green space access, and surface temperatures to prioritise investment and guarantee the network's nodes are evenly distributed to assist those in greatest need first. In this approach, equity is not a desirable result but rather a non-negotiable design parameter.

Finally, redefining "extreme" resets the goal of urban resilience. It is no longer sufficient to provide periodic relief from a rare tragedy; the objective must be to ensure continual access to basic well-being under permanently altering climatic circumstances. The networking of small open spaces, although filled with implementation obstacles, represents a crucial paradigm change. It expands the discussion beyond technical mitigation to a broader perspective of adaptive capacity, in which the everyday urban fabric serves as the fundamental infrastructure for fostering an equitable and climate-resilient city. This research contends that networked thinking is the key first step towards aligning our urban environments with the reality of the environment.

Conclusion

By exploring the concept of “extreme” associated with climate change, we highlight the relationships between open spaces and the urban context in terms of criticality and benefits for people. To create comfortable places, accessible to the population, especially in extreme climatic conditions, the paper illustrates a methodological approach centred on the opportunity to create a system of open spaces conceived as cool islands (even small ones), which infiltrate the urban fabric and function as a technological-environmental infrastructure.

The networking approach is the result of multiple visions. It integrates theoretical work on aesthetic and sustainable ancient and contemporary perspectives, as well as studies of groundwork design and earth movements, with a systemic approach focused on connectivity to improve the functional and environmental dimension. An interesting reference model is provided by the project of a “network of climate and care refuges from a community and ecofeminist perspective” in public spaces in La Prosperitat, a diverse and densely populated

neighbourhood of Barcelona (Amorin-Maia, 2023). The proposal focuses on the use of integrated green, blue and grey strategies, applied at the building scale as well, to create accessible small indoor or outdoor spaces that offer “thermal relief” for people during heatwaves and other extreme climate events.

The research group (Small open spaces as technological devices in the urban ecosystem _NODES) is working on the definition of a set of indicators in a matrix of opportunities and possibilities to offer the chance to adapt to change by modifying the different layout configurations of urban open spaces NET to protect the city from "system failure".

Concerning the challenge imposed by the climatic crisis, which forces us to build a new kind of equilibrium, even more dynamic, several key concepts emerge. We refer to the importance of working on a sustainable proximity and the opportunity of thinking according to an incremental logic (Frettoloso et al., 2024).

Urban form, infrastructure organisation, dense construction, diversity of buildings and open spaces, and shorter distances all play a crucial role in shaping lifestyles towards more sustainable behaviour. Implementing effective strategies such as 15-minute cities and networked urban open spaces can significantly contribute to this shift. These strategies concentrate jobs, services, and housing in a compact, well-connected area and use nature-based solutions to enhance carbon storage, reduce energy consumption and urban emissions, and improve residents' health. The proximity to each Net’s node and links also ensures an equitable distribution of all essential social functions, benefiting all residents with shorter travel times.

The structure of networked urban open spaces, conceived as cool islands, should be based on incremental logic. This would allow the construction of an inclusive, human-scale network model that also considers the lack of economic resources and accessible spaces. Developing processes that work on temporal (short-term and temporary projects) and spatial (small-scale) incremental intervals allows for experimentation by adopting soft approaches. Thanks to the 'micro' and 'short-term' formula, the effectiveness of urban transformation actions improves, increasing the chances of taking place and being 'accepted' by future users, offering a human-scale experience. In conclusion, the networking approach proposes an interconnected open space system designed according to the principles of environmental design and strongly aimed at allowing climate refuges to respond to the urban environmental injustices as well.

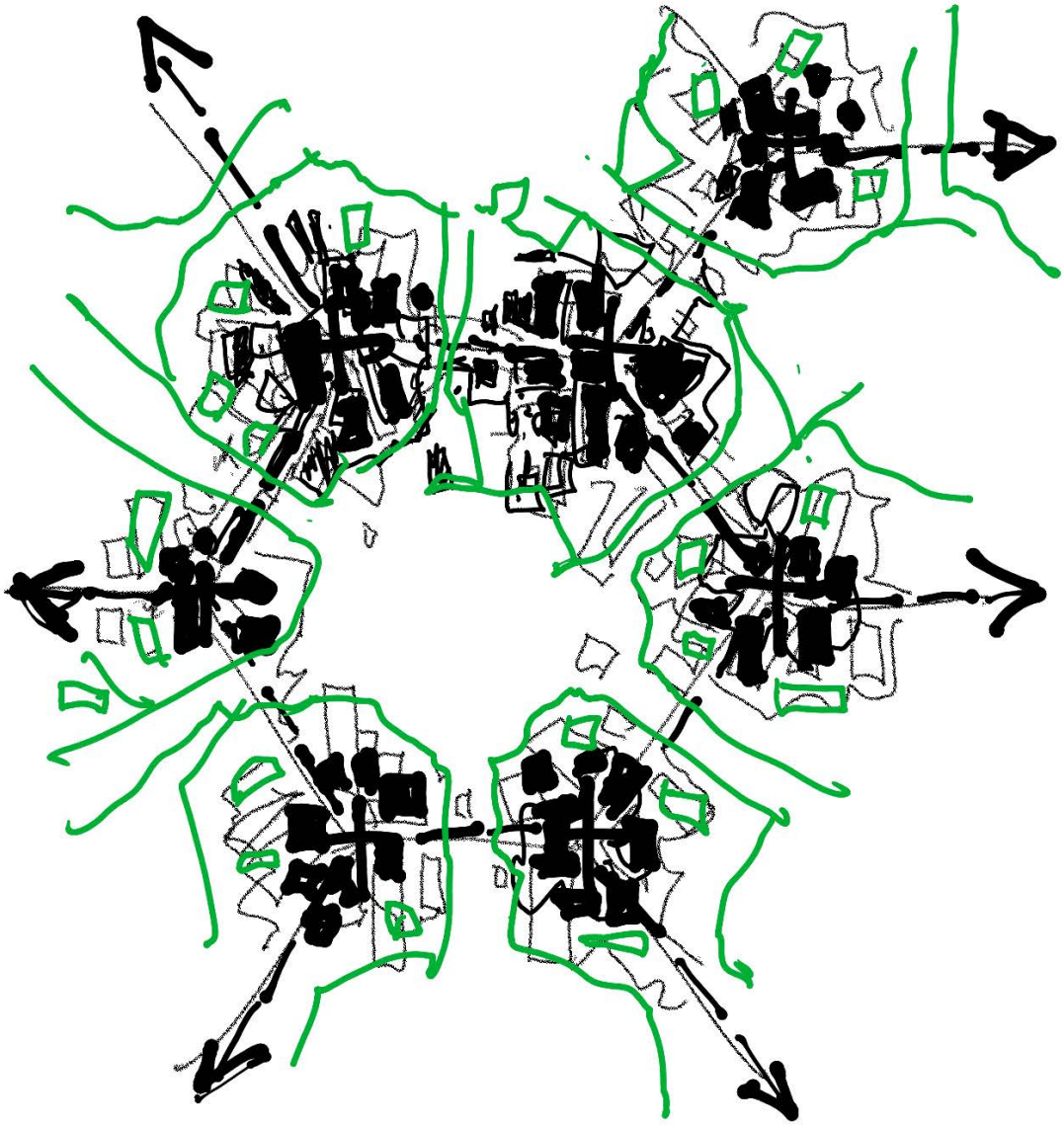

Figure 2. Working on possible configurative scenarios of the urban open spaces network (Holger Kehne, 2024).

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DEPICTING FACTORS AND PARAMETERS OF UHI AND UHI INTENSITY

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Depicting Factors and Parameters of UHI and UHI Intensity

Abstract: Rapid urbanization has intensified the Urban Heat Island (UHI) phenomenon by altering land surfaces, increasing building density, and intensifying anthropogenic activities, which together raise urban temperatures and exacerbate climate risks. As cities continue to expand, UHI has emerged as a critical environmental challenge, not only aggravating global climate change but also directly affecting urban livability, energy demand, and public health. Understanding how UHI forms and evolves is therefore central to developing sustainable planning and design strategies. This study provides a comprehensive review of the literature on UHI formation, highlighting the spatial, temporal, and climatic drivers that shape its intensity. In addition to synthesizing existing research, the paper takes a deeper look into UHI dynamics by examining key analytical factors commonly applied in urban climate studies: Land Surface Temperature (LST), thermodynamic surface properties, the Urban Thermal Field Variance Index (UTFVI), the Normalized Difference Vegetation Index (NDVI), and the Sky View Factor (SVF). Together, these parameters offer a robust framework for assessing UHI intensity, ecological impacts, and urban morphology.

Keywords: Urban Heat Island, Parameters to Investigate UHI, Factors Affecting UHI Intensity

Introduction

Rapid urban population growth, accounting for nearly half of the world's inhabitants and projected to reach 68% by 2050 [1], is transforming natural land surfaces into impervious ones, particularly in urban districts [2]. This process brings challenges such as high population and building density, informal settlements, and pressure on urban services. Rising temperatures from climate change and anthropogenic activities create the Urban Heat Island (UHI), defined as the temperature difference between urban environments and their suburban surroundings [3]. UHI might stem from waste heat, solar absorption, vehicle emissions, dense building forms, altered surfaces, and vegetation loss [4]. These conditions can raise urban temperatures by up to 10°F (5.6°C) compared to suburban and rural areas, a difference referred to as UHI intensity, measured through remote sensing or field observations [5][6]. Effects are often stronger at night, when built form traps heat, amplifying climate change impacts and harming residents and ecosystems [7][8]. Prolonged exposure increases risks of respiratory and cardiovascular disease, heat stroke, and mortality[10]. This paper analyzes UHI's key drivers and reviews principal measurement methods and parameters, providing a foundation for evaluation and mitigation.

Literature Review

Factors influencing the urban heat island phenomenon are commonly categorized into two main groups: spatial factors, referring to the composition and structure of land surfaces,

and temporal factors, encompassing annual and daily variations in air and surface temperatures [11].

Factors Affecting UHI Intensity

The Urban Heat Island (UHI) intensity is commonly expressed as the temperature difference between urban and rural areas ($\Delta Tu{-}r = Tu - Tr$) [12]. This difference is influenced by geographic latitude, as climatic variations and solar geometry determine whether cities experience strong warming or even daytime urban cool islands—more frequent in higher latitudes with low solar angles, but rare in tropical regions where direct solar radiation prevails [8]. Land surface transformation also plays a critical role: the replacement of vegetated or water surfaces with impervious, heat-retaining materials alters local energy balances, decreases evapotranspiration, and increases heat storage [12]. Furthermore, urban geometry and surface thermodynamics—including building orientation, canyon aspect ratio, albedo, and thermal mass—govern heat retention. Tall, narrow street canyons trap radiation through multiple reflections, while materials with high thermal mass absorb heat during the day and release it at night, reinforcing nocturnal warming [13].

UHI intensity and mitigation vary by climate, shaped by temperature, humidity, precipitation, and wind. In humid regions, high humidity and weak winds heighten heat stress, making vegetation essential for shading and evapotranspiration across surface, canopy, and boundary layers [14]. In hot, flat terrains, weak convection restricts heat dissipation; high-rises provide shade but disrupt airflow and humidity, whereas tropical forests and dense vegetation improve shading and evaporative cooling [15]. In hot–arid climates, green spaces are crucial, cooling by up to 4.5°C—almost double the effect in continental zones (0.5–2.0°C) [8]. Although daytime UHI may be moderate, nocturnal UHI peaks due to limited moisture and high thermal storage; vegetation with high nighttime evapotranspiration and airflow through urban canyons mitigate this. Reflective materials also help by reducing heat absorption. In cold climates, daytime heat retention can lower energy demand, yet dense canyon geometries alter solar access, convection, and wind. Strategically placed green belts and vegetated street bands enhance evapotranspiration and thermal comfort [16].

Parameters Used in UHI Studies

Analyzing UHI dynamics involves key parameters reflecting surface and atmospheric conditions, urban morphology, and ecological features. The following subsections outline the most frequently cited parameters in UHI research and their applications in previous studies.

Land Surface Temperature

UHI analysis considers three layers: the surface UHI, canopy-layer UHI, and boundary-layer UHI [17]. Surface UHI develops at ground level due to heat-retaining impermeable surfaces, while the canopy layer spans ground to rooftop heights and reflects human activity. The boundary-layer UHI forms higher in the atmosphere—often a kilometer or more—appearing as a daytime thermal band that thickens at night [16].

UHI intensity has been quantified through remote sensing, thermal imaging, and field measurements, with remote sensing emerging as the most widely used due to its broad coverage and high resolution. Thermal satellite data provide detailed mapping across spectral bands, and since the 1960s Land Surface Temperature (LST) has served as a proxy for near-surface air temperature and land–air interactions. The Landsat series, with its thermal bands, remains central for deriving LST while accounting for atmospheric and surface effects [17][18].

Several algorithms have been created to retrieve LST from thermal imagery. Key examples include the radiative transfer equation, the mono-window algorithm by Wang et al. [17], the split-window method, and the single-channel method by Sobrino et al. [19]. These differ in handling atmospheric correction and spectral data: the split-window method is more effective under high water vapor, while single-channel approaches work better in drier conditions [19][20].

Thermodynamic properties of surfaces

Thermodynamic properties of urban surfaces strongly shape UHI formation and intensity. Heat capacity, conductivity, density, reflectance, emissivity, and albedo govern how materials absorb, store, and release heat. Emissivity measures a material's thermal radiation relative to a blackbody (0–1), while albedo indicates surface reflectivity (0–1), with lower values meaning stronger absorption. Water bodies also provide cooling that reduces surface temperatures and CO_2 emissions. Increasing albedo from 0.25 to 0.40 can lower urban temperatures by about 4°C, effectively mitigating UHI impacts [21].

Replacing natural elements like vegetation, wetlands, and water with artificial surfaces of low albedo and high thermal inertia intensifies heat and reduces airflow. Pavements and roofs have the greatest impact, with traditional materials such as gravel, black EPDM, and bituminous coatings showing very low albedo (0.05–0.15) and high emissivity (~85%), producing surface temperatures of 74–85°C. Metal alternatives can reduce this to 66–77°C, though their high conductivity makes them less suitable in cold climates [22].

In hot climates, replacing conventional roof coatings with cool materials can reduce daytime heat transmission and lower cooling energy demand by 2–40%. Thermochromic coatings offer another option, shifting color and reflectivity with air temperature and solar angle. Effective UHI mitigation depends on selecting materials suited to regional climates to minimize overall energy use [21][23].

Vegetation Index

Green spaces are central to UHI mitigation, reducing air temperatures through evapotranspiration, providing shade, lowering energy demand, and cutting pollution and carbon emissions. Their effectiveness varies by scale, type, spatial arrangement, and climate, with vegetation blocking 60–90% of solar radiation [24]. Green roofs also increase albedo and can lower air temperatures by up to 2.6°C [25].

Vegetation type, scale, and spatial distribution are key factors in UHI studies, making accurate mapping and monitoring essential. High-resolution thermal sensing, often paired with LST retrieval, is widely used to classify vegetation, land use, and land cover, enabling calculation of vegetation indices [26]. The Normalized Difference Vegetation Index (NDVI), developed by Tucker in 1979, is widely used to assess vegetation health and density from red and near-infrared reflectance, while the Normalized Difference Built-Up Index (NDBI) is often applied alongside it to identify urban areas and analyze links with thermal patterns [27]. NDVI ranges from -1 to +1, with values <0 indicating water, near 0 corresponding to bare soil or rock, and higher values reflecting dense vegetation. Thresholds classify -1–0.199 as non-vegetation, 0.2–0.5 as sparse, and 0.5–1.0 as dense vegetation [27].

Land Cover and Use: UTFVI

The physical and radiative properties of urban surfaces strongly drive UHI intensity, as converting green areas to impervious zones disrupts airflow, elevates temperatures, and creates

adverse thermal impacts. The Surface Urban Heat Island (SUHI), measured through LST differences between urban and surrounding areas, is central to assessing urbanization's thermal effects. The Urban Thermal Field Variance Index (UTFVI) is widely applied to quantify UHI intensity and track land use and land cover changes. The Urban Thermal Field Variance Index (UTFVI) is calculated as:

$$UTFVI = (Ts - Tmean) / Tmean,$$

where Ts is the LST at a specific location and Tmean is the mean LST of the entire study area. The UTFVI is widely used to create ecological evaluation maps that show environmental degradation linked to urban form from LST data. Its values are classified into six ecological categories, summarized in the table below.

Table 1: The thresholds of the categories of Ecological Evaluation Indices (EEI) [26].

UTFVI	UHI Effect	EEI
<0.000	None	Excellent
0.000 – 0.005	Weak	Good
0.005 – 0.010	Middle	Normal
0.010 – 0.015	High	Bad
0.015 – 0.020	Higher	Worse
>0.020	Highest	Worst

UTFVI categories reveal an inverse relationship between UHI intensity and ecological quality: values ≤0.010 indicate diverse natural covers and tolerable conditions, while >0.020 reflect degraded or barren areas. Assessments are further shaped by population and building density and anthropogenic heat, but are limited by the spatial resolution of remote sensing and the need for consistent atmospheric and surface conditions. Reliable micro-scale analysis therefore, requires very high-resolution data with detailed ground accuracy [27].

Sky View Factor (SVF)

The Sky View Factor (SVF), introduced in early urban climate research and formalized by Oke (1988), is a key metric for understanding urban thermal environments [28]. Defined as the ratio of radiation received at a point to that from the full hemispheric sky [29], SVF represents the visible sky fraction, ranging from 0 (fully obstructed) to 1 (fully open) [30]. Studies consistently link SVF to UHI: in Montreal, lower SVF reduced temperatures and

improved comfort by limiting solar absorption [31], while Yuan and Chen (2011) showed that adjusting site coverage and building height optimizes SVF to lower UHI without harming functionality [32]. Conversely, higher SVF correlates with greater solar exposure and higher LST [33].

SVF can be estimated through several methods. Geometric approaches (e.g., Oke's H/W model) are simple but imprecise in complex forms [34][35]. Photographic methods, often using fisheye lenses, yield high local accuracy but are labor-intensive and spatially limited [36][37]. Simulation methods employ 3D models for fine-scale studies but require high computation [34], while GPS-based techniques estimate SVF from satellite visibility with reduced accuracy in vegetated or uneven terrain [38][39]. More recently, big-data approaches using street view imagery and deep learning enable automated, citywide SVF mapping, though challenges remain with image consistency and seasonal vegetation [40].

Conclusion

This study brings together the key parameters shaping UHI intensity—LST, surface thermodynamic properties, NDVI, UTFVI, and SVF—providing a comprehensive framework for assessing urban thermal dynamics. Findings indicate that while each of these parameters contributes to heat accumulation in different ways, careful consideration of all of them can significantly minimize UHI effects. Selecting high-albedo and low-thermal-mass materials, preserving or increasing green areas, optimizing urban morphology, and balancing sky view factor are all critical strategies to keep UHI intensity within acceptable thresholds. Accordingly, these parameters can serve as a practical guideline in urban renewal and redevelopment projects, supporting resilient design decisions. Moreover, adhering to the ranges and thresholds highlighted in this study may help cities remain within sustainable thermal limits. At the same time, future research can further validate these observations through long-term monitoring.

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PASSIVE BUILDING DESIGN STRATEGIES FOR DIFFERENT CLIMATIC ZONES IN TURKIYE

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Passive Building Design Strategies for Different Climatic Zones in Türkiye

Abstract: This study comparatively examines the applicability of passive solar design strategies in four different climatic regions of Türkiye (Antalya, İstanbul, Ankara, and Kars). The aim of the research is to identify passive design principles based on regional climatic data, to reveal the potential for reducing building energy demand, and to provide guiding recommendations for architects. Initially, a literature review was conducted to determine passive strategies, followed by an evaluation of climatic data such as temperature, humidity, solar radiation, and wind, in comparison with Climate Consultant software outputs. An office building designed in Ankara was taken as a reference, and scenarios were developed for the other three cities. Findings indicate that shading, cross ventilation, and open plan layouts are priority strategies in Antalya and İstanbul; night ventilation, thermal mass, and earth sheltering are critical in Ankara; while heavy thermal mass, pitched roofs, and super-insulation are essential in Kars. The study highlights the critical role of climate-responsive passive design approaches in improving energy efficiency.

Keywords: Passive **s**olar systems; Energy efficiency; Climate-responsive design; Bioclimatic architecture; Sustainable architecture

Introduction

In recent years, the increasing population and rapid urbanization have significantly raised building energy demands, while fossil fuel consumption and greenhouse gas emissions have reached unsustainable levels. Buildings account for approximately 30–40% of total energy consumption, with heating and cooling systems constituting a major share. This creates a critical challenge in terms of climate change, energy security, and environmental sustainability. Passive solar design stands out as an approach that enhances energy efficiency and improves indoor comfort through the rational use of natural environmental conditions, without requiring additional mechanical systems.

Due to its diverse climatic zones, Türkiye necessitates regionally differentiated passive strategies. However, in the literature, there is a limited number of practice-oriented and comparative studies specifically addressing Türkiye's climatic diversity. This study examines passive design strategies comparatively across four provinces (Antalya, İstanbul, Ankara, Kars), thereby aiming to provide a guiding framework for climate-responsive architectural design. The study is limited to office buildings, while immediate site conditions were excluded from the scope.

Literature Review

Passive building design is one of the most significant approaches developed to enhance energy efficiency and ensure indoor comfort. In the literature, passive strategies are generally categorized as cooling- and heating-oriented methods.

Passive cooling strategies are primarily developed for hot and dry climates to reduce indoor temperatures and minimize mechanical cooling demand. Cross ventilation utilizes natural airflow to bring in cooler air while expelling warm air (Alghamdi et al., 2022). Stack ventilation is based on the principle of warm air rising and exiting through upper openings (Roaf, 2001). Shading devices and cool roof applications play a significant role in reducing direct solar radiation and controlling indoor heat gain (Parker et al., 2002). Building form contributes to cooling through orientation, narrow floor plan, facade surface-to-volume ratio, and roof and window arrangements (Lechner, 2015). Additionally, night ventilation removes accumulated daytime heat using cooler night air, which is particularly effective in hot-dry climates (Santamouris & Kolokotsa, 2013).

Passive heating strategies are essential in cold climates, aiming to reduce energy demand by maximizing solar radiation use. Direct heat gain methods involve capturing solar radiation through glazed surfaces and storing it in thermal mass (Baker & Steemers, 2000). Indirect gain systems such as sunspaces, positioned on the south façade, collect solar radiation and transfer heat to adjacent spaces (Yüre, 2007; Lechner, 2015). Heating-oriented building forms emphasize compact masses, east–west orientation, large south-facing windows, and appropriate insulation solutions to minimize heat loss (Hines, 2023). Earth shelters also utilize soil's thermal properties to provide stable indoor temperatures throughout the year, with studies indicating that such designs are 30–50% more energy efficient compared to conventional buildings (Lechner, 2015).

The prevailing tendency in the literature suggests that when passive design strategies are applied in appropriate climatic zones and integrated with one another, they significantly reduce dependence on mechanical systems while enhancing energy efficiency. In addition, the applicability of these strategies across different climates varies depending on factors such as material properties, building form, and user behavior. This study aims to evaluate the applicability of passive design strategies for different climatic zones of Türkiye, based on the existing literature.

Although numerous studies have addressed passive design strategies, most have either concentrated on a single climate zone or provided only limited comparative evaluations. In a

country like Türkiye, which exhibits distinct climatic variations, there remains a need for comprehensive analyses of how these strategies should be adapted to regional conditions. This study seeks to address this gap by systematically identifying and assessing applicable passive design approaches for different climatic regions, thereby contributing to literature on energy-efficient architectural practices.

Methods

This study examines passive solar design strategies in four different climatic regions of Türkiye: Antalya, İstanbul, Ankara, and Kars. Hourly climatic data (in EPW format) were obtained from international datasets, analyzed using Climate Consultant 6.0 software, and evaluated according to ASHRAE Standard 55 comfort models. Climate-specific strategies were identified for each city: heavy thermal mass and night ventilation in Ankara; lightweight structures and cross ventilation in Antalya; a balance of shading in summer and solar gain in winter in İstanbul; and compact form, super insulation, and central heating in Kars. These methods were used to compare the effectiveness of passive design across climates and to guide sustainable architectural design.

Findings and Discussion

When Ankara, Antalya, Istanbul, and Kars—representing different climatic regions of Türkiye are comparatively examined in terms of passive design strategies, it is observed that climatic conditions have a decisive impact on building configuration and energy efficiency. Since Ankara has a continental climate with hot and dry summers and cold, snowy winters, solutions that balance both heating and cooling needs come to the fore. Antalya, with its hot and humid climate throughout the year, particularly requires cooling and shading, while Istanbul, with its more temperate and balanced structure, is suitable for mixed strategies. Kars, on the other hand, dominated by very harsh winter conditions, is the city with the highest heating demand. These climatic differences directly influenced the orientation of the design strategies determined for each province. Table 1 presents the design strategies suggested by the Climate Consultant program for the four cities.

Table 3 : Design Strategies Recommended by the Climate Consultant Program for the Cities

Ankara	Antalya	İstanbul	Kars
Direct Gain-Glazing	Direct Gain-Glazing	Direct Gain-Glazing	Direct Gain-Glazing
Cool Roof	Cool Roof	-	-
Shading Devices	Shading Devices	Shading Devices	Shading Devices
Earth Sheltering	-	-	-
Night Vent Cooling	Night Vent Cooling	Night Vent Cooling	Night Vent Cooling
-	Form for Cooling	-	-
Form for Heating	-	Form for Heating	Form for Heating
Indirect Gain-Sunspace	Indirect Gain-Sunspace	Indirect Gain-Sunspace	Indirect Gain-Sunspace
Cross Ventilation	Cross Ventilation	Cross Ventilation	-
Stack Ventilation	Stack Ventilation	Stack Ventilation	-
-	-	Direct Gain-Heat Storage	Direct Gain-Heat Storage

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The Climate Consultant program recommends the earth sheltering strategy only for Ankara. However, considering similar climatic conditions, this strategy has also been integrated into the design for Kars. Similarly, although cross and stack ventilation strategies were not directly included for Kars in the Climate Consultant program, opening arrangements enabling these ventilation methods were nevertheless made in this city as well, in order to support indoor air quality when necessary. In addition, although the thermal storage strategy appears to have been recommended only for Istanbul and Kars, given the low night temperatures in Ankara, it is foreseen that this strategy can also be effectively applied there. Therefore, the heat storage potential of thermal mass has also been taken into account in the design for Ankara. This situation demonstrates that passive strategies should be considered not only through program recommendations but also in integration with local conditions.

According to TSE 825 standards, when the humidity and temperature levels of the provinces are examined, Antalya has the highest humidity value, followed by Istanbul, Kars, and Ankara. In terms of temperature, Antalya is also the warmest city; it is followed by Istanbul and Ankara, while Kars has the lowest temperature levels. Considering the U-values, which express the heat transfer capacity of building elements, Antalya has the highest levels with values of 0.45 W/m²K for walls, 0.35 W/m²K for roofs, 0.40 W/m²K for floors, and 1.80 W/m²K

for windows. Kars, on the other hand, has the lowest values with 0.25 W/m²K for walls, 0.20 W/m²K for roofs, 0.25 W/m²K for floors, and 1.80 W/m²K for windows. This ranking reveals that Antalya demonstrates better performance in terms of energy efficiency, Istanbul ranks second, Ankara ranks third, and Kars, due to its low temperatures, requires greater thermal insulation (İzoder, 2024).

Below, the psychrometric chart data obtained through the Climate Consultant program for four different provinces are presented comparatively.

Table 2 : Results Provided by the Climate Consultant Program for the Cities

	ANTALYA (%)	**İSTANBUL (%)**	**ANKARA (%)**	**KARS (%)**
COMFORT	16.6	9.6	15	7.8
SUN SHADING OF WINDOWS	17.7	11.2	10	4.1
HIGH THERMAL MASS	3.3	0.7	7.2	1.9
HIGH THERMAL MASS NIGHT FLUSHED	4.4	1	7.9	1.9
DIRECT EVAPORATIVE COOLING	6.6	0.9	7.8	1.8
INTERNAL HEAT GAIN	31	29.3	25.4	18.2
PASSIVE SOLAR DIRECT GAIN LOW MASS	13.3	14.2	16.7	18.6
PASSIVE SOLAR DIRECT GAIN HIGH MASS	22	20.1	24.2	20.6
WIND PROTECTION OF OUTDOOR SPACES	1	1	0	1.9
HUMIDIFICATION	0	0	0	0
DEHUMIDIFICATION	8.3	13.6	0	0.3
COOLING, ADD DEHUMIDIFICATION IF NEEDED	22	8.7	8	2.1
HEATING, ADD HUMIDIFICATION IF NEEDED	53.1	68.2	77	89.9

When the psychrometric analysis results are examined, it is observed that the comfort range is 16.6% in Antalya, 9.6% in Istanbul, 15% in Ankara, and 7.8% in Kars. This shows that Antalya can provide more comfort throughout the year, while Kars has the lowest comfort conditions. The need for shading is 17.7% in Antalya, 11.2% in Istanbul, 10% in Ankara, and 4.1% in Kars. The heat gain rates are calculated as 31% in Antalya, 29.3% in Istanbul, 25.4% in Ankara, and 18.2% in Kars. Heating demand reaches the highest level in Kars with 89.9%, while it is 53.1% in Antalya, 68.2% in Istanbul, and 77% in Ankara. These values clearly reveal which strategies should be more dominant in the design of each city. Shading and natural

ventilation stand out for Antalya, thermal storage and sunspace for Kars, night ventilation and thermal storage for Ankara, and balanced solutions for Istanbul.

Within the scope of natural ventilation strategies, cross ventilation in Antalya was primarily recommended with four different measures, supported with three in Istanbul and two in Ankara; in Kars, although it was not directly recommended, supportive openings were designed. The inlet heights were arranged as 60–360 cm at entry and 430 cm at exit in Antalya; 60–360 cm at entry and 430 cm at exit in Istanbul; 250 cm at entry and 430 cm at exit in Ankara; and 200 cm at entry and 430 cm at exit in Kars. Stack ventilation was recommended in Antalya, Istanbul, and Ankara. In Antalya, air taken from 60 cm on the north side of a mass with a height of 800 cm was discharged through openings at 120 cm on the south side. A similar design was applied in Istanbul with a height of 750 cm, while in Ankara, inlet openings at 200 cm and outlet openings at 680 cm were used. In Kars, stack ventilation was designed with limited openings of a supportive nature. These results show that ventilation strategies are more limited in cold climates, while wider openings are preferred in hot and humid climates.

In terms of shading elements, eaves with a depth of 29 cm were designed in Antalya, 40 cm in Ankara and Kars, and 45 cm in Istanbul. In Antalya and Istanbul, shading was arranged to ensure maximum comfort in summer while not blocking passive heat gain in winter. Adjustable shutter systems were envisaged for sunspaces and south façade windows in all provinces, thereby preventing overheating in summer. Despite the program's recommendation of flat roofs, pitched roofs were preferred for each province: 25% in Antalya, 30% in Ankara and Istanbul, and 50% in Kars due to heavy snow loads. As roofing material, Marseille-type tiles with high reflectance and thermal emissivity values were applied in all provinces; light colors were chosen in Antalya, Ankara, and Istanbul, while dark colors were used in Kars. The insulation thicknesses were determined as 3 cm in Antalya, 5 cm in Istanbul, 6 cm in Ankara, and 8 cm in Kars. This difference reveals the requirement for thicker insulation in cold climates to minimize heat loss.

Night ventilation was recommended for all provinces and was particularly supported with three different measures in Ankara. By using whole-house fans and natural ventilation, it was aimed to reduce the use of air conditioning by allowing high-mass interior surfaces to store the coolness of the night. Reinforced concrete construction and reinforced concrete flooring stood out in all provinces to provide the necessary thermal mass. In Antalya, lightweight materials were preferred on both floors; in Istanbul, lightweight materials on the upper floor and heavyweight materials on the lower floor; while in Ankara and Kars, entirely heavyweight

construction materials were chosen. For direct heat gain, buildings in all provinces were oriented to the south, and eaves were designed at a depth to ensure summer shading. Double glazing was preferred in Antalya and Istanbul, while triple glazing was preferred in Ankara and Kars. In addition, the glass-to-floor ratio was determined as 10% in temperate climates and 16% in cold climates. For indirect heat gain, sunspaces were applied in all provinces, with double glazing in Antalya and Istanbul, and triple glazing in Ankara and Kars. In Kars, due to extreme cold, a wall instead of glass was used between the sunspace and the office.

Earth sheltering is only proposed for Ankara, but it is also implemented in Kars in the form of a basement. This allowed the soil temperature to be kept below freezing.In landscape arrangements, ash-leaved maple and juniper were used in Ankara, sweetgum and red pine in Antalya, Judas tree and stone pine in Istanbul, and birch and black pine in Kars. While water features are not recommended in humid regions, artificial water elements were included in the design in arid Ankara.

When all these results are evaluated, it is seen that passive design strategies differ significantly according to the climate of each province. While Antalya's hot and humid climate necessitates shading, cool roofs, and cross ventilation, Istanbul, with its more temperate conditions, has a balanced design with mixed strategies. Ankara stands out in thermal storage and night ventilation due to its large day–night temperature differences, whereas Kars, with its very cold climate, ensures user comfort through strategies such as heating, sunspaces, and earth sheltering. As a result, addressing passive design strategies in integration with climatic data emerges as an indispensable requirement in terms of both energy efficiency and user comfort.

Conclusion

Passive solar energy offers an effective strategy for sustainable building design across Türkiye's diverse climatic regions. This study has demonstrated that the integration of passive solar systems can both achieve significant energy savings and reduce environmental impacts.

The findings emphasize the necessity of climate-specific design approaches. In Ankara, performance in both summer and winter was optimized through night ventilation and thermal mass balance. In Antalya and Istanbul, passive cooling capacity was enhanced by open-plan layouts, deep overhangs, and the use of shutters. In Kars, comfort under low-temperature conditions was achieved through high insulation and effective thermal mass utilization.

These results highlight the importance of optimizing building orientation, glass-to-floor ratios, shading devices, and thermal mass balance according to regional climates. Rather than

uniform solutions, climate-responsive strategies based on local data increase energy efficiency and strengthen sustainability.

Recommendations:

- Validation of proposed strategies through on-site prototypes,
- Comparative studies of energy efficiency across different building types,
- Economic analyses of local material use,
- Revising national and regional regulations based on these insights.

In conclusion, passive design strategies based on regional climate data form the basis of sustainable building production in Türkiye and provide significant contributions to both academic literature and design practice.

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INTEGRATING THE SUSTAINABLE DEVELOPMENT GOALS INTO INTERIOR ARCHITECTURE EDUCATION

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Integrating The Sustainable Development Goals Into Interior Architecture Education

Abstract: This study includes the project and outputs carried out with interior architecture and environmental design students as part of a semester course, integrating sustainable design approaches and implementation methods with the United Nations Sustainable Development Goals (UN SDGs). This study, conducted over a total of 16 weeks of class hours with 34 students, aims to teach students current topics, terms, literature knowledge, and design approaches related to sustainability. Being the Department of Interior Architecture and Environmental Design, the inclusion of most environmental parameters in the educational process has facilitated the course being taught not only at the level of interior design but also on a more environmentally integrated scale. The method used accepted the SDGs as a reference point for starting the design, thus supporting students in both questioning the relationship between the SDGs and design and learning about the work done in the fields of architecture and design related to the SDGs.

Keywords: Sustainable Development Goals, Climate Change; Interior Architecture and Environmental Design, Interior Design.

Introduction

The concept of sustainability has now become one of the key topics in our professional or social lives. Professionals from different disciplines are trying to address sustainability from different angles, essentially seeking good solutions for the built environment, nature and ecosystem that have been harmed due to human-induced developments. Architecture and design are among the most important platforms where significant aspects of sustainability are addressed. It encompasses different topics such as land use, transportation, buildings, energy efficiency, water and waste management, etc. Each of these areas contains data related to all three dimensions of sustainability; environmental, social, and economic which are supported by architecture and design to provide solutions. The built environment, planning, architecture and design, interact with every goal and most crucially: not just on an aspirational level or as future potential, but through realized buildings, settlements and cities all over the world (UIA, 2020). The Sustainable Development Goals (SDGs), set by the United Nations (UN), in this point, highlight fundamental concepts, can vary from macro scales to micro scales for the professions such as architecture, urban design, landscape architecture, and city planning, guide them for a more systematic approach to reach out well planned sustainable future.

Considering the remarks above, this study includes the project outputs of a total of 34 students at Ankara Medipol University, Department of Interior Architecture and Environmental Design, with the scope of the "Sustainable Design for Interior Architecture" course conducted in the Fall Semester of 2023/2024. The aim of the course is to recognize the principles and

strategies of Sustainable Design, to ensure the adoption of sustainable design strategies, and to understand how the concept of sustainability is used in architectural design. At the same time, learning how the effects of climate change and sustainable development goals are addressed in architecture, and mastering the techniques of recycling and upcycling in design. In the first half of the term, first, students were expected to prepare a glossary consisting of unchanging, evolving, and renewing terms from literature on sustainability to develop a strong perspective on the context. Then, students were expected to use these terms in the final project associated with the selected 12 SDGs (Figure 1).

Figure 1: The UN Sustainable Development Goals addressed in the ‘Sustainable Design for Interior Architecture’ course.

The given 12 SDGs have been researched by students divided into groups, their sub-goals and indicators evaluated, and they have been examined in the context of spatial analyses in interior architecture. With the help of the prepared glossaries, they created a concept for each SDGs, including many terms related to sustainability. In line with the developed concept, they produced an interior object in the studio entrance halls, which are also used as gathering and exhibition spaces within the faculty, based on the needs. One of the strongest aspects of this

study is to emphasize the potential of design to create awareness. The interior objects produced by the students have been evaluated in terms of their potential to raise awareness about functionality and sustainability. The course included a comprehensive literature review and discussions on sustainability's origins, its development, and various architectural methods with the investigation of the best practices.

Design has the power to shape perception, and architects, working in all scales, are essential to minimizing climate change in all sectors. From the strategic definition and briefing stages onwards, architects can influence the sustainability of project outcomes by integrating traditional creative and technical skills with an up-to-date understanding of environmental, social, and economic impacts (UNGC, 2020). As a result, the main aim of the project is to positively influence the students' awareness in this context. However, the biggest challenge was The main challenge of the research is its limited length of time because in a single semester there are 14 weeks and with 2 hours of classes each week meaning a total of 28 class hours spent on product development. 34 students were assigned to the class; as a result, at the end of the semester 34 glossary designs were produced as students study individually, there were analysis posters for each selected 12 SDGs and worked as pairs, 17 interior objects were produced as the final project.

Literature Review

Sustainable development is a constantly developing subject that may trigger changes in human behavior and institutions focused on balancing social, economic, and environmental aspects of development. This issue has grown greatly since the 1980s, and it got widespread attention in 2015 with the establishment of the 2030 Agenda and sustainable development goals (SDGs) (Serafini et al., 2022)

The Sustainable Development Goals (SDGs) were established during the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012. The aim was to establish a framework of universal objectives that address the urgent environmental, political, and economic concerns confronting the world to achieve a more equitable and sustainable future for all. The agenda included 17 Sustainable Development Goals (SDGs), with specific objectives and indicators for each, as established by the United Nations, totaling 169 targets and 213 indicators that constitute a worldwide action plan. (United Nations, 2015 & United Nations, 2017).

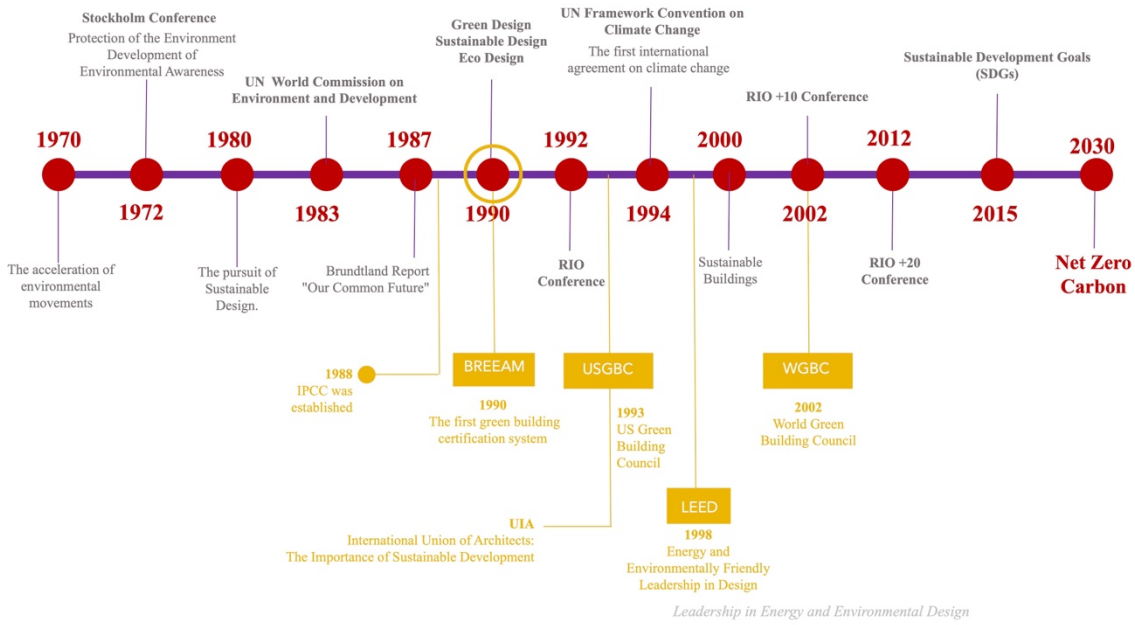

Figure 2: Sustainability timeline chart (developed by the author)

In 2015, over 190 nations committed to achieving 17 sustainable development goals (SDGs) by 2030, which seek to promote sustainable global social and economic advancement and to enhance universal peace. Public institutions, enterprises, organizations, and people are all urged to participate in this challenge (García-Feijoo et al., 2020). Higher Education Institutions (HEIs) are pivotal for sustainable growth throughout the domains of teaching, research, outreach, and management (Bhowmik et al., 2018). Moreover, higher education institutions are tasked with ensuring that people recognize their responsible roles and equipping future professionals with the skills and abilities necessary to address the issues of sustainable development (García-Feijoo et al., 2020) hence they (HEIs) play a crucial role in accomplishing that challenge (Serafini et al., 2022).

Sustainable development encompasses a variety of dimensions as well as social and political, in the process of solving the problem. Among these, environmental sustainability is the one that is connected to the other components in both directions and people have a big role to play in creating environments that last. Interior design is a profession that supports human life within the environment and creates spaces where people may live and work. In other words, the interior environment is the first and closest area to meet human requirements (Ayalp, 2012; Andereas, 2019, Lee, 2014).

According to the extensive literature review it is seen that there is a strong relationship between sustainable development goals and interior architecture/ and environmental design. The SDGs offer a universal framework for enhancing social welfare and supporting environmental sustainability and guiding efforts to solve pressing global problems (Kayaduran M. & Koca, 2024). On the other hand, as a profession with the ability to shape living environments and meet environmental obligations, interior architecture plays an important role in advancing the SDGs and improving quality of life by defining the relationship between individuals and spaces through the use of psychological and psychological parameters (Mendler, Odell, & Lazarus, 2006; Kang & Guerin, 2009; Ayalp, 2012; Kayaduran M. & Koca, 2024). According to the distribution of publications about Sustainable Development Goals based on the research analyzing current literature at the end of the 2024, it is seen that most of the publications is about, respectively, SDG13, SDG11, SDG3, SDG12, SDG7, SDG15, SDG6, SDG2, SDG9, SDG4, SDG14 (Kayaduran M. & Koca, 2024). Through design, waste management, and material selection and recycling, interior architecture can directly contribute to these objectives (Kayaduran M. & Koca, 2024; Lee at all., 2013; Ayalp, 2012; Süzer & Yılmaz, 2010).

Sustainable interior materials; achieving zero waste

Indoor air pollution can be 2 to 5 times higher than outdoor pollution, posing serious health risks since people spend about 90% of their time indoors. Pollutants from building materials such as flooring, paints, and adhesives can affect the respiratory system, skin, eyes, and digestion. Therefore, interior designers play a key role in selecting healthy and sustainable materials to create safer indoor environments. Emphasizing the use of sustainable materials is essential not only for promoting occupant health but also for supporting long-term environmental and economic sustainability (EPA, 2013b; Nussbaumer, 2004; Szenasy, 2012; Stieg, 2006; Lee at all., 2013).

One of the most important methods for achieving sustainable interior design is through sustainable building materials. As Ayşin Sev (2009) states in her book on Sustainable Architecture, all activities aimed at creating environmentally friendly buildings that prioritize the use of renewable energy sources, efficiently utilize energy, water, materials, and the surrounding space, and protect human health and comfort, form the foundation of sustainable architecture. In sustainable material selection, the life cycle, which is based on the fundamental logic of "production, use, and disposal" shown in Figure 3, is considered. The fundamental

approach to sustainable interiors is preventing pollution in production, reducing waste volume, and increasing the number of recyclable components (Aktaş, 2013; Sev 2009).

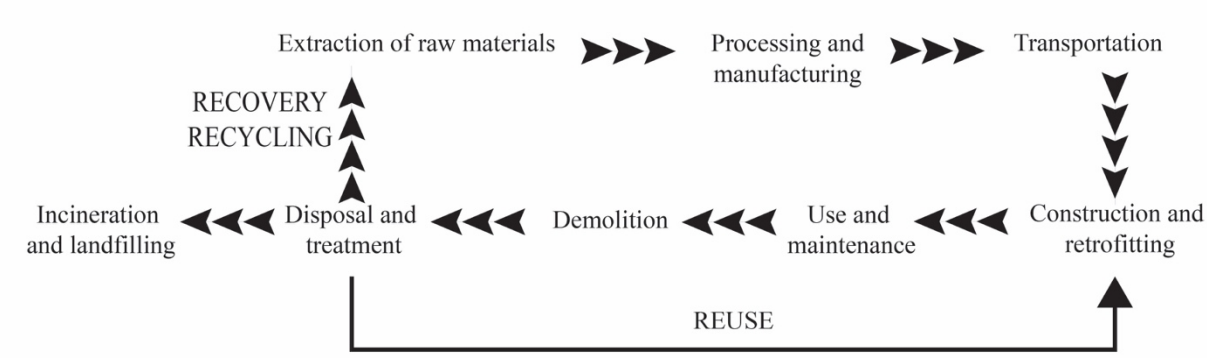

Figure 3: Stages in the life cycle of building materials (Barbhuiya &Das, 2023; Sev, 2009)

On the other hand, while recycling forms an important part and theory of building materials and sustainable material use, upcycling and the zero-waste theory are more helpful in reaching the final product. Giving a product that has become waste a new function and bringing it back into use is the most basic definition of upcycling. In theory, recycling is the process of converting waste materials into new materials and products. Upcycling, on the other hand, promotes not producing waste and re-functionalizing waste now it is produced, without it being converted back into its raw material. Mr. In fact, recycling is an industrial process. Zero waste production is a resource and waste management approach based on circularity (Zero Waste, 2025).

There are concrete examples of the zero-waste approach and upcycling, which embody the effort to create no waste, that have been implemented in many countries around the world. One of the examples is from the Urselmann Interior, a company based in Düsseldorf, renovated its own office interiors using biodegradable, recyclable, or upcycled materials (figure 4).

Figure 4: Upcycle Office designed by Urselmann, Germany (Photo: Magdelena Gruber)

The other example is the Upcycle House designed by Lendager Arkitekter in Denmark which is an experimental project, intended to highlight possible ways to reduce carbon emissions by using upcycled and recycled construction materials and in contrast to a benchmark home, Upcycle House has achieved an 86% decrease.

Figure 5: Upcycle House designed by Lendager Arkitekter, Denmark (Photo; Jesper Ray)

How SDGs guide interior architecture

SDGs are tools with applicability in every sector, addressing physical, social, and economic impacts in the design of structures aimed at sustainable development. According to UIA (2022), the built environment is a major consumer of energy and natural resources, and a producer of waste. The guidebook published by SDGs regarding architectural approaches emphasizes how effective SDG's architectural approaches are in achieving the sustainability goal. Figure 7 provides examples of projects related to the SDGs included in this guidebook. The Kvadrat Soft Cells are designed as a material to be used modularly on interior walls and ceilings, contributing to the acoustics of the space, and represent a design model that includes targets for SDG 9 – Industry, Innovation, and Infrastructure. The panels are designed for disassembly, and most components and materials can easily enter recycling streams. The example of Upcycle Studios contributes to SDG 12 – Responsible Consumption and Production. Upcycle Studios has been designed with the mission to construct a residential area using upcycled and local waste materials without compromising on aesthetics, quality, or price (UIA, 2022). As seen in this example, an interior design is created by incorporating the theory of upcycling, and its connection to SDGs is examined.

Figure 6: SDG's architectural approaches to achieve the sustainability goals (UIA, 2022)

Another important study examining the relationship between SDGs and the architecture is the guide published by RIBA (2019), which outlines the key performance metric and a set of design principles. Within this study, the main materials aimed at minimizing carbon emissions in the construction sector were created through the SDGs. These long-term goals are clear, measured, achievable, and open about the relationship between expectations and results. They stay away from long lists and extraneous details, and they consider the triple bottom line meaning of sustainability, which means balancing the value for people, the environment, and the economy (RIBA, 2019). The system, which is based on a total of 8 SDGs as shown in Figure

8, is directly or indirectly related to the use of sustainable building materials.

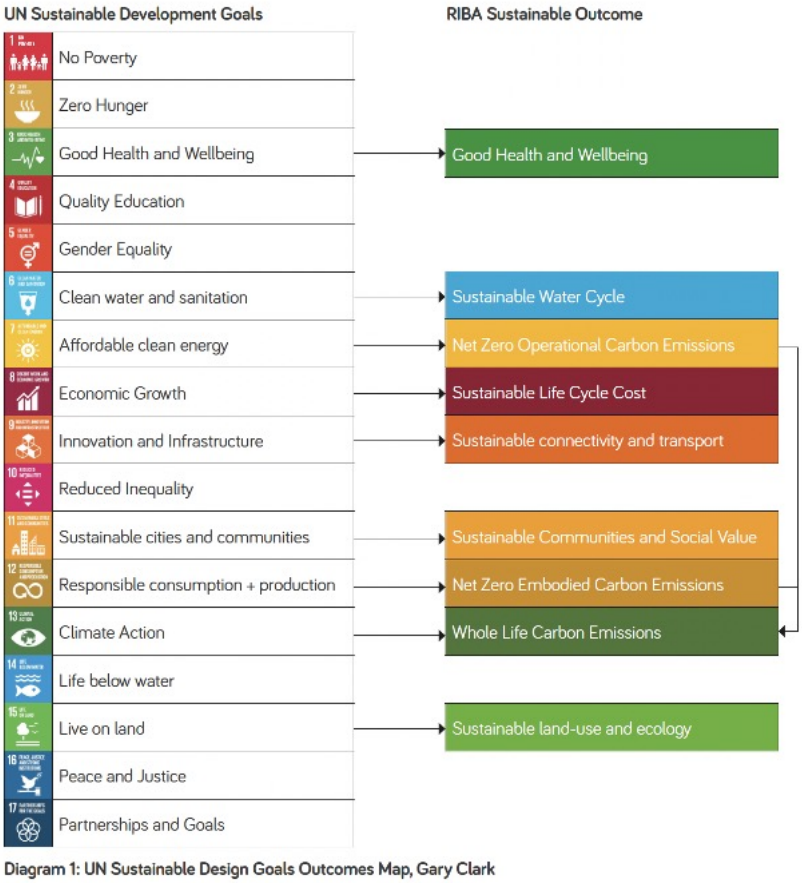

Figure 7: UN Sustainable Design Goals Outcomes Map, Gary Clark (RIBA, 2019)

Following the UIA 2023 World Congress Architects - Sustainable Futures – Leave No One Behind (UIA2023CPH), to build a strong understanding of the current state of the art in architectural research and industry efforts, an international mapping of over 100 researchers and practitioners currently working to achieve the sustainable development goals has been published. In the study, which consisted of a total of six panel titles, the second title, Design for Rethinking of Resources, was directly linked to SDG 9 and SDG 12. It includes the engineering of new materials, recycling of waste and use of bio-based materials lends the possibility to start the cycle of production sustainably (Thomsen & Miller, 2020). From these various projects and research, an example of a pavilion design contributing to SDG 12 is given in Figures 9. Consequently, the direct association of architecture with the SDGs also reveals that the built environment must be addressed. In this case, it can also be mentioned that each of the 17 SDGs

is addressed fully within the built environment, in both architectural and interior design approaches.

Figure 8: SDG's architectural approaches to achieve the sustainability goals (Thomsen & Miller, 2020)

Methods

Upcycle is the process of converting waste materials, by-products, or unwanted products into new materials or products of better quality, value, or environmental benefit. Unlike recycling, which often involves breaking down materials to their raw form, upcycling retains the original material's integrity and enhances its utility or aesthetic value. This approach not only reduces waste and consumption but also promotes sustainability by creatively repurposing existing resources, minimizing environmental impact, and fostering innovative design solutions. As a result, for the final project students are expected to find waste materials suitable for their concept using the upcycle approach and design furniture/product or material for the designated design space.

The course is designed to be completed in a total of 16 weeks and 14 hours of class time, including both theory and practice. One class was assigned for the midterm exam and one

class for the final jury. Students were expected to start thinking, designing, and developing their term dictionaries from the 2nd week onwards as their first assignment. The first 7 weeks of the course were planned and conducted for literature, terminology, and theoretical knowledge transfer, while the last 7 weeks were in the form of project critiques. The midterm exam was administered as a theoretical and literature-based written and multiple-choice test, intended to assess how well students had grasped the information before starting the final project.

Table 1: Course Schedule and Topics

Month	Week	Lectures
OCT 2023	1	Introduction course
	2	Sustainability and Sustainable Development
	3	Introduction To Sustainable Design and Climate Change
	4	Sustainable Design and Architecture: Green and Sustainable Buildings
	5	Sustainable Building Materials: Recycle and Upcycle, Zero Waste
NOV 2023	6	Sustainable Design and Awareness Raising, Sustainable Development Goals and Design Solutions
	7	Upcycle Design In Interior Architecture and Good Practises
	8	Mid-Term Exam (Theory Based)
	9	Studio Critics: Analysis of SDGs & Conceptual Ideas
DEC 2023	10	Studio Critics: Analysis of SDGs & Conceptual Ideas
	11	Studio Critics: Conceptual Ideas & Initial Design
	12	Studio Critics: Initial Design & Product/Object/Material Design
	13	Studio Critics: Product/Object/Material Design
JAN 2024	14	Studio Critics: Product/Object/Material Design & Exhibition Area
	15	Studio Critics: Product/Object/Material Design & Exhibition Area
	16	Exhibition Presentation: Product and Terminology Dictionary

Throughout the semester, students are required to develop 1 main project and 2 supporting projects within the framework of sustainable development goals. First, they are expected to conduct comprehensive research on the development goals and develop a concept based on the assigned development goal. As a result of the research, students were expected to design a glossary of terms and then prepare a poster that introduces the development goals that they are

assigned to work on. For the final project, using all the knowledge they have gained, students are expected to find waste materials suitable for their SDG concept using the upcycle approach and design furniture/product or material for the designated design spaces which are the entrance halls of the design studios and instructor's offices.

Table 2: Given HW briefs for the students

HW1 Glossary Of Terms	In addition to what you have learned in the course about Sustainability, Green Design, Sustainable Design, Climate Change, and Sustainable Development Goals, you are expected to create a glossary of terms that can be used as keywords through your own research. The design of the glossary is flexible, but it should be submitted in two stages (draft + final) in print format.
HW2 SDG Poster	You are required to create an informative/educational poster about the "Relationship Between Sustainable Development Goals and Design" based on what you have learned in the course, the provided/recommended resources, and your research. While preparing the poster, it is expected that the keywords from the individually created glossary will also be included. The development goal will be assigned to you / It will be a group project / Each group will submit one A0 poster.
HW3 Upcycle, Join The Cycle	Based on the concept developed from the Sustainable Development Goal, you are expected to design an interior material/product/object to be used in the specified spaces by utilizing the waste materials you have found. The project, which should be developed using the upcycling approach, will require you to design a poster explaining your design approaches, concept, and processes as the final outcome. The designed product will be in its real dimensions / It will be exhibited alongside the poster within the designated space for the design.

The assigned homework and submissions are shown in Table 3. The terms were studied individually in dictionaries, while HW2 and HW3 were studied as a group. Considering that students are working with climate change and Sustainable Development Goals for the first time, it is anticipated that a more efficient outcome will be achieved in groups of two.

Table 3: Assignments, timeframes, and working method for the project

	Time Schedule	Working Model	Content
HW1a	3 weeks	Individual	Glossary of Terms (Draft Submission)
HW1b	3 weeks	Individual	Glossary of Terms (Final Submission)
HW2	2 weeks	Group	Poster Design: SDGs and Design Relation (Analysis)

HW3	7 weeks	Group	Product Design + SDG Conceptual Design Poster

Not all SDGs are included in the project. The 12 SDG courses that would best align with interior and architectural design were selected by the course instructors and students chose from among these SDGs (Figure 1). Design or concept predictions related to the 12 SDGs are also shown in Table 4.

Table 4: Given SDGs, work areas, anticipated concept + design outputs

Group	SDGs	Working Area	Foreseen Outcomes
1	SDG 2	Interior Design Studio III Entrance Hall	Management of food waste, Sustainable food production and consumption, Spatial design for food production, Food storage, zero waste, upcycling methods
2	SDG 3	Interior Design Studio III Entrance Hall	Interior comfort, interior air control, spatial design for well-being, day light control, interior space materials for comfort of studio users
3	SDG 4	Interior Design Studio III Entrance Hall	Learning spaces and psychological effects, flexible and functional studio design, studio design for multiple and single users, colour usage in interior design
4	SDG 6	Interior Design Studio III Entrance Hall	Waste water management, water consumption, wastewater systems
5	SDG 7	Interior Design Studio I Entrance Hall	Lighting design, studio electricity usage, passive energy strategies, clean energy, design of openings/windows/walls/doors, zero waste, upcycling methods
6	SDG 7	Interior Design Studio I Entrance Hall	Lighting design, studio electricity usage, passive energy strategies, clean energy, design of openings/windows/walls/doors, zero waste, upcycling methods
7	SDG 8	Interior Design Studio I Entrance Hall	Comfortable studio design, safety issues in studios, ergonometric furniture, noise control systems and materials
8	SDG 11	Interior Design Studio I Entrance Hall	Interior area and outer are integration, environmental impacts, interior design and environment relation, common working areas, visual and physical communication in design
9	SDG 9	Interior Design Studio I Entrance Hall	Innovative solutions for design materials, modular design, sustainable material production
10	SDG 12	Interior Design Studio	Usage of natural sources, source management and design, circular living habitats, awareness raising in design, zero waste, upcycling methods

		I Entrance Hall	
11	SDG 14	Faculty Entrance Hall	Protection of water habitats and ecosystems, water management
12	SDG 15	Faculty Entrance Hall	Natural resources and local material usage, environmental impacts in interior design, interior landscape ideas
13	SDG 2	Faculty Entrance Hall	Management of food waste, Sustainable food production and consumption, Spatial design for food production, Food storage, zero waste, upcycling methods
14	SDG 8	Faculty Entrance Hall	Comfortable studio design, safety issues in studios, ergonometric furniture, noise control systems and materials
15	SDG 9	Faculty Entrance Hall	Innovative solutions for design materials, modular design, sustainable material production
16	SDG 15	Faculty Entrance Hall	Natural resources and local material usage, environmental impacts in interior design, interior landscape ideas
17	SDG 11	Faculty Entrance Hall	Interior area and outer are integration, environmental impacts, interior design and environment relation, common working areas, visual and physical communication in design

As part of the final project, students were asked to design products tailored to the needs of the entrance halls of 2 design studios and academic offices (Figure 9). In the project, where the integration of indoor and outdoor spaces was also requested to be examined, the indoor and outdoor connections of all three areas were questioned.

Figure 9: Designated areas for the final project

Additionally, the evaluation criteria for all desired deliverables in the process are provided in Table 4.

Table 5: HW1a, HW1b, HW2 and HW3 evaluation criterias

HW1a /HW1b Glossary terms		**HW2 SDG Analysis – Poster**		**HW3 Product or Material Design**	
Evaluation Criteria	Weight of the Grade (%)	Evaluation Criteria	Weight of the Grade (%)	Evaluation Criteria	Weight of the Grade (%)
Design	20	Poster Layout	20	SDG Number (Geometric Module Design)	10
Concept	20	Visual Design	25	Poster Design (Visually)	15
Content	50	Content	30	Poster Design (Information)	15
Colour Usage	10	Information/Thoughts	25	General Design Concept	15
				Process Management	5
				Final Product/Material	40

Findings and Discussion

Throughout the semester, a total of 33 dictionaries were produced as part of HW1, 17 posters were produced as part of HW2, and 17 posters and 17 product designs as part of HW3. All of these were exhibited and evaluated on-site as an open exhibition within the scope of the final jury (Figure 10).

Figure 10: Open exhibition as the final jury

First, 33 glossaries of terms were successfully delivered as pocketbooks within the scope of HW1, and it was observed that the information from the literature provided during the lessons and the terms researched were utilized. Common terms found in the glossary are shown in Table 6. The terms learned within the scope of the assignment, which are directly or indirectly related to sustainability, were prepared entirely based on the student's own knowledge and initiative and yielded beneficial results in terms of providing an information base for the HW2 project assignment. It has been observed that the terms included in the dictionary are not only within the scope of the interior design profession but are also general terms related to sustainability, design, and climate change. As part of the assignment, students were expected to become generally familiar with sustainability terms, and recognizing the terms was the main goal.

Table 6:Glossary of Terms; Common Terminologies used by students

Waste Management	Ecosystem	Environmental Pollution	Greenhouse Gas
Carbon Emission	Waste	Green Building	Greenhouse Gas Effect
Circular Economy	Disposure	Sustainable Building	Waste Recovery
Recycling	Environmental Sustainability	Carbon Neutral	Climate
Upcycling	Social Sustainability	Net Zero Emission	Weather Forecast
Carbon footprint	Economic Sustainability	Carbon Cycle	Climate Change
Energy Efficiency	Eco-Design	Awareness Raising	Urban Heat Island
Compost	Air Pollution	Global Warming	Green Economy
Ecology	Biophilic Design	Waste Hierarchy	Biodegradable
Zero Waste	Electronic Waste	Mycelium	Biomaterial
Building Waste	Sustainable Architecture	Green Innovation	Net Zero Carbon
Sustainable Material	Environmental Law	Sustainable Development	Fossil Fuel

Common terms used by students are only shown, and different terms are also available in submissions.

In the interior design profession, color usage and visual design are aesthetically important, so students were expected to also think about physical designs of the dictionaries. Therefore, as part of the assignment, students were expected to prepare their work paying attention to their use of color, graphics, and visuals.

Figure 11:Glossary of Terms

A total of 17 interior materials/products were also designed by the students on a one-to-one scale and placed in the exhibition areas for presentation. The outputs and concepts students obtained from the SDGs they worked on are shown in Figure12. In places where it was not possible to derive concrete concepts directly from the SDGs, it was observed that they produced concepts suitable for awareness and perception-building efforts related to the SDGs. All the inferences and concept-finding efforts made have been in perfect alignment with the SDGs and their sub-targets. Regarding SDG 2, SDG 4, and SDG 14, which are not included in the method stated in Figure 9 but were suggested to the students by the course instructor:

- SDG 2: Designs that do not perfectly align with the goal were produced. During this process, it was observed that students struggled to generate design concepts and ideas related to this SDG.

- SDG 14: Designs that do not perfectly align with the goal have emerged. During this process, it was observed that students struggled to generate design concepts and ideas related to this SDG.
- SDG 4: Easily understood by students, allowing for concept and idea extraction.

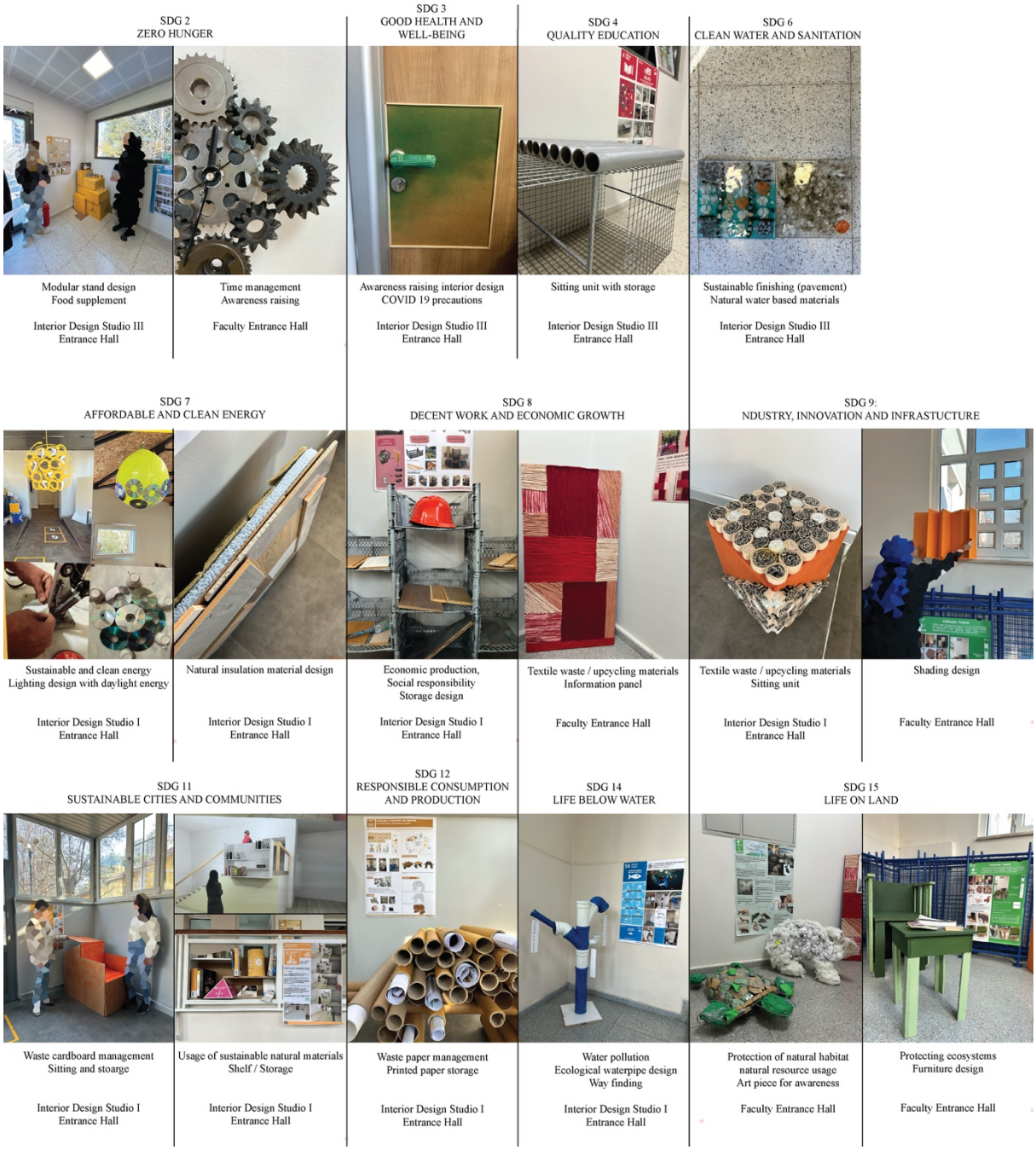

Figure 12: HW3 Final project products and concept outputs

The method used in this study, the project process, and the information gained were beneficial for students to become more familiar with the topic of sustainability and its many subtopics. The fact that SDGs were used as a reference to create the concept and design idea for the interior product to be produced has yielded positive results. The main purpose of this course is to teach students general and current terms related to sustainability, provide basic literature knowledge, demonstrate the methods of using sustainability in architectural or interior design approaches, and examine the areas of use and relationship of the SDGs with the field of architecture. The emerging terms, dictionaries, and project products have served all purposes. It is considered that students receive the most basic information within the scope of the course if they wish to specialize in sustainability fields in their professional lives.

Acknowledgments

We would like to extend our sincere thanks to all 34 of our students for their efforts throughout the course and for the valuable outcomes they have produced through their hard work. They have successfully managed the process by working devotedly throughout the semester on topics that are highly technical, theoretical, up to date, and new. The results they contributed to this academic work are highly valuable and measurable.

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BRIDGING DESIGN AND PERFORMANCE: TEACHING PASSIVE SOLAR ARCHITECTURE THROUGH SIMULATION-BASED STUDENT PROJECTS

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Bridging Design and Performance: Teaching Passive Solar Architecture through Simulation-Based Student Projects

Abstract: This paper presents the outcomes of a graduate-level design studio at Çankaya University, centred on the development of a Passive Solar Research Centre. Within the course framework, students explored passive design strategies such as Trombe walls, solar chimneys, green roofs, and photovoltaic integration, while employing simulation tools including Autodesk Forma, Ecotect Analysis, and FenestraPro. The projects combined conceptual design with quantitative performance assessments, addressing daylighting, thermal comfort, microclimate, and energy demand. Results revealed strong winter performance through effective passive heating but also highlighted the recurring challenge of summer overheating and glare, underscoring the need for adaptive shading and ventilation strategies. Beyond technical performance, students envisioned the centre as a living laboratory and educational platform, integrating social and experiential functions to raise awareness of sustainability. The collective outcomes illustrate the pedagogical value of simulation-based design education in preparing future architects to respond to climate change and energy efficiency imperatives.

Keywords: passive design; design education, building performance; building simulation

Introduction

Architectural education has undergone a profound transformation in the past two decades, shaped largely by the growing urgency of the climate crisis and the recognition that the built environment plays a decisive role in both energy consumption and carbon emissions. Increasingly, schools of architecture are expected to move beyond purely formal or aesthetic explorations and to embrace performance-oriented design, where energy efficiency, environmental sustainability, and occupant well-being are integral components of the design process. This pedagogical shift has been accelerated by the integration of digital technologies into the studio environment, which allow students not only to conceptualize but also to simulate and evaluate their projects with quantitative precision (Francis & Asmar, 2020; Hopfe,et.al. 2022; Kalpkirmaz & Voss, 2022).

Within this global context, the graduate-level courses *YTE 505/506 Building Project* at Çankaya University were designed as a unique pedagogical experiment. The course revolved around the design of a Passive Solar Research Centre, to be situated on the university campus. The guiding theme was the exploration of passive solar design principles, whereby solar energy is collected, stored, and redistributed without reliance on mechanical systems. Such an approach emphasizes the multifunctionality of building components: windows, walls, and roofs serve not only as enclosures but also as mediators of energy flow, simultaneously addressing structural, architectural, and thermal requirements.

The project brief provided to students was deliberately constrained and realistic. The design was to encompass a compact building of approximately 150 square meters, with spaces

for two to six staff members, including offices, a kitchenette, and wet areas. Students were free to propose either single-story solutions or designs incorporating mezzanine levels.

The purpose of this paper is to synthesize the outcomes of five individual student projects developed within this course, each of which approached the design of the Passive Solar Research Centre from a different angle. Collectively, these projects illustrate how emerging architects can engage with environmental data, test design hypotheses, and learn to articulate sustainability not as an afterthought but as a generative driver of architectural form and space.

The paper therefore aims to present an integrated account of the students' work, highlighting both convergences and divergences across their approaches. By analysing these projects together, it becomes possible to identify common lessons regarding the performance of passive solar systems, the interplay of daylighting and thermal comfort, the role of microclimatic and material considerations, and the value of embedding educational and social functions within sustainable architecture. In doing so, the abstract underscores the pedagogical benefits of simulation-supported design studios, showing how they can prepare future architects to confront the twin challenges of climate change mitigation and user-centred design.

Methodology

The methodology adopted in this course combined the iterative logic of the architectural design studio with the analytical rigor of simulation-based research. Students began by interpreting the project brief and site conditions, developing conceptual proposals that aligned with passive solar principles. Site orientation, topographical integration, accessibility within the campus, and functional organization were considered alongside aesthetic and symbolic gestures, resulting in diverse architectural expressions.

Once preliminary design ideas were established, students employed digital simulation tools to evaluate their proposals against environmental performance metrics. Autodesk Forma was utilized to conduct solar radiation studies, daylight potential mapping, microclimate analyses, and wind comfort evaluations. This allowed students to visualize how their buildings would interact with sun paths, prevailing winds, and seasonal climatic conditions. FenestraPro was applied in several projects to assess façade performance, focusing on glazing ratios, shading strategies, and solar loads on different orientations. Autodesk Ecotect Analysis was employed for more detailed energy modelling, including heating and cooling degree-day calculations, mean radiant temperature distributions, daylight factor simulations, and thermal comfort analyses under different seasonal scenarios.

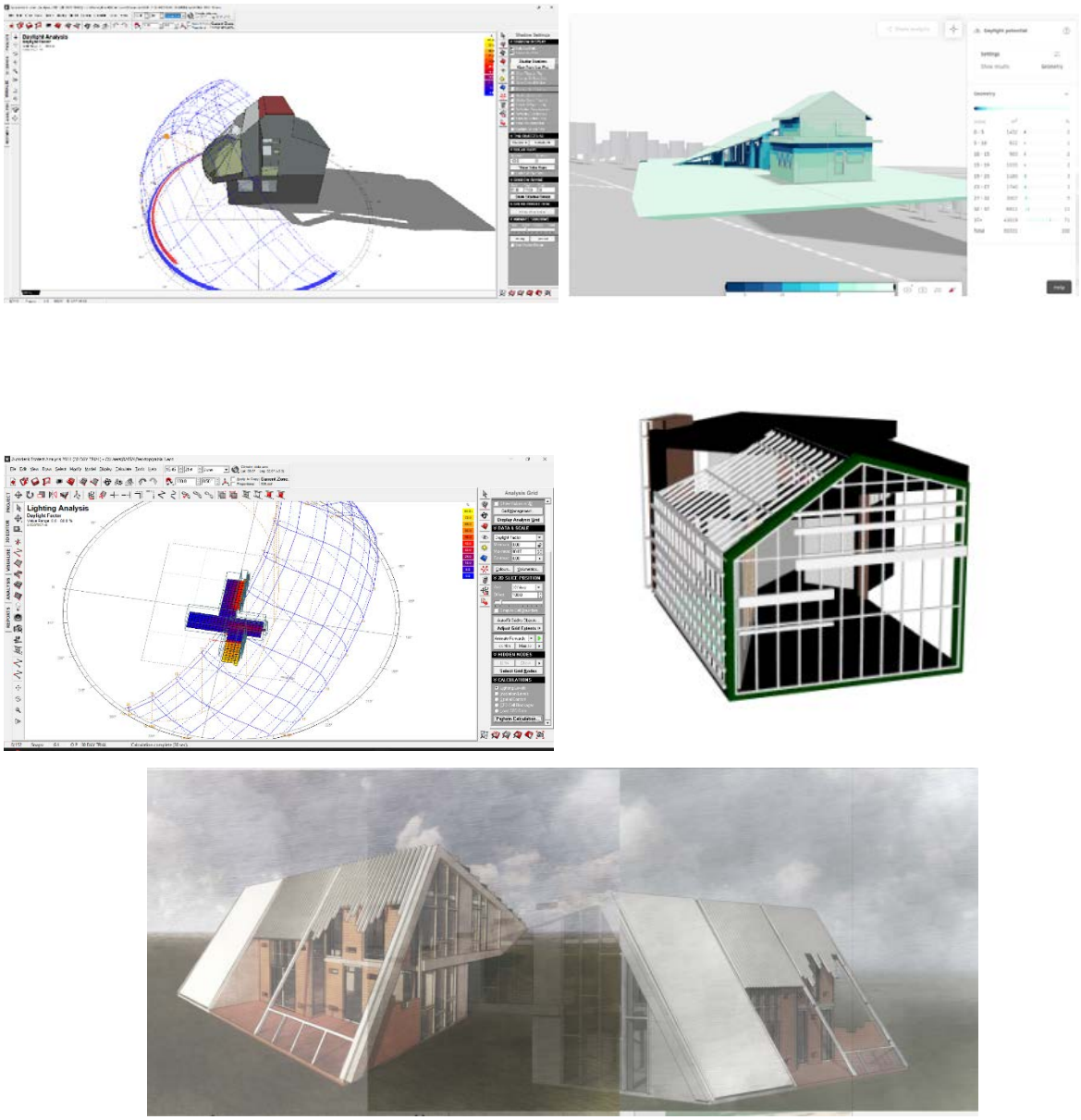

Figure 1. Examples of project models of each student.

Crucially, the methodology emphasized seasonal performance testing, with students asked to simulate building behaviour on critical dates such as 21 June (summer solstice) and 21 December (winter solstice). These dates were chosen to capture the extremes of solar exposure and thermal demand, thus allowing students to test whether their passive systems could balance summer overheating with winter heat gains. Some students also extended their analysis to spring and autumn equinoxes, thereby producing a more nuanced understanding of transitional periods.

Another important aspect of the methodology was the requirement to connect quantitative findings with qualitative reflections. Students were asked not only to report simulation results but also to interpret them in terms of architectural implications: How did daylight factor distributions affect spatial programming? How could wind comfort analyses inform landscape design? What lessons about material choice emerged from embodied carbon considerations? In this way, the projects fostered a culture of critical reflection, where data was not seen as a deterministic constraint but as a catalyst for creative problem-solving.

Finally, the methodology extended beyond technical performance to encompass the educational and social role of architecture. Students were encouraged to design their centres not merely as laboratories for passive solar research but also as public-facing facilities—spaces where peers, visitors, and the broader community could learn about sustainable design through direct experience. This pedagogical orientation reinforced the broader aim of the course: to position architecture as both a scientific and cultural endeavour, simultaneously addressing environmental imperatives and public engagement.

Findings and Discussion

A comparative review of the five student projects reveals a rich diversity of strategies, yet also a set of recurring challenges and insights that cut across all proposals.

One of the most striking aspects was the **variety of passive solar systems** integrated into the projects. One student explored the Trombe wall as a dual-purpose system: a thermal mass that absorbed and re-radiated solar heat in winter while facilitating buoyancy-driven ventilation in summer. This not only reduced reliance on mechanical systems but also created an educational feature, making the building itself a didactic tool. Another student employed a solar chimney and sunspace combination, which significantly improved natural ventilation and daylight penetration, thereby reducing HVAC loads and enhancing interior comfort. A third student prioritized the use of a green roof and an “Energy Café,” conceptualizing the building as a social space where sustainability could be experienced through both ecological and cultural practices. Others emphasized photovoltaic integration, with one project estimating an annual production of approximately 122,000 kWh—enough to offset a substantial portion of the building’s operational demand. Still others experimented with extensive glazing and inclined roof forms to maximize daylighting, though these strategies simultaneously highlighted the risks of overheating and glare.

Daylighting emerged as both a strength and a weakness across the projects. In several proposals, public and social areas achieved high daylight factors, reducing the need for artificial lighting. However, deeper spaces such as laboratories, virtual reality rooms, and cafés often suffered from inadequate daylight, necessitating artificial supplementation. Conversely, spaces with large-glazed surfaces sometimes experienced excessive brightness and potential glare, particularly during summer months, underscoring the need for dynamic shading systems. Thus, the projects collectively illustrated the delicate balance between maximizing daylight benefits and mitigating its unintended consequences.

Thermal comfort analyses reinforced this theme of balance. Across all projects, winter performance was strong: south-facing façades and glazed surfaces effectively captured low-angle sunlight, raising indoor temperatures and reducing heating demand. Yet summer performance posed significant challenges. Simulations consistently showed indoor temperatures approaching or exceeding 28°C in June scenarios, even when external temperatures remained moderate. One project's degree-day analysis quantified the imbalance: approximately 445 heating degree days contrasted with 602 cooling degree days, indicating that the cooling load was more critical than the heating load. These findings highlighted the importance of integrating passive cooling strategies—shading devices, natural ventilation, and thermal mass—to complement the passive heating strategies that worked so effectively in winter.

Microclimatic and wind analyses further enriched the discussion. Several students discovered that the prevailing north-west winds could be harnessed for natural ventilation, while others used vegetation strategically to create "wind-shadows" that improved outdoor comfort and reduced infiltration loads. In one case, comfort indices suggested that over 90 percent of outdoor areas were suitable for sitting or standing activities in May, demonstrating that carefully orchestrated landscape design could significantly enhance user experience. These insights underscored the interdependence of architecture and landscape in shaping environmental performance, and the importance of designing not only the building envelope but also its microclimatic context.

Materiality and embodied carbon considerations, though less emphasized than operational performance, also surfaced in several projects. One student explicitly addressed embodied energy by advocating for low-carbon and recyclable materials, reminding peers that sustainability must be understood in life-cycle terms rather than operational metrics alone. Another highlighted the importance of thermal envelope performance, recommending low-

emissivity glazing and low-U-value walls to reduce heating and cooling loads. These reflections enriched the projects by situating them within the broader discourse of whole-life carbon, which is increasingly recognized as essential in both professional practice and architectural education.

Perhaps the most distinctive finding, however, was the consistent emphasis on the educational and social role of the Passive Solar Research Centre. Students envisioned their buildings not merely as technical facilities but as experiential learning environments. The Trombe wall was conceived as a live demonstration of passive heating and ventilation. The Energy Café was designed as a social hub where renewable energy and sustainability could be observed in practice. Exhibition areas, research laboratories, and parametric façades were all framed as tools for raising awareness and inspiring behavioural change. This orientation reflects a growing recognition among students that architecture must not only perform sustainably but also communicate sustainability, fostering cultural transformation alongside technical efficiency.

Conclusion

The synthesis of these five projects yields several important conclusions for architectural education and practice. First, the course demonstrated the pedagogical power of simulation-based design studios. By engaging with tools such as Autodesk Forma and Ecotect Analysis, students were able to translate abstract principles of passive solar design into measurable performance outcomes. This not only deepened their technical competence but also cultivated a mindset of critical reflection, where design intuition was tested against evidence and refined accordingly.

Second, the projects underscored the technical effectiveness of passive solar systems, while also revealing their limitations. Trombe walls, solar chimneys, green roofs, and PV panels all contributed to improved energy performance and occupant comfort. Yet the universal challenge of summer overheating highlighted the necessity of integrated design strategies that balance heating and cooling, daylight and shading, aesthetics and performance. The findings remind us that sustainability is not achieved through isolated devices but through holistic systems thinking.

Third, the projects illustrated the broader contributions of architecture to education and culture. By framing the Passive Solar Research Centre as a living laboratory, students emphasized that buildings can function not only as shelters or workplaces but also as

pedagogical instruments. In this sense, the projects exemplified a vision of architecture that transcends technical efficiency to become a medium of social and cultural change.

Finally, the outcomes point to promising future directions. The integration of dynamic façades and adaptive shading systems could mitigate overheating while preserving daylight benefits. The incorporation of embodied carbon analyses alongside operational energy simulations could ensure more comprehensive sustainability assessments. Occupant-centric evaluations—surveys, post-occupancy studies, and behavioural simulations—could further align design intentions with lived experiences.

In conclusion, the extended abstract presented here synthesizes five student projects that collectively embody the evolving paradigm of architectural education. They show that when design studios embrace simulation-based learning and sustainability as central themes, students are empowered to produce architecture that is not only environmentally responsible but also socially meaningful. The Passive Solar Research Centre projects thus serve as both technical explorations and cultural statements, demonstrating how the next generation of architects can contribute to a low-carbon, climate-adaptive, and socially engaged built environment.

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COMMUNITY ENGAGEMENT AND CO-DESIGN PROCESSES FOR SUSTAINABLE URBAN REGENERATION. THE UTOPIZE HORIZON EUROPE PROJECT.

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Community Engagement and Co-Design Processes for Sustainable Urban Regeneration. The Utopize Horizon Europe Project

Abstract: This paper illustrates the objectives, methodological framework and expected results of the European Project *Utopize – Urban Transformation through Open Participation and Inclusivity for citiZen Empowerment*, funded under the Horizon Europe programme. The project promotes new models of collaborative, participatory and regenerative urban governance, geared towards the sustainable transformation of public spaces, in line with the principles of the New European Bauhaus. Through a transdisciplinary and phased approach, *Utopize* integrates nature-based solutions, digital technologies and co-design practices, with the aim of strengthening the active role of local communities in decision-making processes. The paper focuses on the pilot case study of the Ponte Lambro neighbourhood in Milan (Italy), on of the pilot projects of *Utopize*, a peripheral urban area characterised by environmental and social challenges, but at the same time endowed with untapped potential. *Utopize* aims to generate concrete impacts in terms of social inclusion, quality of public space and resilience, developing a replicable model of participatory urban regeneration in European contexts.

Keywords: community engagement; co-design; public space design; New European Bauhaus; digital technologies

Introduction

Addressing climate change necessitates profound structural shifts in both lifestyles and resource management. The urgency of this challenge has brought it to the forefront of political agendas across all levels of governance (IPCC, 2023).

In response to this emergency, the European Union has set itself the goal of achieving climate neutrality by 2050 and is moving towards this goal by committing, on the one hand, to reducing greenhouse gas (GHG) emissions by at least 55% by 2030 and, on the other, to increasing the climate resilience of its territories. In this regard, the European Green Deal[1] has been defined, with related initiatives (Kılkış et al., 2024). Among these, the New European Bauhaus (NEB), active since 2021, connects the domains of science, technology, art and culture with the aim of creating sustainable, inclusive and attractive living spaces. The built environment is responsible for 40% of the EU's energy consumption and 36% of greenhouse gas emissions[2], so it is necessary to focus research and experimentation on innovative, circular and regenerative approaches to building production and urban development .

While buildings constitute a major source of habitat degradation, environmental pollution, and resource depletion, advancements in the construction sector remain

[1] For further information: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

[2] See national data on air pollutant emissions for 2005-2021 available at: https://www.eea.europa.eu/data-and-maps/dashboards/necd-directive-data-viewer-7.

comparatively slow, economically burdensome, and constrained in their capacity to optimise adopted technical solutions. (EC-JRC, 2016).

Innovative approaches to urban transformation are therefore essential to enable progress towards sustainability. However, their effectiveness depends primarily on reconfiguring governance models (Mussinelli, 2023). Traditional hierarchical governance models, which are no longer effective, are gradually evolving towards decentralised, inclusive, transparent models that respond to citizens' needs. This cultural and structural change reflects a more general shift in society, driven by digital technology, demographic change and social and political instability.

The importance of incorporating citizen engagement, foresight and design thinking into governance models is also highlighted in the *Future of Government 2030+* report as a condition for redefining the relationship between citizens and the public administration, strengthening the democratic legitimacy of governments and mutual trust (Vesnic Alujevic, et al., 2019). However, this change is complex to implement due to the complexity of social issues and disparities in citizens' skills. Possible answers come from collaborative governance, which allows the strengths of the public, private and civil society sectors to be combined to improve the quality of services through community-led solutions with immediate and tangible impacts.

This is the context for the *Utopize* project – *Urban Transformation through Open Participation and Inclusivity for citiZen Empowerment*[3], which this contribution presents, explaining its objectives, methodological aspects and expected results.

The project was funded by the European Commission in September 2024 as part of the Horizon Europe programme "New governance models for the co-design and co-construction of public spaces in neighbourhoods by communities (Horizon-Miss-2024-Neb-01-02)" and aims to rebuild the community's relationship with public spaces and the natural environment, promoting social cohesion and improving the sustainability of neighbourhoods. Within the broad partnership, for Italy, the Municipality of Milan and the Politecnico di Milano are following the project trial in the Ponte Lambro pilot neighbourhood, in the south-east of the Lombard capital, in a marginal urban context with problems of environmental and social degradation and serious issues regarding connections with the city centre[4] .

[3] *Utopize* is coordinated by Cim Região de Coimbra, in collaboration with Coimbra University, Politecnico di Milano, Örebro University, Aalto University, Municipality of Penacova, Municipality of Milan, Municipality of Karlskoga, Consultancy company Volcano, Zentrum für Soziale Innovation, European Association for Innovation in Local Development, Inova+, InnCrease.

[4] The other *Utopize* pilot neighbourhoods are Karlskoga in the Bergslagen region of Sweden and Penacova in Portugal.

Cultural background

The *Utopize* project stems from European policies to strengthen collaborative and participatory governance models and tools in response to contemporary emergencies and challenges, particularly in the fight against climate change.

The project proposes Utopia Labs, where citizens actively co-design public spaces, promoting inclusion, cultural identity and innovation to encourage individual and collective responsibility for local change.

In particular, *Utopize* aligns with the objectives and definitions set out by the NEB, which conceptualises governance as a multidimensional framework, distinguishing among the following components: "collaborative governance", which promotes cross-sector partnerships to co-create public policies; "participatory governance", which allows citizens to engage directly in decision-making processes; "regenerative governance", which aims to restore and improve social and environmental systems; "decentralised governance", which allows local communities to lead projects tailored to their specific needs; "smart governance", which integrates digital technologies to optimise resource use and improve transparency. In the vision expressed by the NEB, it is only by integrating these different components of governance that quality spaces can be designed, both in urban and rural areas. Moreover, this vision is also fully in line with the European principle of subsidiarity[5] .

Utopize also draws on the results of other European research projects to build a comprehensive picture of existing knowledge and contribute to a broader understanding of the role that public spaces play in fostering social relations within communities. In particular, *Utopize* collaborates with actions funded under the Horizon Europe programme that focus on the revitalisation of local communities, bio-based business models, social innovation, NEB tools and innovative governance models[6] .

The interim and final results of *Utopize*, which will conclude in 2028, will be shared in the New European Bauhaus hub.

Methods

The *Utopize* project aims to provide tools for designing sustainable, inclusive and attractive public spaces. The proposed design approach is gradual and structured in phases of

[5] See: https://www.europarl.europa.eu/factsheets/en/sheet/7/the-principle-of-subsidiarity.

[6] In particular: Horizon-CL2-2022-Democracy, Horizon-CL6-2021- Governance, Horizon-CL5-2021-D4, Horizon-CL4-2021-Resilience, Horizon-CL4-2023-Human, Horizon-Miss-2021-Cit, Horizon-Miss-2021-NEB, Horizon-Miss-2021-Clima and Horizon-CL5-2024-D4.

progressive deepening: identification (recognition of key challenges, information gathering and identification of potential solutions), exploration (testing of engagement models in real contexts, iterative refinement), refinement (formalisation of successful strategies and methodologies, consolidation of results and translation into actionable recommendations). This will enable the definition of robust, scalable and effective governance models.

Participation is a cross-cutting theme throughout all project phases, understood as strengthening the sense of belonging to the place and the commitment of each member of the community, as individuals and as a group, to the care of their neighbourhood. In particular, *Utopize* stimulates and strengthens participation through the organisation of workshops and training and local activation events, collective site visits, explorations and interpretations of the landscape[7] , and the provision of interactive co-design platforms for citizens.

The physical transformations implemented by *Utopize* are focused on sustainability, understood in its broadest sense, and on interdisciplinarity. From an environmental standpoint, the project develops solutions that systematically integrate nature-based strategies (NBS) with the utilization of regenerated materials, aiming to design public spaces that achieve zero-emission performance (Bologna et alii, 2020). From a social perspective, *Utopize* also involves marginalised communities in the co-creation of sustainable public spaces, ensuring that the benefits of the transformations are shared equally within the community. From an economic perspective, the design strategies favour the use or reuse of locally sourced materials, promoting local know-how, traditions, craftsmanship and culture.

Utopize takes a transdisciplinary approach, bringing together experts in architecture, engineering, design, social sciences, environmental studies and local cultural organisations. This cross-sector collaboration ensures that the solutions are scientifically sound, culturally relevant and tailored to the specific needs of each context. By combining practical experience with scientific and technical knowledge, *Utopize* facilitates peer learning processes and strengthens the bonds between people, places and nature to create resilient and innovative solutions for the efficient management of territories and communities.

The design model developed with *Utopize* is currently undergoing an initial phase of application testing and evaluation of results in three different demonstration neighbourhoods, in urban (Ponte Lambro in Milan, Italy), peri-urban (Karlskoga in the Bergslagen region of Sweden) and rural (Penacova in Portugal) contexts. The results of the trials, which are currently

[7] These participatory tools have also been borrowed from the experience of ecomuseums (Riva et al., 2022).

underway, will provide guidance on the scalability and replicability of the participatory model in other neighbourhoods, allowing for any necessary adjustments to be made.

From an operational point of view, *Utopize* has been broken down into specific objectives, which in turn have made it possible to divide the project into work packages, tasks and actions, listed below:

- Studying and refining models and methodologies for involvement and participation in the co-design and transformation of public spaces.

  Within the Utopia Labs, local communities are initially activated through meetings aimed at gathering needs and aspirations for the development of neighbourhood public spaces. At the same time, a detailed study of existing engagement models is conducted to ensure that they are adapted to the socio-economic and contextual characteristics of each demonstration neighbourhood. In a subsequent phase, advanced technologies are made available to the collaborating communities to visualise and model the future development of the neighbourhoods. In particular, reference is made to digital tools such as Extended Reality (XR), including Augmented Reality (AR) and Virtual Reality (VR), with interactive web access. These tools transfer content from specific technical systems such as Geographic Information Systems (GIS), Digital Twins and 3D BIM-NBS libraries, encouraging citizen involvement and offering immersive platforms for urban planning and design.
- Pilot and refine selected engagement models to promote social cohesion, trust, community belonging and skills development.

  To engage and empower local communities, training workshops with a limited number of participants are promoted (digital literacy, social innovation and inclusive decision-making), as well as design sessions, coordination and online mentoring by experts on funding and exchange programmes. Following this training phase, larger local activation and co-design events are promoted. These events are aimed at refining project ideas. In this phase, the demonstration neighbourhoods also establish twinning arrangements with other areas to verify the actual replicability of the model and create a solidarity network of communities dedicated to sustainable and lasting urban transformation.
- Assessing the impact of the *Utopize* project on community engagement, inclusiveness, sustainability and the quality of public spaces

A framework for evaluating preliminary results and impacts is implemented as part of the project. This evaluation framework requires that data collection and interpretation be conducted extensively by citizens involved in the *Utopize* project and communicated to the community and local stakeholders, as well as published in specialised journals to inform future urban planning projects and influence broader policy discussions on urban development.

- Disseminating project results to maximise impact.

  The results of *Utopize* will be communicated through a comprehensive dissemination strategy, including academic papers, the drafting of a white paper, dissemination on social media and a dedicated website, and presentations to the public and policy makers. This phase also involves collaboration with the NEB hub to share and compare good practices and experiences in other contexts.

- Ensure efficient and effective project management.

  Through exchanges between partners and the organisation of meetings, *Utopize* is constantly monitored in terms of its timetable, budget and the achievement of shared objectives.

Findings and Discussion

Trials in the demonstration neighbourhoods were officially launched in June 2025. The Municipality of Milan, with scientific support from the Politecnico di Milano, is particularly involved in monitoring the development of project activities in the Ponte Lambro demonstration neighbourhood.

Ponte Lambro is located on the eastern border of the municipality of Milan. It is a rural settlement that underwent significant development in the second half of the 20th century with the construction of several residential buildings, mainly public. The surrounding conditions limit Ponte Lambro's integration with neighbouring districts due to the presence of significant physical barriers (the Tangenziale Est ring road, the railway, the Lambro river, Linate airport and the Paullese provincial road). Ponte Lambro is therefore an enclave that is difficult to access.

On the other hand, this condition has preserved a natural environment worthy of protection and enhancement. However, in recent years, the Lambro river, which runs alongside the neighbourhood, has become a critical issue due to frequent flooding and unresolved

hydraulic problems, as well as the progressive deterioration of water quality and the landscape along its banks.

Over the years, there have been several programmes and projects for the redevelopment and regeneration of the neighbourhood, with building and energy renovation works, but also initiatives to reclaim public spaces and promote social development. However, the results achieved have been limited to improvements at the building level without producing significant urban and social benefits. The most ambitious programmes have mostly remained unimplemented or have been significantly scaled back due to the lack of public funding. There has been a lack of clear public leadership and effective involvement of the community and local stakeholders (Riva, 2023).

Today, the Ponte Lambro neighbourhood is facing problems related to the presence of abandoned "non-places", which have been stripped of their identity and effectively removed from public use. However, several opportunities are emerging, linked, for example, to the completion of the PalaItalia for the 2026 Milan-Cortina Winter Olympics in the nearby Santa Giulia neighbourhood, which will see the construction of a pedestrian walkway connecting Ponte Lambro, as well as other initiatives by the Municipality of Milan with the Housing Department for the redevelopment of existing heritage. The solutions proposed are mostly contingent, linked to funding opportunities, while the citizens are calling for structural solutions that respond to the environmental emergency but at the same time increase the usability of the area and the quality of public spaces.

This is the context for the *Utopize* project, which aims to rebuild the community's relationship with public spaces and the natural environment as a prerequisite for curbing abandonment, vandalism and degradation. For Ponte Lambro in particular, *Utopize* will define a "toolbox" for the implementation of the Milan City Council's Air and Climate Plan, with the aim of achieving carbon neutrality by 2050 (Riva, 2025).

The projects proposed for Ponte Lambro are located in three areas considered strategic for improving the environmental and social quality of the neighbourhood. These are a large agricultural area owned by the municipality on the western edge of the town, a green area to the south of the neighbourhood intended to accommodate a hydraulic regulation structure, and an urban park near a problematic public housing complex built in the 1970s.

For the first two areas, discussions with the community are focusing on urban forestry measures and the creation of reservoirs for sustainable water management and to combat the intense weather events caused by climate change.

For the urban park, the idea under discussion is to enhance public services and improve accessibility and usability.

The design of these areas is also being carried out with the support of Extended Reality tools, as well as specific training programmes to consolidate activities already underway in the context. As part of the participation process, the creation of a collaboration agreement will also be proposed, to supplement the existing civic agreement on water quality monitoring, to enable citizens to promote community initiatives and manage the areas through events, educational workshops and art installations.

Utopize revives the idea of the UNESCO Neighbourhood Laboratory, provocatively promoted in the early 2000s by Renzo Piano. The Ponte Lambro Utopia Lab will therefore be a place where citizens can co-design and co-implement local interventions, as well as serving as a historical memory of the area, reflecting on the failures of past public interventions in order to promote a new collective vision for the neighbourhood.

In essence*, Utopize* is moving in the direction of activating stable forms of participation, both in terms of collaboration between the internal skills of the Municipality of Milan and in terms of the involvement of local actors, in order to build a shared vision of local development towards which projects, interventions and skills can converge in a unified manner.

Conclusion

Ponte Lambro is an emblematic neighbourhood in the Milan metropolitan area, where suburban management problems are exacerbated by environmental and infrastructural issues that relegate the neighbourhood to an enclave that is physically and functionally separated from the rest of the city. On the other hand, Ponte Lambro is a strategic resource for the development of the metropolitan city due to its environmental and cultural value. The *Utopize* project transforms it into a laboratory for experimenting with a different model of urban suburb management, focused on participation, care for common goods, the co-creation of new values and quality of life.

At a critical stage in the governance of the city of Milan, with the revision of the Territorial Government Plan (PGT) currently underway, the *Utopize* experiments could be an opportunity for a concrete revival of urban planning on a large inter-municipal scale, starting from the needs of local communities, with solutions that are tailored to those needs and are effective, sustainable and inclusive. This approach also brings citizens closer to local government bodies, increasing mutual trust and collaboration.

More generally, based on the results of ongoing experiments in Sweden and Portugal, the *Utopize* project will offer tools to increase social integration and incorporate community-led solutions into the fabric of public decision-making processes. Utopia Labs allow for the testing, on a local scale with reduced complexity, of collaborative governance models that can then be usefully scaled up and transferred to the urban and wider area. They also make it possible to verify the impact of co-design and co s in the management of public spaces, as a pivot around which to promote widespread, effective and long-lasting urban regeneration interventions.

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WATER SUSTAINABILITY

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MULTI-SCALE APPROACH TO INTEGRATED WATER RESOURCE MANAGEMENT FOR ARCHITECTURAL AND URBAN RESILIENCE IN THE EUROPEAN CONTEXT

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Multi-Scale Approach to Integrated Water Resource Management for Architectural and Urban Resilience in the European Context

Abstract: Climate change is causing increasingly intense and frequent extreme water-related events, making it necessary to adopt architectural and urban measures capable of increasing the resilience of cities. This contribution aims to demonstrate how integrated rainwater management can be implemented through multi-scale approaches, each involving the adoption of recurring architectural strategies. To this purpose, based on the analysis of recurring design practices, a matrix of general objectives, specific objectives and architectural macro-strategies is developed. This matrix is used to analyse a set of representative case studies in the European context, divided into three application scales: district/neighbourhood, site and building. The paper illustrates in detail three projects representative of each application scale, allowing to understand how architectural strategies recur according to the multiscale nature of the intervention.

Keywords: integrated water management; resilient design; multi-scale approach

Introduction

In the light of the global climate crisis, sustainable and conscious water management plays a strategic role in increasing urban resilience to extreme weather events such as flooding and drought. The main water-related issues related to climate change are concentrated in urban areas and can essentially be traced back to two central challenges: the qualitative and quantitative management of large volumes of water generated by increasingly violent and frequent extreme weather events (IPCC, 2023), exacerbated by high soil sealing and outdated sewerage systems (Gawlik et al., 2017); the widespread scarcity of water resources, due to increased demand, overexploitation or poor management (Un-Water, 2024), further amplified by future scenarios of prolonged drought (IPCC, 2023).

These criticalities worsen in climatic regions most vulnerable, like the Mediterranean hotspot, where the increase in extreme precipitation and flash floods (Llasat et al., 2016) is associated with a paradoxical progressive process of drying (Hertig & Tramblay, 2017). These conditions amplify the risks for cities, making it essential to implement measures to adapt to extreme events, while ensuring the conservation and protection of water resources.

Mitigation and adaptation strategies have entered European policies long before the Green Deal, which however set more ambitious targets (European Commission, 2019). With the new European Adaptation Strategy, climate neutrality is supplemented by the goal of climate resilience by 2050, making the drafting of national adaptation plans a formal commitment for Member States (European Commission, 2021). Despite the progress made at European level, climate adaptation is still struggling to be effectively integrated into national

action plans: in 2022, 82% of plans focus exclusively on mitigation (Triollet et al., 2022). This highlights the urgent need to promote a systemic and integrated vision of climate resilience. Sustainable water management is of key importance, supported by multi-scale design approaches for the adoption of synergistic strategies tailored to specific local conditions.

Objectives

This contribution aims to demonstrate how sustainable water resource management methods can be incorporated into design practices at multiple scales, highlighting how each application scale involves specific recurring architectural strategies. The analysis and synthesis of design experiences reveal three macro-strategies for integrated water resource management:

- source control, consisting of measures to prevent and reduce water runoff and potential pollution, limit consumption and improve local environmental quality;
- water diversion, which involves conveying water to water bodies, downstream Sustainable urban Drainage Systems (SuDS) or public sewers, providing benefits in terms of speed and flow reduction and potential integration of purification functions;
- water reception, consisting of accommodating water inside or close to flood-proof structures designed to contain it, reducing flood risks.

In order to understand how the three macro-strategies recur in relation to the multiscale nature of the intervention, a matrix of priority objectives and specific sub-objectives related to the three architectural strategies is developed. Each of the three priority objectives is divided into 12 specific sub-objectives, which can be implemented through one or more architectural macro-strategies (Fig. 1). This matrix is applied to analyse a set of case studies selected from the international scene, particularly in Europe, as examples of best practice in sustainable and integrated urban stormwater management. Each project is contextualised climatically and classified according to three scales of application: district/neighbourhood, site (including open spaces on a plot such as squares or courtyards) or building.

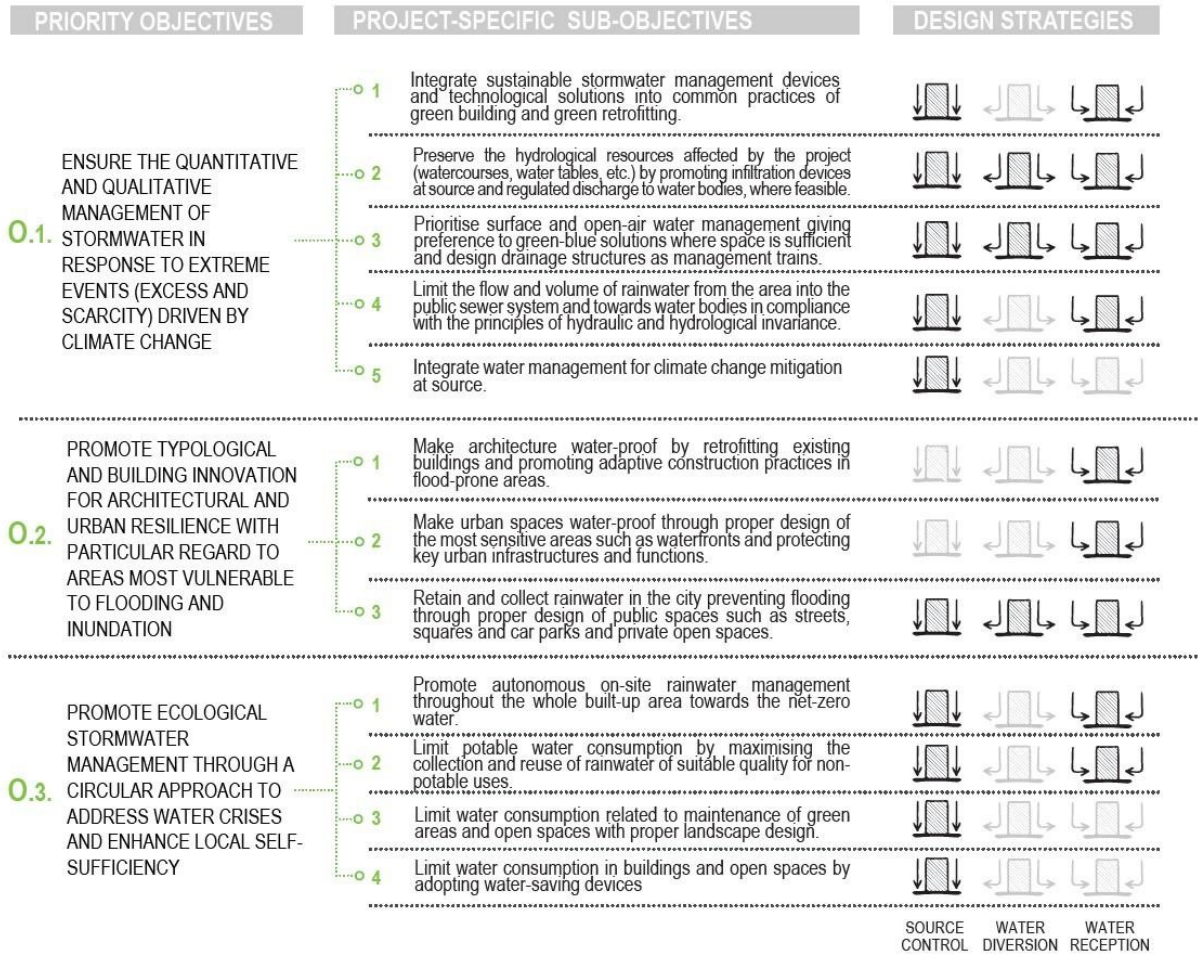

Figure 1. Matrix of priority objectives, project-specific sub-objectives and design strategies for integrated rainwater management (© the Authors [LMG]).

The paper illustrates the methodological process of case studies selection and describes in detail three representative projects for each application scale. The analysis and comparison of the three case studies allows for critical considerations on architectural strategies related to project objectives and application scales.

Methodological process of case studies selection

Starting from an initial list of 50 global case studies, chosen for their effectiveness in innovative and sustainable urban stormwater management, the selection is based on two main criteria: scale and technological component. Urban and regional scale projects and high-tech projects difficult to apply in ordinary contexts are excluded. From the remaining 37 projects, similar ones or those lacking adequate documentation are eliminated, resulting in a final selection of 17 case studies, all located in Europe and completed or nearing completion (Fig. 2). These projects provide replicable examples in ex-temperate climates such as the

Mediterranean hotspot, focusing on regeneration in consolidated urban areas predominantly residential, mostly completed, tested and monitored over time.

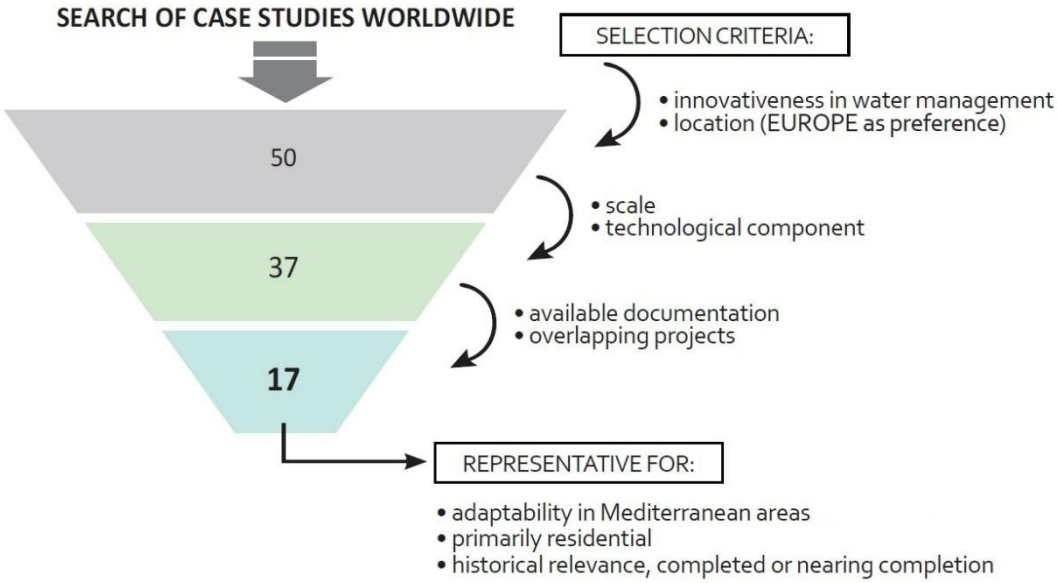

Figure 2. Case studies selection process and criteria used to identify the 17 representative projects (© the Authors [LMG]).

The decision to focus on Europe, already included in the initial selection phase, aligns with EU regulatory and policy framework, providing replicable design strategies towards the 2050 climate resilience European goal.

Among the 17 case studies, three projects with different typological characteristics are selected, representative of the three different application scales:

(1) Ekostaden Augustenbor, Malmö, Sweden (district/neighbourhood);

(2) Clarenhof, Mechelen, Belgium (site);

(3) Nuremberg Prisma, Nuremberg, Germany (building).

Case studies analysis

The three selected case studies (Fig. 3) provide a multi-scale overview of the architectural strategies that can be applied within the design process for integrated and sustainable stormwater management (Fig. 4).

Figure 3. The three case studies analysed. From left: Ekostaden Augustenbor (© Jorchr, via Wikimedia Commons); Clarenhof (© Enidanc, via Flickr); Nuremberg Prisma (© Aarp65, via Wikimedia Commons).

The Augustenborg neighbourhood in Malmö has faced decades of flooding due to an outdated combined sewer system. Heavy rains damaged basements, garages and infrastructure, and untreated sewage overflowed into waterways due to overwhelmed treatment plants.

Climate projections indicate winter rainfall may rise by 50 mm by 2080, worsening flood risks.

The Ekostaden Augustenborg project, launched in the 1990s, introduces a new paradigm of sustainable urban drainage based on three principles: infiltration, detention and slow transport. The solutions implemented include over 6 km of open channels and ditches, 10 retention ponds and 30 green roofs, covering a total of 2,100 m². The 9,500 m² Botanical Roof Garden is the largest in Scandinavia and features extensive and intensive green roofs, including experimental ones. Green roofs retain about 50% of annual rainfall, reducing peak flows and contributing to an overall reduction in runoff of 20% through evapotranspiration (Kazmierczak & Carter, 2010).

The stormwater management system is divided into three sections, each with different design approaches (Månsson et al., 2021). In the southern area, the first to be built, the system follows a strongly architectural design inspired by the 1950s consisting of visible gutters, concrete channels and ornamental ponds. The system is designed to handle events with a 25year return period. In the northern area, a more naturalistic approach is adopted, involving swales, vegetated ponds and hidden gullies connected directly to the gutters. The system is sized for ten-year rainfall events, with a greener and less formal aesthetic. Finally, along Augustenborgsgatan, a separate system is built consisting of a conventional underground pipe, made necessary for topographical reasons. This diverts rainwater directly to the urban canals, relieving pressure on the main sewer network.

Thanks to its integrated system, Ekostaden Augustemborg now handles 90% of rainwater from impervious surfaces locally using open-air solutions, almost completely relieving the combined sewer system, which carries nearly exclusively wastewater. The system

has proven to be remarkably effective over time: since its completion, there have been no further floods, even during the exceptional rainfall event of 2007, classified as a fifty-year rainfall, which severely affected other parts of the city (Kazmierczak & Carter, 2010). In addition to hydraulic improvements, the project has brought environmental, social and aesthetic benefits, increasing biodiversity and creating enjoyable public spaces, making Augustenborg one of the finest examples of urban resilience to date.

The Clarenhof project redevelops a decayed parking block in the centre of Mechelen into a multifunctional complex of 64 apartments, 32 dwellings, two commercial units, and underground parking (WIT architecten, n.d.). Built around a semi-public water garden, it is characterised by the reopening of the historic "Vliet" watercourse, a key infrastructure for sustainable rainwater management.

Within the courtyard, public and private paths define topography and space. The surfaces vary in permeability, gradually becoming more permeable and vegetated as they approach the Vliet. Rainwater is collected via channels and overflow systems and conveyed into the watercourse, while the private gardens promote infiltration and aquifer recharge.

The project uses three main water management systems: rainwater reuse, buffering, and water-saving measures (Dudek, 2012). Each home is equipped with a 3,000-litre cistern that collects rainwater from the roofs; this is connected to a unit that allows the water to be reused for toilets, washing machines, irrigation and car washing. In drought conditions, an integrated buffer volume is filled with drinking water to ensure continuity of use. In the apartments, reuse is limited to shared areas (i.e. garden irrigation, taps in the car park and supply for commercial activities). Buffering occurs via the cisterns of individual homes, which overflows into the city drainage system, and through the Vliet, which receives the excess water from the collective cisterns of the apartments and the green areas, including green roofs, and overflows in the separate city rainwater-sewer. Green roofs also act partly as buffers, retaining and slowing down runoff. Water-saving measures include: dual-flush toilets (6-9 litres for solid waste, 3-4.5 litres for liquids) that allow an average saving of 40,000 litres of water per family per year; lowflow shower heads and aerators reducing water and energy by 40%; hot water recirculation systems to minimise waste; thermostatic taps and efficient mixers that optimise water flow and temperature.

The sustainable management system adopted significantly reduces the pressure on the sewerage network, preserves water resources and improves environmental quality.

Figure 4. Multi-scale stormwater management in the case studies analysed. From left: Ekostaden Augustenbor (Mottaghi et al., 2021); Clarenhof (Dudek, 2012); Nuremberg Prisma (Corfone, 2012).

Located in the centre of Nuremberg, the Prisma project consists of two buildings arranged at an angle on a completely sealed 6,000 m² site. The buildings have mixed functions: commercial spaces on the ground floor, offices on the middle floors and duplex apartments on the upper floors. A glass greenhouse connects the blocks above underground parking. The project is built to passive house standards, ensuring high energy efficiency (sdg21, 2016).

The project focuses on completely on-site rainwater management. All rainwater collected from roofs and tanks on the fifth-floor flows into a 240 m³ underground cistern, after being filtered through purification biotopes (Hoyer et al., 2011). From here, the water feeds two circuits: one irrigates the tropical plants in the greenhouse and a 100-metre watercourse; the other activates a natural air conditioning system consisting of five coloured glass water walls. In summer, falling water draws hot air down, cooling the environment; in winter, the same water – kept at 18°C – preheats incoming air (Dreiseitl & Grau, 2009). Before installation, simulations assessed the effectiveness of the natural air conditioning, with results later confirmed in practice. In summer, plants and water walls reduce the internal temperature by up to 3°C. Night ventilation and greenhouse openings double airflow, further lowering the internal temperature (sdg21, 2016).

Collected rainwater is reused for multiple purposes: in addition to irrigation and natural air conditioning, it supplies fire-fighting systems and a series of open-air elements – such as indoor and outdoor pools, water walls and water features – which contribute to the spatial and sensory quality of the environment. Surplus water is stored in a 50 m³ gravel layer below the parking. Here, thanks to the permeability of the sandy soil and the depth of the water table, water can naturally infiltrate the subsoil (sdg21, 2016).

Fully independent from the public sewer network, the system improves evaporation, infiltration, temperature, and humidity. Designed to handle ten-year return period rainfalls, Nuremberg Prisma adapts to even to more intense rainfalls, thanks to its multiple integrated components that are still efficient and well maintained today (Hoyer et al., 2011).

Discussion and conclusions

The three case studies, critically analysed and compared via the matrix developed, show how source control, water diversion and water reception strategies can be applied in a synergistic and multi-scale approach (Tab. 1).

Table 1. Presence of the three architectural strategies in the case studies analysed referring to their application scales.

	District/ neighbourhood	*Site*	*Building*
	Augustenborg, Malmö, Sweden	**Clarenhof, Mechelen, Belgium**	**Nuremberg Prisma, Nuremberg, Germany**
S1. Source control	○	●	●
S2. Water diversion	●	○	-
S3. Water reception	○	-	-

Notes. (●) identifies the main strategy; (○) identifies any complementary strategies; (-) means that the strategy is not implemented

At the end of the process, project-specific summary sheets have been developed. Each sheet is divided into two main sections: the first section classifies projects by scale of application and summarises key information, including geographical location and project details; the second section analyses the case studies according to the reference matrix, specifying the project inputs, the main objectives pursued, and the strategies adopted. Where multiple strategies are present, the main strategy is identified, followed by one or both complementary strategies.

It is interesting to note that, based on the project objectives, the three macro-strategies act synergistically the greater the scale of intervention. This depends directly on the higher spatial articulation and on the technical features of the solutions adopted. In Augustenborg (Fig. 5), water diversion emerges as the driving strategy: a dense network of swales and open drains conveys water away from critical areas, mitigating peak flows. At a complementary level, source control is provided by permeable surfaces, while water reception occurs in basins and floodable areas. This synergy makes the neighbourhood a pioneer in high resilience standards. The Clarenhof complex (Fig. 6) integrates widespread on-site measures for soil unsealing,

rainwater recovery and water saving, with source control as its main strategy, supported by water diversion, resulting in controlled transport toward and through the Vilet itself, reconnecting to the public network. Finally, in the Nuremberg Prisma (Fig. 7), water follows a virtuous cycle of collection, filtration, reuse and infiltration, all integrated into the building scale. Source control is the only feasible strategy and makes the building a highly efficient ecosystem that is totally independent in stormwater management from the public network.

The constant presence of source control shows that effective management must begin at the source, integrating permeable surfaces and on-site reuse. Water diversion and water reception strategies are more viable at site and neighbourhood scale and, when combined with the former, act as a "management train" where multiple sequential interventions work together to enhance stormwater resilience.

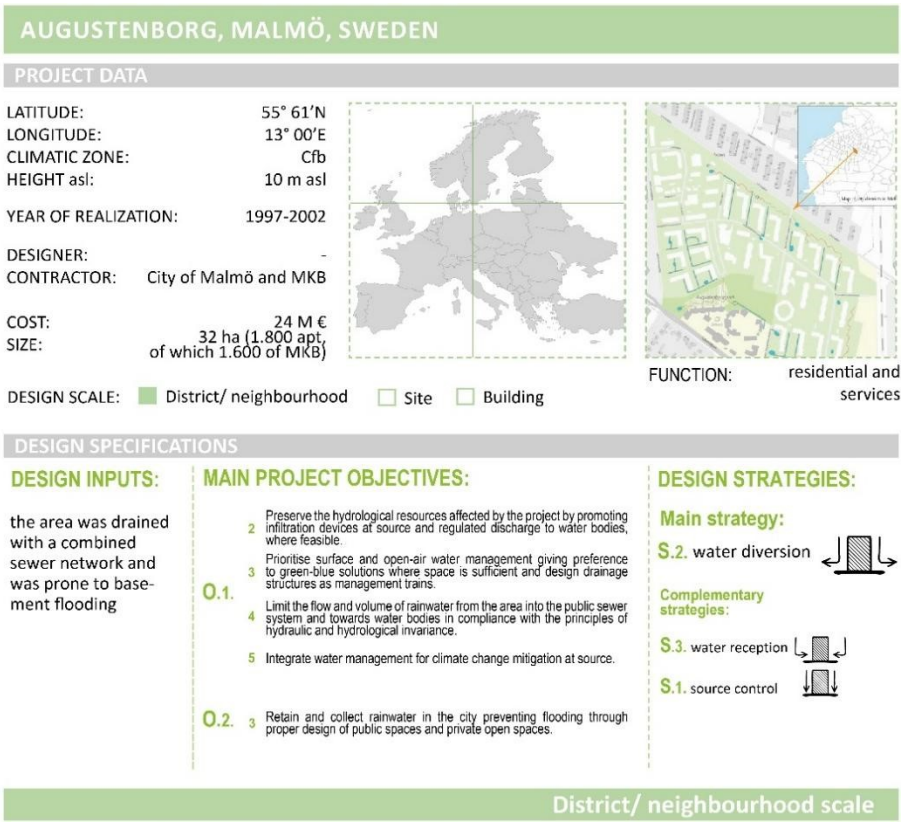

Figure 5. Summary sheet: Ekostaden Augustenbor (© the Authors [LMG]). Localization plan extract from (Mottaghi et al., 2021)

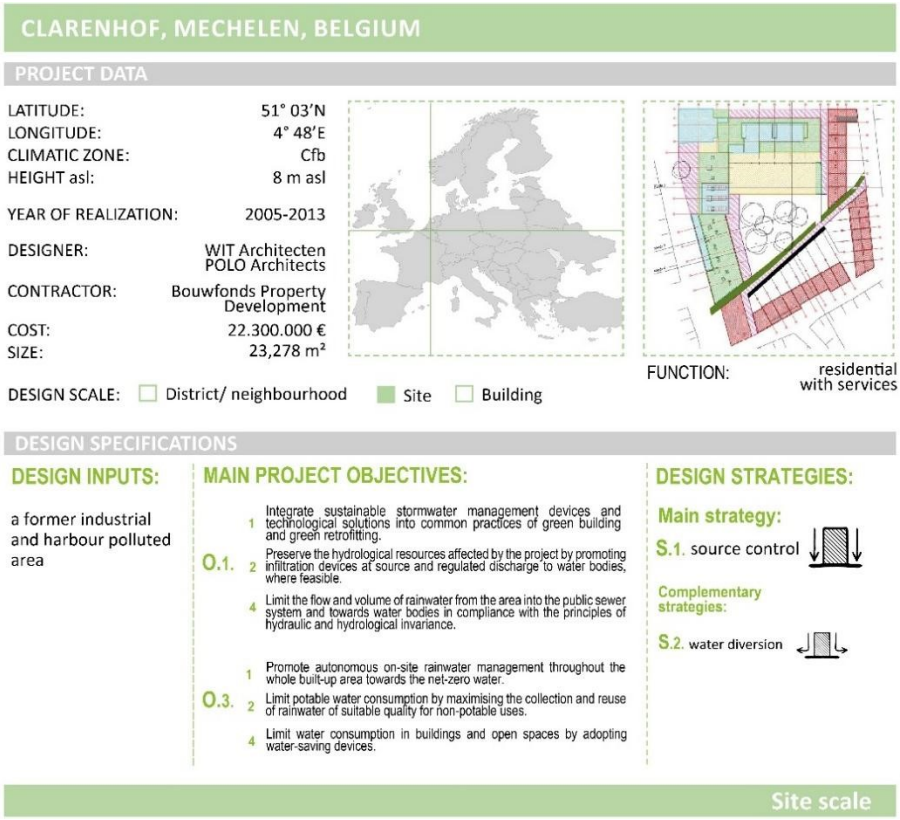

Figure 6. Summary sheet: Clarenhof (© the Authors [LMG]). Typological plan from (Dudek, 2012)

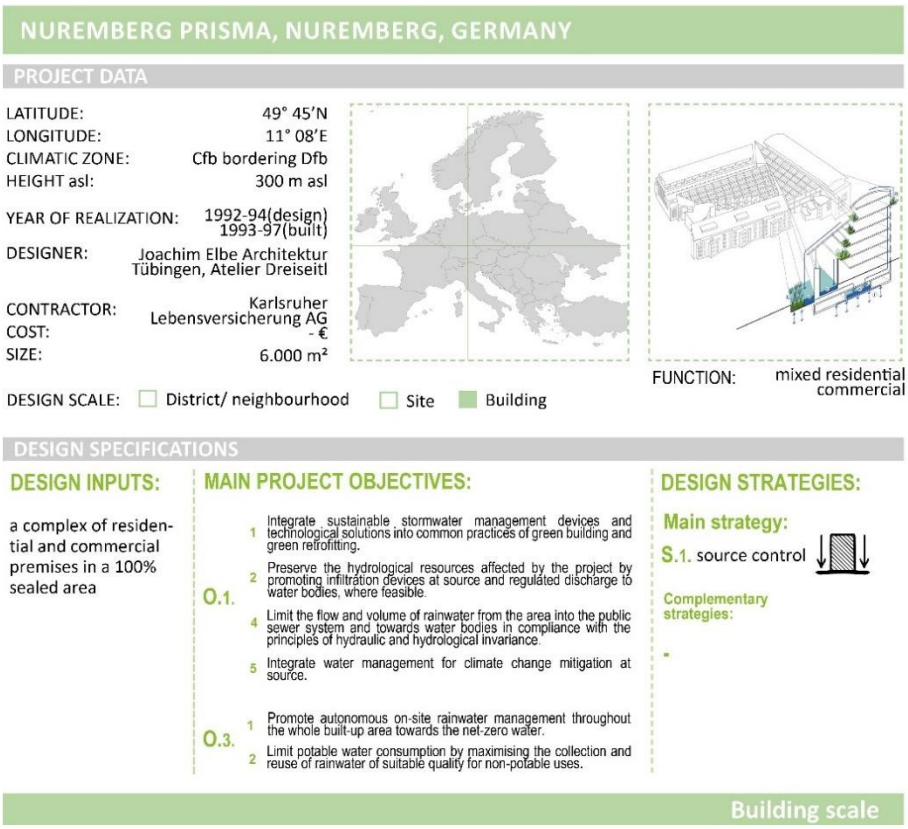

Figure 7. Summary sheet: Nuremberg Prisma (© the Authors [LMG]). Axonometric section from (Corfone, 2012)

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ECONOMY AND SUSTAINABILITY

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FINANCING THE ENERGY TRANSITION: A COMPARATIVE ANALYSIS OF GREEN URBAN DEVELOPMENT IN GERMANY AND TURKEY

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Financing the Energy Transition: A Comparative Analysis of Green Urban Development in Germany and Turkey

Abstract: This paper examines and compares the financing strategies for energy transition and green urban development in Germany and Turkey, framed within the Green New Deal and global climate goals. While Germany operates within the European Green Deal framework, leveraging robust financial instruments such as the Climate and Transformation Fund (KTF), KfW loans, and green bonds, Turkey is in the early stages of building its green financing ecosystem. Turkey's efforts are supported primarily by international funding, public-private partnerships (PPPs), and evolving domestic policies. Germany's approach is characterized by extensive national and EU-level financial support, stringent regulatory frameworks like the Building Energy Act, and strong private sector engagement. Turkey, on the other hand, focuses on energy efficiency, urban greening, and sustainable transport development, albeit at a smaller scale and with less regulatory maturity. The paper highlights key financial mechanisms, public investments, and challenges faced by both nations, concluding that Germany's advanced ecosystem provides a model for scaling green urban infrastructure, while Turkey's emerging framework offers substantial growth potential. The findings provide insights for policymakers and stakeholders aiming to enhance green urban development financing in varying economic and regulatory contexts.

Keywords: Green Urban Development, Energy Transition, Financing Mechanisms, Green New Deal, Climate Goals

Introduction

The global shift to a low-carbon economy places green urban development at the forefront of climate action, as cities drive significant energy use and emissions. International initiatives like the European Green Deal highlight the need for investment in renewable energy, energy efficiency, and sustainable planning, supported by strong policies and financing ecosystems.

Germany and Turkey exemplify contrasting approaches. Germany, aligned with the EU's Green Deal, leads with diverse financing tools—state loans, green bonds, and publicprivate partnerships—under its comprehensive Energiewende program focused on decarbonization and energy efficiency. Turkey, committed to the Paris Agreement with a 2053 net-zero target, is developing its green urban financing framework, heavily relying on international funds and emerging partnerships. Although progress is visible in energy efficiency and urban greening, its regulatory and financial systems are less mature.

This paper compares their financing strategies, alignment with climate goals, instruments used, and challenges faced, aiming to draw lessons for improving green urban development financing in diverse contexts.

Literature Review

Financing Mechanisms for Green Urban Development

The financing of green urban development is pivotal to achieving global sustainability goals, requiring substantial investments in renewable energy, energy efficiency, and sustainable urban infrastructure. Adamowicz (2022) provides a conceptual framework for green fiscal policies, emphasizing the role of green bonds, subsidies, and public-private partnerships (PPPs) in mobilizing capital for sustainable development goals (SDGs). Through a qualitative synthesis, the study highlights how these mechanisms support energy transitions across diverse economic contexts, offering a foundation for comparing Germany and Turkey. Similarly, Erdogan (2024) employs econometric modelling to analyse the linkages between green fiscal policies, energy consumption, economic growth, and environmental degradation in Germany. The findings indicate that targeted fiscal interventions, such as tax incentives and green subsidies, reduce environmental degradation by up to 15% while promoting sustainable urban growth, providing a benchmark for Germany's financing strategies.

Policy Frameworks and the European Green Deal

The European Green Deal (EGD) shapes energy transition policies, influencing both EU member states and neighbouring countries like Turkey. Keskin and Güneş (2023) utilize qualitative policy analysis to examine the EGD's implications for Turkey, identifying challenges such as limited financial resources and regulatory gaps that hinder alignment with EU sustainability standards. Their work underscores the need for tailored financing models to support Turkey's energy transition. Complementing this, Akçalı et al. (2023) adopt a spatial analysis approach to explore Turkey's low-carbon energy transition within the EGD framework, highlighting how geographical and political factors influence financing and policy adoption. In Germany, the EGD aligns with national policies like the Building Energy Act and the Climate and Transformation Fund (KTF), which support large-scale investments in renewable energy and urban infrastructure (BMWK, 2023). These studies collectively emphasize the importance of policy coherence in financing green urban development.

Urban Planning and Green Infrastructure

Urban planning is critical to integrating energy transitions with environmental sustainability. Hansen et al. (2023) employ a case study methodology to investigate green infrastructure planning in Germany, focusing on biodiversity and stakeholder engagement.

Their findings show that participatory planning enhances the effectiveness of urban greening projects, reducing urban heat by 2–3°C and capturing significant CO_2, offering insights into Germany's advanced urban strategies. In Turkey, urban greening initiatives, such as those supported by international donors like the UNDP, are emerging but limited by regulatory maturity and funding scale (UNDP, 2025). These studies highlight the methodological diversity—case studies, policy analysis, and econometric models—in understanding green urban development, yet few adopt a comparative approach across developed and emerging economies.

Gaps and Contributions

While existing literature provides valuable insights, it often focuses on single-country contexts or specific aspects of energy transitions. For instance, Erdogan (2024) and Hansen et al. (2023) offer robust analyses of Germany's financing and urban planning but lack comparison with emerging economies like Turkey. Similarly, Keskin and Güneş (2023) and Akçalı et al. (2023) focus on Turkey's EGD alignment but do not contrast it with developed economies. This study addresses these gaps by employing a comparative qualitative case study approach, analysing financing mechanisms in Germany and Turkey. By integrating recent literature and diverse methodologies, it offers novel insights into tailoring financing strategies to diverse economic and regulatory contexts, contributing to both theoretical understanding and practical policy design.

Method

Research Design and Input collection

This study employs a comparative qualitative analysis to evaluate the financing mechanisms for green urban development in Germany and Turkey. By utilizing fictive illustrative examples that reflect small- to medium-scale budgets, the study demonstrates how financing mechanisms are applied across different project sizes. These examples are based on

generalized trends, publicly available information, and synthesized insights from policy and academic literature.

The data for this study was collected from both primary and secondary sources to provide a clear and balanced analysis of green urban development financing in Germany and Turkey.

Primary sources include reports and documents from local government initiatives and policies, information from funding programs like the KfW Development Bank in Germany and Türkiye Kalkınma ve Yatırım Bankası in Turkey, as well as project summaries from international development institutions such as the European Investment Bank (EIB) and the World Bank. These sources offer direct insights into the financial mechanisms and policies shaping green urban development in each country.

Secondary sources include academic research, global climate finance reports from organizations like the International Renewable Energy Agency (IRENA) and the United Nations Development Programme (UNDP), and case studies from organizations such as EBRD. These sources provide additional context and help highlight broader trends and challenges.

Due to the constraints imposed by limited access and confidentiality, fictive examples had to be created. The examples presented herein are founded upon publicly available information and general trends, thus offering realistic scenarios to facilitate the comparison. This methodological approach guarantees the continued relevance and significance of the analysis, even in the presence of incomplete data.

Fictive Illustrative Examples with Small and Medium Budgets

The following fictive examples reflect smaller-scale projects, focusing on community-level initiatives and medium-sized budgets.

Aspect	Example 1: Germany – Community Solar Panel Installation Program	Example 2: Turkey – EnergyEfficient School Retrofit Program	Example 3: Germany – Urban Greening for Climate Resilience	Example 4: Turkey – Green Space Development in Suburban Neighborhoods
Funding Scale	€50,000–€200,000 per community	€30,000–€100,000 per school	€100,000–€500,000 per city	€50,000–€150,000 per neighborhood

Key Financing Sources	KfW Bank loans, regional government grants, crowdfunding	Türkiye Kalkınma ve Yatırım Bankası, EU IPA funding	Green bonds, EIB co-financing	Local municipalities, environmental NGOs, international donors (e.g., UNDP)
Project Scale and Outcomes	Rooftop solar panels for 50 homes, generating 200,000 kWh/year, reducing CO_2 by 50 metric tons annually, €300–€500 in energy savings/household	Retrofitting 10 schools, 40% energy reduction/school, saving €5,000 annually/school, 20 metric tons CO_2	Planting 500 trees, installing 10 green roofs, lowering urban temps by 2–3°C, capturing 10 metric tons CO_2 annually	Development of a 2-hectare park, increasing green coverage by 15%, reducing flood risks, creating 20 temporary jobs
		reduction/school annually		
Policy Alignment	Renewable Energy Sources Act (EEG)	Energy Efficiency Strategy (20202030)	National Strategy on Urban Greening	National Climate Change Strategy
Relevance	Supports small-scale renewable energy projects, engages communities, ensures equitable clean energy access	Demonstrates ability to implement smallscale energy efficiency projects in public institutions with domestic and international support	Integrates costeffective urban greening for climate adaptation	Highlights Turkey's potential to implement localized green urban development with modest budgets

The table summarizes small-scale green urban development projects in Germany and Turkey, focusing on funding, outcomes, policy alignment, and local relevance.

In Germany, programs like the Community Solar Panel Installation (budgets €50,000–€200,000) use KfW loans, regional grants, and crowdfunding to support decentralized renewable energy, reducing CO_2 emissions by 50 tons annually and saving households €300–€500 each year. The Urban Greening for Climate Resilience program (€100,000–€500,000) invests in green infrastructure funded by green bonds and EIB co-financing, mitigating urban heat and capturing 10 tons of CO_2 yearly, aligned with national strategies.

Turkey's Energy-Efficient School Retrofit Program (€30,000–€100,000) funded by Türkiye Kalkınma ve Yatırım Bankası and EU IPA cuts energy use by 40%, saving €5,000 per school annually. The Green Space Development program (€50,000–€150,000), backed by

municipalities, NGOs, and UNDP, enhances urban green areas, reduces flood risk, and creates jobs, aligning with Turkey's climate strategy.

Overall, Germany benefits from a mature financing ecosystem and regulatory framework enabling community-driven renewable and greening projects, while Turkey leverages international funding and partnerships to meet local needs. Both demonstrate how small-scale initiatives advance national sustainability goals, offering insights for policymakers.

Findings and Discussion

The comparison of green urban development financing in Germany and Turkey highlights key differences shaped by regulatory frameworks, financial maturity, and institutional capacity.

Germany's advanced ecosystem utilizes diverse instruments like the Climate and Transformation Fund, KfW low-interest loans, green bonds, and EIB support to finance largescale energy-efficient retrofits, renewables, and sustainable infrastructure, achieving major emission reductions (e.g., 10 million tons annually from retrofits). Strong regulations such as the Building Energy Act ensure high standards, complemented by urban greening and sustainable mobility initiatives.

Challenges include high upfront retrofit costs and balancing short-term economics with long-term climate goals, while opportunities exist in scaling renewables, innovative financing, and enhancing urban mobility.

SWOT Analysis for Germany (Green Urban Development Financing)

Strengths	Weaknesses
- **Advanced Financial Ecosystem:** Comprehensive mechanisms like KfW loans, Climate and Transformation Fund (KTF), and green bonds ensure consistent funding.	- **High Upfront Costs:** Retrofitting buildings and infrastructure projects require significant initial investment.
- **Strong Regulatory Framework:** Policies like the Building Energy Act (GEG) mandate energy efficiency and renewable integration.	- **Economic Transition Costs:** Balancing shortterm economic concerns with long-term environmental goals can be challenging.
- **EU-Level Support:** Access to European Investment Bank (EIB) funding and alignment with the European Green Deal provides additional resources.	- **Grid Integration Challenges:** Scaling renewable energy systems requires substantial upgrades to grid infrastructure.
- **Private Sector Engagement:** High levels of private investment through mechanisms like green investment funds and PPPs.	- **Public Acceptance Issues:** Resistance to largescale projects (e.g., wind farms) due to local opposition.

Opportunities	Threats
- **Scaling Renewable Energy:** Expanding decentralized renewable energy systems (e.g., community solar projects).	- **Economic Volatility:** Rising energy prices or economic downturns could limit public and private investments.
- **Emerging Technologies:** Integration of smart cities, energy storage systems, and advanced energy efficiency technologies.	- **Global Competition:** Other nations advancing their green financing frameworks could challenge Germany's leadership role.
- **International Collaboration:** Sharing expertise and financing models with emerging economies to support global energy transitions.	- **Regulatory Overhaul Risks:** Potential delays or resistance during policy updates to meet evolving EU and climate goals.
- **Scaling Urban Mobility:** Further investments in sustainable public transport and EV infrastructure to decarbonize urban areas.	- **Resource Limitations:** Potential shortages of skilled labor or materials for retrofitting and renewable energy projects.

Figure 1. *SWOT Analysis for Germany (Green Urban Development Financing)*

Turkey's financing ecosystem for green urban development is still emerging, relying heavily on international funding sources such as loans and grants from the World Bank and EBRD, as well as public-private partnerships (PPPs). While state-owned banks, like Türkiye Kalkınma ve Yatırım Bankası, and experiments with green bonds show promise, Turkey's domestic financing mechanisms are limited in scale compared to Germany's. Efforts in energy efficiency, such as retrofitting public institutions, and urban greening initiatives, like metro expansions and electric bus fleets in Istanbul and Ankara, are notable but smaller in scale and impact due to resource and regulatory constraints. Turkey faces challenges including dependency on external funding and limited regulatory maturity but has opportunities to strengthen domestic financing, expand retrofitting programs, and build institutional capacity through international partnerships.

Strengths	Weaknesses
- **International Financing Cooperation:** Strong reliance on loans and support from organizations like the World Bank, EBRD, and EU IPA funding.	- **Limited Domestic Capacity:** Reliance on external funding due to underdeveloped domestic green financing mechanisms.
- **Growing Public-Private Partnerships (PPPs):** Increasing use of PPPs for urban transport and green infrastructure projects.	- **Evolving Regulatory Framework:** Lack of stringent, enforceable standards for energy efficiency and green development.
- **Emerging Green Bonds:** Early steps toward green bond issuance signal potential for future domestic private sector involvement.	- **Small Scale of Projects:** Green urban development projects are often smaller in scale and localized, limiting broader impact.

- **Focus on Energy Efficiency:** Programs like the Energy Efficiency Strategy (2020–2030) aim to improve public and private building performance.	- **Institutional Weaknesses:** Insufficient capacity in evaluating and managing green projects at the local and national levels.
Opportunities	**Threats**
- **Scaling Domestic Financing:** Expansion of state-owned banks like Türkiye Kalkınma ve Yatırım Bankası to provide low-interest loans for green projects.	- **Economic Dependency:** Continued reliance on international funding exposes projects to risks of fluctuating global financial support.
- **Expanding Green Bonds:** Developing a robust framework for issuing green bonds to attract private investment and diversify funding.	- **Regulatory Delays:** Slow implementation of green financing frameworks and policies could hinder progress toward climate goals.
- **International Partnerships:** Leveraging technical expertise and funding from international organizations to scale urban sustainability projects.	- **Climate Vulnerabilities:** Rising impacts from climate change (e.g., heatwaves, flooding) could strain resources and delay progress.
- **Urban Mobility Expansion:** Further development of metro networks, electric buses, and bike-friendly infrastructure in urban centers.	- **Political and Economic Instability:** Political uncertainties or economic challenges could disrupt long-term green financing initiatives.
- **Capacity Building:** Training local governments and financial institutions to better evaluate and manage green projects.	- **Global Market Risks:** Competition for international climate financing from other developing nations could reduce funding availability.

Figure 2. *SWOT Analysis for Turkey (Green Urban Development Financing)*

These SWOT analyses provide a clear breakdown of each country's strengths, weaknesses, opportunities, and threats in financing green urban development. Germany's advanced ecosystem demonstrates leadership but faces challenges in cost and public acceptance, while Turkey's emerging framework relies on international support and has significant room for growth in domestic financing and institutional capacity.

Conclusion

Summary of Key Findings

This comparative analysis reveals distinct approaches to financing green urban development in Germany and Turkey. Germany's mature ecosystem, supported by the Climate and Transformation Fund, KfW loans, green bonds, and EU-level funding, enables large-scale investments in energy efficiency, renewable energy, and urban greening, achieving significant emission reductions. Turkey's emerging framework relies heavily on international funding from institutions like the EBRD and World Bank, supplemented by PPPs and nascent green bond

initiatives. Despite challenges like regulatory immaturity and limited domestic financing, Turkey's efforts in energy-efficient retrofits and urban greening demonstrate growth potential aligned with its 2053 net-zero target.

Future Research Directions

Future research could extend this comparative analysis to include additional countries, such as Poland or Brazil, to test the generalizability of financing models across diverse economic systems. Longitudinal studies tracking the long-term impacts of green financing mechanisms in Germany and Turkey could clarify their scalability and effectiveness, particularly for small-scale projects like those in the fictive examples. Additionally, incorporating stakeholder perspectives—such as those of local communities, private investors, or NGOs—could provide deeper insights into barriers and opportunities for green urban development. Exploring the role of emerging technologies, such as smart grids or energy storage systems, in enhancing financing efficiency could further advance the field.

Contribution to Theory and Practice

This study contributes to the literature by offering a novel comparative analysis of green urban development financing in Germany and Turkey, bridging developed and emerging economy perspectives. It highlights the importance of policy coherence, diverse financial instruments, and international cooperation in scaling energy transitions. Practically, it provides evidence-based strategies for policymakers to enhance green financing, from leveraging EUlevel support in Germany to building domestic capacity in Turkey. By addressing contextspecific challenges and opportunities, the study paves the way for more sustainable urban futures, aligning with global climate goals like the Paris Agreement and the European Green Deal.

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A COMPARATIVE ANALYSIS IN THE REAL ESTATE MARKET BETWEEN NAPLES AND ISTANBUL

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A Comparative Analysis in the Real Estate Market Between Naples and Istanbul

Abstract: In recent years, the international real estate market has been shaped by climate pressures, stricter rules on energy efficiency and sustainability. In this scenario, metropolitan cities play a key role as hubs of innovation, serving as laboratories for technological experimentation. The study analyses the metropolitan cities of Naples and Istanbul, both port cities with a rich historical and cultural heritage, characterized by different growth dynamics and urban planning approaches. Naples has a dense urban fabric, stratified through centuries and constrained by strict archaeological and landscape constraints, which significantly influence sustainable real estate development. Istanbul, by contrast, has undergone decades of rapid expansion, driven by demographic growth, infrastructure demands, and policies aimed at attracting foreign investors. This study compares the real estate market of these two metropolitan areas, focusing on newly built properties designed to comply with contemporary sustainability standards.

Keywords: building sustainability; real estate market; comparative analysis; urban development.

Introduction

In recent decades, growing social awareness of environmental and energy efficiency issues has led to the development of structured strategies reshaping approaches to architectural and urban design (Katafygiotou et al., 2023; IFC, 2023). The urgent need to mitigate environmental damage, combined with social pressure and market trends, has encouraged the spread of concepts such as sustainable construction and green architecture, also in accordance with the SDG of Agenda 2030 These principles are increasingly used not only as design guideline but also as commercial lever in the promotion of real estate projects (Falkenback et al., 2010).

At the same time, some operators are exploiting this demand by inflating the value of buildings marked as “eco-sustainable”, promoting projects that often fail to meet standards (Osmanoğlu, 2018). The increasing interest of potential buyers in sustainable properties (Katafygiotou et al., 2023) often conflicts with the desire to live in central urban areas or districts rich in services and infrastructure. Metropolitan cities thus offer stimulating opportunities for the experimentation of innovative technologies, but also face major challenges, especially in urban contexts subject to historical, artistic or landscape constraints (IFC, 2023).

Literature Review

The real estate market is influenced by various factors, and among these, sustainable practices are playing an increasingly significant role at international level (Newell et al., 2021; Lorenz et al., 2007). Numerous studies have examined the relationship, showing how

sustainability affects both investment decisions and property values, with energy-efficient buildings associated with higher sale prices and greater attractiveness for investors and buyers (Fuerst & McAllister, 2011; Jackson, 2009). At the same time, the implementation of sustainable building strategies faces challenges linked to regulatory constraints in each country, high construction costs, and the actual environmental awareness of stakeholders (Azhar et al., 2011; Ding, 2008).

Italy's situation is characterised by a predominantly old building stock, about 75% of properties were constructed before 1990 – before sustainability regulations (ANCE, 2023) – and are therefore inefficient in energy performance. Nevertheless, there are encouraging signs of transition towards sustainability, supported by national and European regulations, such as the "Green Homes Directive" (Directive 2024/1275). Turkey presents a similar condition in terms of building stock age (75%) but is undergoing a more rapid acceleration towards the energy transition, with energy demand growing at an annual rate of 4.4% (SHURA 2019). This study fits into this context, comparing real estate dynamics in Naples and Istanbul, which are important metropolitan centres, and both cities are internationally significant urban destinations. While tourism represents an important economic resource, it also generates issues associated to 'overtourism' (UNWTO,2018; Capocchi et al., 2019). Tourist influx of tourists affects residents' quality of life, infrastructure management, cultural heritage sustainability. Moreover, overtourism impacts the real estate market through gentrification, rising property values, and the intensive conversion of residential properties into tourist accommodation (Koens et al., 2018; Sdino&Magoni, 2018).

Methods

The comparative analysis between Naples and Istanbul was conducted by collecting date on real estate market and construction sector. Regarding the Italian case, the main sources of reference were the *Osservatorio del Mercato Immobiliare*, the *Associazione Nazionale Costruttori Edili* and the *Agenzia delle Entrate*. For the Turkish case, data were obtained from the *Türkiye İstatistik Kurumu*, the Central Bank of the Republic of Turkey, the Banking Regulation and Supervision Agency, and the Endeksa platform.

The structure of the article provides, in the fourth and fifth sections respectively, a synthetic overview of the real estate market in the two countries, Italy and Turkey and in the historic centres of the examined cities. The sixth section is dedicated to a comparative analysis, highlighting similarities and differences. The results are explained in the concluding section.

Real estate market trends in Naples, Italy

In 2024, the Italian economy showed signs of moderate growth, with GDP rising by 0.7% compared to the previous year and a recovery supported by stronger domestic demand, particularly gross fixed investments (+0.5%) and final national consumption (+0.6%). As for the residential sector, signs of recovery emerged, with a 1.3% increase in transactions and around 720,000 homes sold, following the sharp decline recorded in 2023 (Rapporto Immobiliare, OMI, 2025).

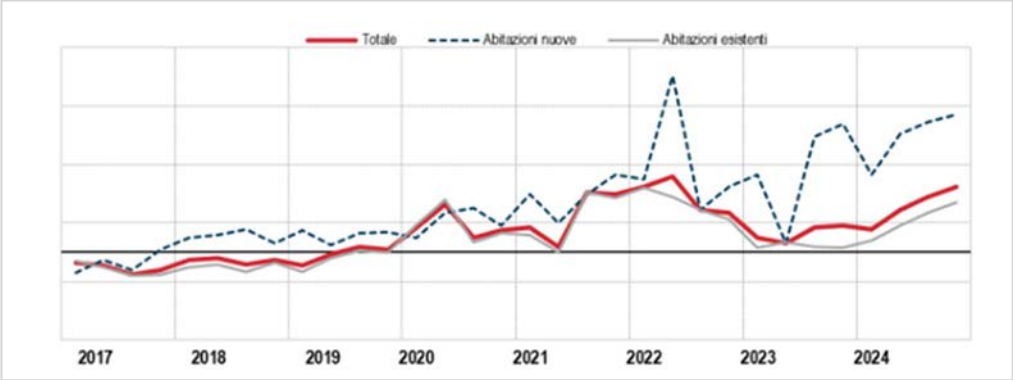

Figure 1. Year-on-year percentage changes in the price indices of new and existing homes. Source: ISTAT, available at link: https://www.agenziaentrate.gov.it/portale/documents/20143/9134978/StatisticheOMI_RES_I_2025.pdf/16d00394-7a6b-eb4b-27df-c9a9fa294cf2?t=1749553171606

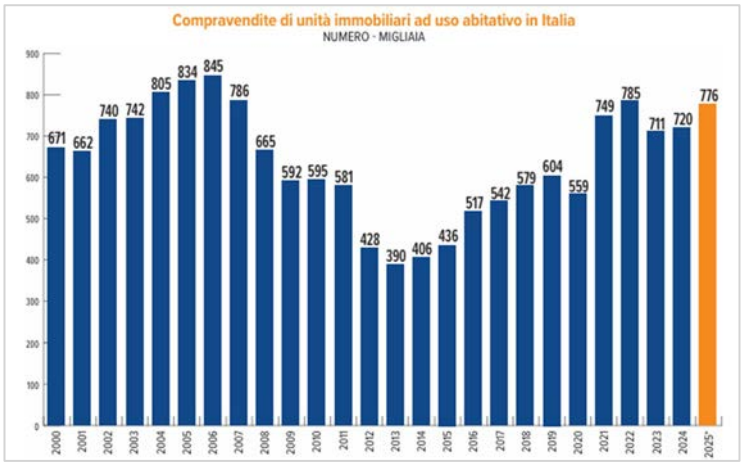

Figure 2. Transactions of residential real estate units in Italy. Source: ANCE, available at link: https://ance.it/wp-content/uploads/allegati/2025_SCENARI_REGIONALI_CAMPANIA.pdf

In the first quarter of 2025, housing transactions in Italy grew by more than 11% yearon-year, involving all areas. In Campania, the residential market improved in 2024, with 42,351 transactions (+0.9% compared to 2023), supported by ECB rate cuts that boosted mortgages (+7.7%). However, the residential market in Naples recorded a slight decline in transactions (–2.7%) and in the House Market Index (–1.8%), while remaining above the regional average. Central and historic areas slowed down (Historic Centre –15.9%, Semi-Historic –7.7%), while peripheral, semi-central, and prestigious zones showed resilience and growth (Eastern

Periphery +6.9%, Hill Area +4.2%, Prestigious Area +11.3%). Prices stabilized at around €2,178/sqm (+0.6%), with increases mainly in more affordable peripheral areas and consolidation in hill and prestigious districts (SR Campania, OMI, 2025).
Regarding the rental market, Naples, with just over 2,100 rental contracts, registered €116.1 per sqm, placing it below the national average but in line with other large cities such as Genoa and Turin.

Macroaree urbane	Quotazione media €/m² 2024	Quotazione media Var % 2024/23
CENTRO ANTICO	2.255	2,2%
PERIFERIA NORD	1.930	0,2%
PERIFERIA OCCIDENTALE	2.214	2,2%
PERIFERIA ORIENTALE	1.463	2,7%
SEMICENTRO STORICO	1.823	1,7%
SOBBORGHI OCCIDENTALI	1.569	2,6%
SOBBORGHI ORIENTALI	1.253	1,2%
SOBBORGHI SETTENTRIONALI	1.280	3,7%
ZONA COLLINARE	3.474	-2,4%
ZONA PREGIATA	4.178	-0,5%
NAPOLI	**2.178**	**0,6%**

Figure 3. Average price, annual variation, and differential by urban macro-area. Source: Agenzia delle Entrate, available at link: https://www.agenziaentrate.gov.it/portale/documents/20143/9121062/SR2025_Campania.pdf/1cd20472-b7dd-cb79-67cc-74a0a2858cee?t=1749122257719

Compravendite di unità immobiliari ad uso abitativo nella provincia di Napoli - NUMERO

	2021	2022	2023	2024*	I trim. 2024*	II trim. 2024*	III trim. 2024*	IV trim. 2024*
Comune capoluogo	8.106	8.327	7.982	7.767	1.868	2.154	1.625	2.121
Altri comuni della provincia	13.568	14.280	13.275	13.490	3.150	3.612	2.779	3.948
Totale provincia	21.674	22.607	21.257	21.257	5.019	5.766	4.404	6.069
Var. % rispetto allo stesso periodo dell'anno precedente								
Comune capoluogo	27,8	2,7	-4,1	-2,7	-4,6	-1,0	-3,8	-1,9
Altri comuni della provincia	31,3	5,3	-7,0	1,6	-3,0	4,2	-0,7	5,0
Totale provincia	30,0	4,3	-6,0	0,0	-3,6	2,2	-1,9	2,5

* Dati provvisori

Elaborazione Ance su dati Agenzia dell'Entrate

Figure 4. Transactions of residential real estate units in the province of Naples. Source: ANCE, available at link: https://ance.it/wp-ontent/uploads/allegati/2025_SCENARI_REGIONALI_CAMPANIA.pdf

In the metropolitan area of Naples, the residential new-build sector is gaining increasing importance. In fact, in 2022, building permits for new homes and extensions recorded a significant increase in Campania (+34.9% compared to 2021), with the province of Naples rising by +26.9%. This trend reflects a growing interest in new construction, driven by the demand for modern housing and the need to replace obsolete and energy-inefficient buildings. Sustainability plays a central role, with new properties required to meet strict efficiency standards in line with the EU's climate neutrality goals for 2050. The city of Naples, and particularly its historic centre, must nevertheless contend with constraints arising from high

urban density, limited available land, and the presence of historic buildings (Forte & De Paola, 2020; ANCE, 2024).

Real estate market trends in Istanbul, Turkey

The Turkish economy is strongly influenced by the construction and real estate sectors. According to data provided by Trading Economics, these economic sectors contributed more than 5% of the national GDP and played a central role in the national economy. Although they have experienced a steady and considerable contraction in recent years, due to factors such as rising production costs and a reduction in foreign direct investment, these sectors continue to remain competitive and attractive within the international real estate market.

Real estate sales increased by 35.8% in June 2025 compared to the same month of the previous year, reflecting both a recovery in market activity and a likely prevention of purchases in anticipation of further price increases. In 2024, Istanbul confirmed its leading role in the Turkish real estate market, with 17,656 property transactions, followed by Ankara with 9,428 and Izmir with 5,987 (TÜİK, 2024).

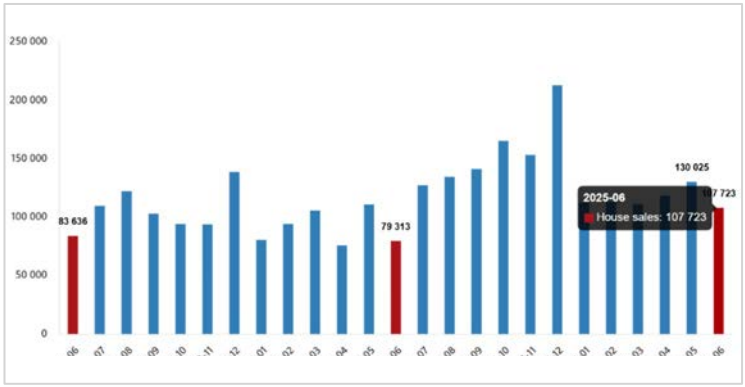

Figure 5. House sales statistics, June 2025. Source: *Türkiye İstatistik Kurumu*, available at link: https://data.tuik.gov.tr/Bulten/Index?p=House-Sales-Statistics-June-2025-54141 Market activity is focused in metropolitan areas and economically dynamic regions (TCMB, 2025), where demand is strong due to both population growth and interest from foreign investors.

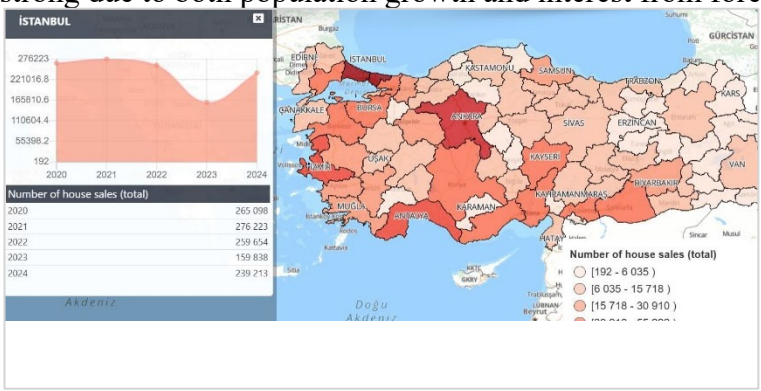

Figure 6. Number of house sales (total), 2024. Source: Turkish Statistical Institute, available at link: https://cip.tuik.gov.tr/

Since 2017, the Turkish government launched a citizenship-by-investment programme (Investropa, 2025) aimed of attracting foreign investment. This strategy has contributed to a significant economic boost for the city but has also led to a sharp increase in market prices, both for sales and rentals. The Istanbul property market is particularly attractive and dynamic, especially in the luxury and high-end segments. The house price index rose by 27.4% in nominal terms in September 2024 (TCMB, 2025). However, net of inflation, real prices declined by 14.7%, highlighting the strong impact of macroeconomic factors on purchasing power and investment returns (BRSA, 2024). As a result, foreign demand for property in Turkey continued to decline, compared to previous years, accounting for only 1.6% of total residential transactions (BRSA, 2024). Nevertheless, Istanbul remains the epicentre of real estate activity in Turkey, with 239,213 properties sold last year (TÜİK, 2024). High level of internal migration and ongoing urban regeneration projects have also contributed to maintaining a high transaction volume. The average sale price of residential properties in Istanbul recorded a nominal increase of 6% in October 2024. Average rental prices have risen significantly, reflecting a persistent imbalance between supply and demand, especially in central neighbourhoods.

Figure 7. Analysis of real estate market trends. Source: Endeksa, available at link: https://www.endeksa.com/en/analysis/turkiye/istanbul/index/for-sale/house

Regarding the sustainability of Istanbul's real estate market, it is noteworthy that over 30% of residential properties in the city are newly constructed – either for sale or buy-to-let – whit approximately 50% equipped with smart home technology (home automation, security systems, and energy management). The government promotes the design and construction of properties using sustainable materials and energy-efficient systems, sometimes employing sustainable building as a real estate marketing strategy within the real estate sector

(Osmanoğlu, 2018). While the availability of energy-efficient properties can be advantageous on several fronts, it also leads to significant increases in sales prices and rental discrimination, with exorbitant rents that are often prohibitive and tend to exclude certain categories of tenants.

Discussion: Naples vs Istanbul

Since 2005, with Law 5366, Istanbul has undergone significant urban transformations, more than other Turkish cities, primarily through "the renovation and revitalization of deteriorated historical and cultural assets." This has paved the way for both physical and social transformation of the city's historic centre, which has lost much of its rich historical heritage (Şahin, 1990). Gentrification in Istanbul is not only a risk but a tangible reality. Historic bohemian neighbourhoods such as Beyoğlu, Karaköy, and Galata have been transformed by foreign investors for tourism purposes, with the development of boutique hotels and high-end establishments. International brands are replacing the original businesses, threatening to obscure the uniqueness of these places, and rendering them like many other urban centres that have undergone the same process, leading to a terrible cultural homogenization.

The tourism-driven demand has driven up rental prices, pushing the historic local community out of central areas. Even more peripheral areas, such as Balat, Fener, and Moda, originally developed as working-class districts, are undergoing transformation, welcoming commercial spaces, cafés, and creative hubs for young professionals. While this contributes to the regeneration of these areas, it also increases rents and the risk of local community dispersion. Key factors accelerating gentrification include foreign investment, driving demand for luxury apartments and the growth of short-term rental markets.

Similarly, in Italy, particularly in Naples, the spread of short-term tourist rentals has exacerbated pressures on the real estate market. While this process has incentivised the valorisation of an otherwise marginalized building stock, it has also produced critical effects on the urban and social fabric, including progressive gentrification, displacement of lowincome residents and students, and the replacement of neighbourhood businesses with touristoriented services. The result is a historic centre increasingly geared toward tourist consumption, exposed to the concentration of property in the hands of large investors and the loss of social identity (Cerreta et al., 2020). According to the 2024 Censis-Federproprietà Report, over 44% of Italians identify short-term rentals as one of the main causes of rising prices and declining liveability in highly touristic districts. (3rd Federproprietà-Censis Report, 2024).

Beyond the risk of losing the authenticity of central areas, there is also an increased possibility of creating social tensions between longtime residents and investors, who may be perceived as "invaders." Moreover, rising rents affect not only the historic centre but also its surrounding areas, which poses a huge risk for Istanbul, that, unlike other European cities, is very widespread. Given its size, the gentrification process may not affect all peripheral areas uniformly. However, the potential completion of the phenomenon, if extended to the entire historic centre, could mean a huge loss of land for local communities.

Conclusion

The real estate markets of Naples and Istanbul exhibit markedly divergent dynamics. Naples is characterized by a rather static real estate market, with relatively stable prices and moderate rental yields. Urban growth dynamics are severely constrained by historical and bureaucratic restrictions, that also significantly limit the transition to energy-efficient buildings. In contrast, the absence of stringent constraints in Istanbul is accelerating the process of sustainable development. Real estate investments in Naples are not particularly attractive to foreign investors, instead Istanbul continues to draw significant international interest. In both cities, tourism represents a key driver of the economy, but it also poses substantial risks to local identity. While the process of gentrification in Naples is confined to the historic centre, in Istanbul the phenomenon is dangerously expanding well beyond the central areas.

These differences highlight how historical, political, and regulatory conditions can decisively shape real estate market dynamics and urban development strategies. This highlights the need for context-specific approaches to facilitate sustainable management and the protection of local identity, especially in metropolitan areas characterized by tourism pressures and rapid transformations.

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REUSE-ORIENTED ARCHITECTURAL PROJECTS IN THE CONTEXT OF CIRCULARITY: A REVIEW

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Reuse-Oriented Architectural Projects in the Context of Circularity: A Review

Abstract: This study examines reuse practices within circular architecture, a key strategy for mitigating waste and resource consumption in construction and demolition (C&D). Forty-seven projects utilizing salvaged materials were identified and analysed based on three main criteria
The projects are predominantly located in Northern Europe (34 cases) and vary in scale from 19 m² to 81,711 m². They include 17 residential, six social, five office, four commercial, two religious, two industrial, two park, and 13 miscellaneous functions. Thirty-six are architectural projects, nine are interior designs, and two are landscape projects
Nine projects incorporated products from recycled materials, while 13 reused non-construction sector materials. Only two projects were designed for disassembly. Sixteen architectural projects implemented eco-friendly strategies for their operational phase.
While reuse-driven projects offer valuable insights for methodological advancement, the available empirical data remains limited.

Keywords: circular design, reuse-oriented architectural design, salvaged materials

Introduction

Reuse reduces resource and energy consumption and waste generation by extending materials and components' service lives through replacement, transformation, or repurposing (Nußholz et al., 2019). Contrary to popular belief, the core of the circular economy lies in the term 'use', not 'cycle' (Baker-Brown, 2024). Although a cornerstone of the circular economy, reuse has received insufficient attention in the literature as a design issue, and its limited number of architectural examples remain underexamined.

This study aims to analyse reuse-oriented architectural cases to contribute field data to the literature and provide a perspective for future research. The selected examples will be analysed regarding their general characteristics, material features, disassembly properties, and eco-friendly strategies.

Literature Review

According to Virtanen et al. (2017), material-driven design -a derivative of design for reuse- operates at the intersection of science and design, guided by material properties and constraints. This approach introduces a new logic where available materials dictate the design process.

Reuse at various scales has been documented since antiquity (Gür and Sezgin, 2019). The concept has regained prominence through the circular economy, which responds to the environmental destruction of uncontrolled consumption. Reuse offers potential solutions to

dwindling resources, rising construction costs, high embodied energy and carbon of materials, and growing waste management challenges and associated environmental problems.

However, architectural practice struggles to transition from the linear model, resulting in a scarcity of reuse-driven design examples (Durmisevic, 2019). This practical gap is mirrored in academia; Hossain & Ng's (2019) analytical review indicates that circular economy research prioritizes strategies other than reuse.

Methods

Systematic literature analysis was used in the study and its methodological setup was structured based on the PRISMA protocol in line with systematic review standards.

In the first stage, Scopus and Google scholar databases were searched in the title / abstract / keyword fields using the keywords "Re-use examples in Architecture", "Circular buildings Case Studies" and "Upcycle in Architecture + examples". Topics outside the fields of architecture and interior architecture were excluded. Due to the limited results obtained from academic sources, online architectural magazines such as Architizer and ArchDaily were examined in the second stage. In addition, the author websites of the projects accessed from these platforms were scanned. 55 sources were reached accordingly.

Eligibility criteria were defined as follows:

- Inclusion: Built projects explicitly utilizing reused, upcycled, or repurposed materials as a primary design strategy, with sufficient public documentation.
- Exclusion: Projects using only newly manufactured recycled-content products or those with unverifiable claims or insufficient data.

Finally: 8 projects were excluded as per the abovementioned criteria. The final sample for analysis comprised **47 cases**. Data from each case was extracted into a structured matrix for comparative analysis (Table 1).

Findings and Discussion

The author, function, year of construction, country and area information of the 47 projects selected to be examined within the scope of the study are given in Table 1.

Table 1. General characteristics of the selected projects

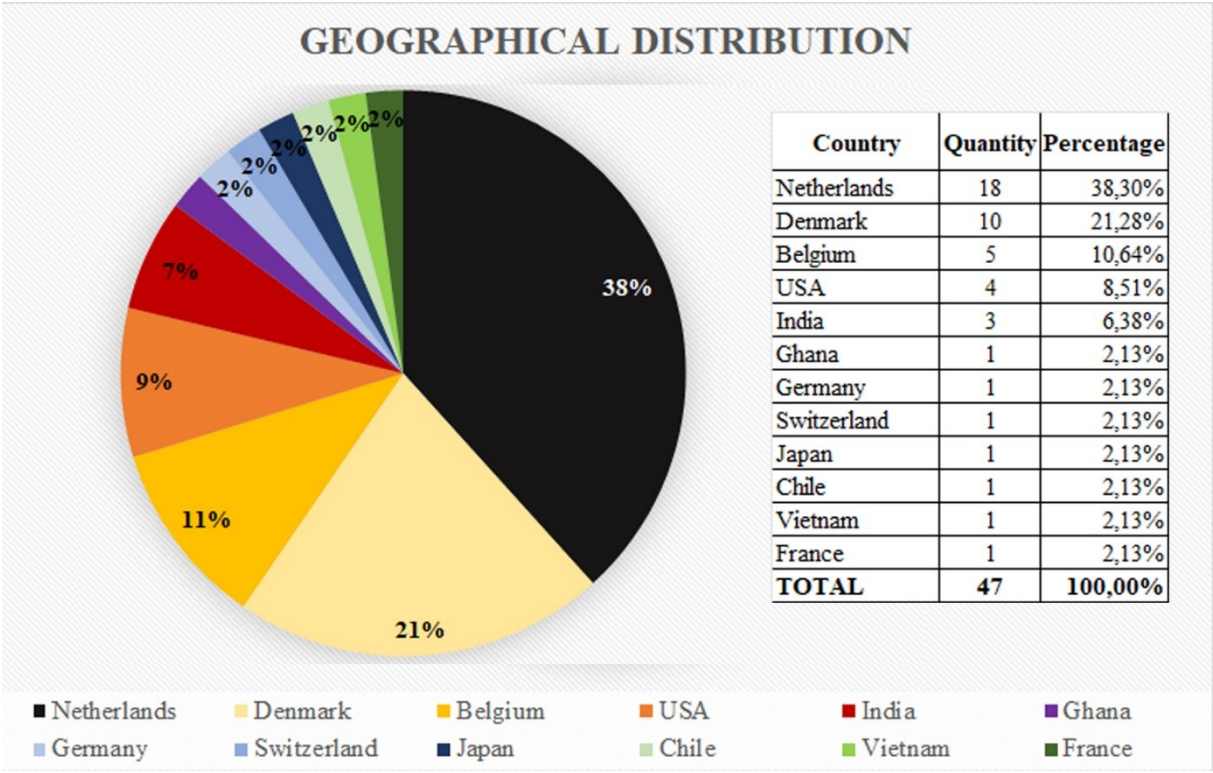
No	PROJECT NAME	ARCHITECT	FUNCTION	PROJECT TYPE	YEAR	COUNTRY	AREA	REFERENCES

1	New headquarters of the Council of the EU.	Samyn & Partners	Public	Architecture	2016	Belgium	53815m²	(Samyn & Partners, n.d.)
2	La Fabrique	Bureau A	Housing	Architecture	2013	Switzerland		(Archello, n.d.a)
3	Kamikatz Public House	Hiroshi Nakamura & NAP	Commercial +Hospitality	Architecture	2015	Japan	141m²	(Castro, 2018)
4	Strijps Bultje	Piet Hein Eek	Social	Architecture	2013	Netherlands	279m²	(Architizer, 2017)
5	Vegan House	Block Architects	Housing	Architecture	2014	Vietnam	92m²	(Architizer, 2019)
6	Glass Chapel	Auburn University Rural Studio	Religious	Architecture	2000	USA		(Rural Studio, 2019)
7	Collage House	S+PS Architects	Housing	Architecture	2015	India	520m²	(Architizer, 2016)
8	Upcycle Studios	Lendager	Housing	Architecture	2018	Denmark	3000m²	(Lendager, 2025)
9	Karstadt Re-Parked	Lendager	Commercial +office	Architecture	2025	Germany	20179m²	(Lendager, 2025)
10	Resource Rows	Lendager	Housing	Architecture	2019	Denmark	2270m²	(Lendager, 2025)
11	TRÆ	Lendager	Commercial	Architecture	2024	Denmark	14850m²	(Lendager, 2025)
12	Waste Retreat	Lendager	Housing	Architecture	2018	Denmark	173m²	(Lendager, 2025)
13	Grønttorvet	Lendager	Social	Architecture	2022	Denmark	1060m²	(Lendager, 2025)
14	Woods, Augusthus	Lendager	Office	Architecture	2021	Denmark	21500m²	(Lendager, 2025)
15	The Swan	Lendager	Education	Architecture	2022	Denmark	1436m²	(Lendager, 2025)
16	Lisbjerg	Lendager	Housing	Architecture	2022	Denmark	20000m²	(Lendager, 2025)
17	Upcycle House	Lendager	Housing	Architecture	2013	Denmark	140m²	(Lendager, 2025)
18	UN17 Village	Lendager	Housing	Architecture	2020	Denmark	35000m²	(Lendager, 2025)
19	Hortus Ludi	Architectuur Maken	Housing	Architecture	2019	Netherlands	3448m²	(Architectuur Maken, n.d.)
20	Circular Dune House	Architectuur Maken	Housing	Architecture	2020	Netherlands	213m²	(Architectuur Maken, n.d.)
21	The City is my Living Room	Architectuur Maken	Housing+ social	Architecture	2021	Netherlands	3220m²	(Architectuur Maken, n.d.)
22	Zadkine Hotel lobby	Architectuur Maken	Hospitality	Interior Architecture	2021	Netherlands	237m²	(Architectuur Maken, n.d.)

23	Cityscape in front of Zadkine College	Architectuur Maken	Commercial	Interior Architecture	2022	Netherlands	1242m²	(Architectuur Maken, n.d.)
24	Circular interior for the AVR	Architectuur Maken	Office	Interior Architecture		Netherlands	260m²	(Architectuur Maken, n.d.)
25	The Canaan	Ashams Ravi	Housing	Architecture	2020	India	232m²	(Gogoi, 2020)
26	UPCycle Offices	Gensler	Office	Architecture - Adaptive Reuse	2018	USA	81711m²	(Gensler, n.d.)
27	The Circular Pavilion	Encore Heureux	Social	Architecture / Temporary	2015	France	70m²	(Encore Heureux, 2024)
28	Bang Brewing	Alchemy Architects	Industrial	Architecture	2013	USA	130m²	(Alchemy Architects, 2021)
29	Manav Sadhna	Yatin Pandya	Education + Social	Architecture	2008	India	515m²	(Rethinking The Future, 2022)
30	Wheel Story House	Samuel Mensah Ansah	Housing	Architecture		Ghana		(Wang, 2016)
31	Recycled Materials Cottage	Juan Luis Martínez Nahuel	Housing	Architecture	2009	Chile	112 m²	(ArchDaily, 2011)
32	Jewish Reconstructionist Congregation Synagogue	Ross Barney Architects	Religious	Architecture	2008	USA	2880m²	(AIA, n.d.)
33	Blade-Made Wikado	Superuse	Park	Landscape	2009	Netherlands	1200m²	(Blade–Made, n.d.)
34	Blade-Made Terneuzen	Superuse	Park	Landscape	2016	Netherlands		(Superuse; 2025)
35	Villa Welpeloo	Superuse	Housing	Architecture	2009	Netherlands	400m²	(Superuse; 2025)
36	Office Q-dance	Superuse	Office	Interior Architecture	2019	Netherlands		(Superuse; 2025)
37	Housing Cooperative W1555	Superuse	Housing	Architecture	2022	Netherlands		(Superuse; 2025)
38	KEVN	Superuse	Social + commercial	Architecture	2020	Netherlands		(Superuse; 2025)
39	Boschgaard	Superuse	Housing	Architecture	ongoing	Netherlands		(Superuse; 2025)
40	Valkenburg	Superuse	Industrial	ArchitectureAdaptive Reuse	2019	Netherlands		(Superuse; 2025)
41	BlueCity Offices	Superuse	Office	Interior ArchitectureAdaptive Reuse	2017	Netherlands	1300m²	(Superuse; 2025)

42	Art Zaanstad	Superuse	Social	Interior ArchitectureAdaptive Reuse	2017	Netherlands	2000m²	(Superuse; 2025)
43	Buitenplaats Brienenoord	Superuse	Social	ArchitectureAdaptive Reuse	2020	Netherlands		(Superuse; 2025)
44	Realco Cafetaria	Rotor	Commercial	Interior Architecture	2023	Belgium		(Rotor, n.d.)
45	Kunsthal Extra City	Rotor	Social	Interior Architecture	2021	Belgium		(Rotor, n.d.)
46	Sanitary block	Rotor	Other	Architecture	2019	Belgium	19m²	(Rotor, n.d.)
47	Librebook bookshop	Rotor	Commercial	Interior Architecture	2016	Belgium	80m²	(Rotor, n.d.)

Geographically, the Netherlands leads with 18 projects, followed by Denmark (10), Belgium (5), the USA (4), and India (3) (Figure 1).



Country	Quantity	Percentage
Netherlands	18	38,30%
Denmark	10	21,28%
Belgium	5	10,64%
USA	4	8,51%
India	3	6,38%
Ghana	1	2,13%
Germany	1	2,13%
Switzerland	1	2,13%
Japan	1	2,13%
Chile	1	2,13%
Vietnam	1	2,13%
France	1	2,13%
TOTAL	**47**	**100,00%**

Figure 1 Breakdown of projects by country

Of the 35 projects with area data, sizes range from 19 m² to 81,711 m². Approximately 36% are under 1,000 m², while 15% exceed 10,000 m² (Table 2).

Table 2. Distribution of project areas

Area (m^2)	Quantity	Percentage
Unknown	12	25,53%
0-199	9	19,15%
200-999	8	17,02%
1000-1999	5	10,64%
2000-3499	6	12,77%
3500-9999	0	0,00%
10000-19999	1	2,13%
>20000	6	12,77%
TOTAL	**47**	**100,00%**

Functionally, the sample comprises 17 residential, six social, five office, and four commercial projects. There are also two religious, two industrial, two park, and 13 miscellaneous projects (Figure 2).

Function	Quantity	Percentage
Housing	17	36,17%
Social	6	12,77%
Office	5	10,64%
Commercial	4	8,51%
Industrial	2	4,26%
Park	2	4,26%
Religious	2	4,26%
Social + Commercial	1	2,13%
Social + Educational	1	2,13%
Public	1	2,13%
Educational	1	2,13%
Commercial + Hospitality	1	2,13%
Hospitality	1	2,13%
Commercial	1	2,13%
Other	1	2,13%
Housing + social	1	2,13%
TOTAL	**47**	**100%**

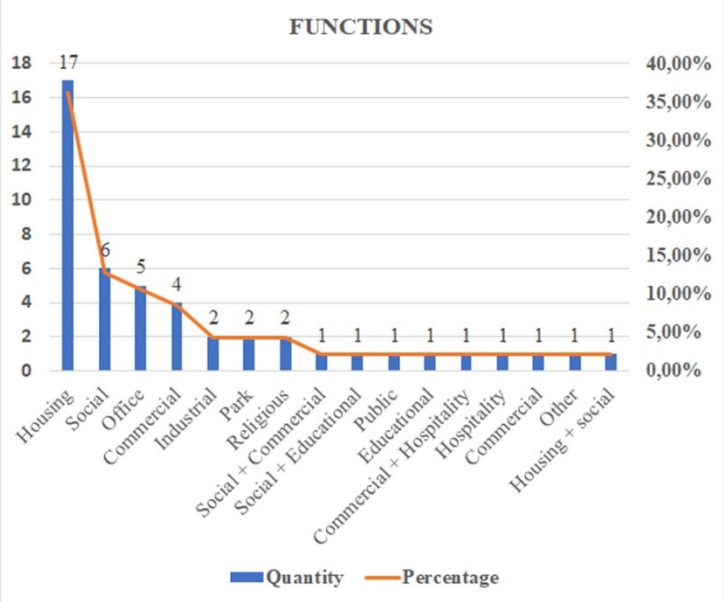


Figure 2. Functions of the Projects

Thirty-six projects are architectural works (including one temporary structure), nine are interior designs, and two are landscape projects, all post-2000.

Firms specializing in reuse dominate the sample: Lendager Group and Superuse Studios each have 11 projects, followed by Architectuur Maken (6) and Rotor (4).

Material Features of Selected Projects

Across the 47 projects, 272 instances of salvaged materials or products made from recycled materials were documented. The number of material types per project varies, from one (in seven projects) to a maximum of 21 salvaged materials and nine recycled products in the "Upcycle House" (Lendager, 2025). Nine projects specifically incorporated products manufactured from recycled materials, such as PET, circular concrete, and brick derivatives.

Thirteen projects reused 34 non-construction materials. Superuse Studios frequently employed materials like waste contour plates and signboards (four projects each) and decommissioned wind turbine blades (two projects). Other notable examples include waste cable reels in "Wheel Story House" (Wang, 2016) and "Villa Welpeloo," and vegetable crate timber and oil cans in "Manav Sadhna" (Rethinking The Future, 2022). "Villa Welpeloo" also features steel beams from a textile machine and a used scissor lift (Superuse, 2025).

Wood was the most prevalent salvaged material, used 40 times across 30 projects. It was followed by brick (10 projects), steel (7), glass (6), and tiles (3). Regarding building elements, windows were reused in 18 projects (20 instances) and doors in 11 projects (12 instances). Insulation materials were reused in nine projects, lighting in seven, tables in six, while kitchen cabinets, chairs, and sanitary fittings were each reused in three projects.

Disassembly Properties of Selected Projects

Design for deconstruction aims to facilitate future disassembly, enabling adaptability during a building's operational life and maximizing material reuse at the end of their service life (Arup, n.d.); therefore, it is also referred as design for future reuse. However, only two projects in the sample were designed for disassembly: "The Circular Pavilion" (Archdaily, 2015) and "KEVN" (Superuse, 2025), both employing dry construction techniques.

Eco-Friendly Strategies of Selected Projects

While circular design is inherently eco-friendly at a macro scale, this study also examines which specific operational-phase strategies reuse-oriented projects employ.

Sixteen of the 36 architectural projects implemented such strategies. Five are by Lendager Group and three by Superuse Studios. Photovoltaic panels are the most common (eight projects), followed by green roofs (six projects) and rainwater harvesting (three projects)

Other notable strategies include a carbon-neutral radiation heater in "Kamikatz Public House" (Castro, 2018), a nature-integrated design in "The Canaan" (Gogoi, 2020), water-to-air heat pumps in "Resource Rows" (Lendager, 2025), and an estimated 76,551 kg CO_2 saving in "Hortus Ludi" (Architectuur Maken, n.d.).

In addition, three projects stand out for their more advanced approaches. The first is UN17, a laboratory for the U.N. sustainable development goals; where rainwater is harvested, vegetables and ecological food are produced locally. It is designed to generate surplus energy for external distribution as power and heating. Roof gardens aim to enhance neighbourhood biodiversity (Lendager, 2025).

The "Jewish Reconstructionist Congregation Synagogue" project's bioclimatic design includes local planting to reduce water use in a special way, tinted glasses to reduce solar gain, insulated curtain walls and stairwells that act as buffer zones; in addition to sensor windows activating a rooftop fan to ventilate and cool the building (AIA, n.d.).

The Boschgaard project stands out for its social aspects, self-sufficiency, passive measures, and biodiversity features. It achieves a 70% CO_2 reduction compared to the current standard. This is accomplished through building orientation, insulated building envelope, photovoltaic cells, and geothermal heat usage. Ground probes provide stable heat for heat pumps, and rainwater is harvested. All roofs and open areas are designed to promote high biodiversity. Additionally, since the project is intended for a community, many spaces, as well as tools and vehicles, are designed be shared. Both the site garden and adjacent urban space will be managed by residents and cultivated together with neighbours (Superuse, 2025).

Conclusion

This review analysed 47 projects to understand reuse practices within the circular economy, a critical response to C&D waste and resource consumption.

The concentration of cases in Northern Europe (34 projects) aligns with regional environmental policy strengths, as evidenced by high EPI rankings for Germany (3rd), Finland (4th), and Sweden (6th) (Block et al., 2024).

The sample's diversity in scale challenges the notion that reuse supply chains cannot handle large orders (Ali, 2019). The variety of functions (17 residential, 30 non-residential) demonstrates demand across sectors.

The prevalence of projects post-2008 and the dominance of specialized firms (32 projects by Lendager, Superuse, Architectuur Maken, and Rotor) indicate that reuse-oriented design remains a nascent, specialist practice.

Nine projects incorporated products manufactured from recycled materials. Innovative applications of such products are particularly evident in the projects by Architectuur Maken (n.d.). Recycled products might be utilized when direct reuse is not feasible, as their integration typically necessitates an industrial process

Material analysis reveals that wood is the most prevalently salvaged material, followed by brick, steel, glass, and roof tiles. It is noteworthy that these materials were prioritized for direct reuse despite their inherent suitability for conventional recycling, underscoring a commitment to the higher principles of the circular economy. The reuse of non-construction materials (13 projects) expands waste diversion but introduces uncertain end-of-life management challenges. The innovative reuse of reinforced concrete (RC) building elements in "Karstadt Re-Parked" is particularly noteworthy given the RC structure's global prevalence (Lendager, 2025). Furthermore, the Indian architects represented in this sample by three projects employed a notably diverse material palette. Their designs demonstrate a bold approach, characterized by the innovative integration of salvaged components, biodegradable materials, and waste sourced from other sectors.

Only two of the projects are designed for deconstruction. While deconstruction is crucial for enhancing a building's adaptability during its operational life and securing a future material bank, its implementation faces significant barriers. The core challenge lies in procuring salvaged materials that are inherently suitable for disassembly from a market that is already constrained. Furthermore, upcycling existing salvaged materials for disassembly often entails prolonged design and construction timelines, leading to increased costs.

Conversely, the adoption of operational eco-friendly strategies in 16 architectural projects is significant, though local context must be considered for a full assessment.

In conclusion, this review underscores that while the number of reuse-oriented architectural projects remains limited, their successful execution across diverse scales, functions, and material palettes proves their practical viability. This scarcity highlights a significant gap between circular theory and built practice, necessitating stronger drivers for adoption, such as supportive policy frameworks and economic incentives. The findings presented here aim to contribute to the literature by translating isolated cases into a collective knowledge base, challenging the perception of reuse as a niche practice. However, the field

suffers from a lack of robust, quantitative, performance-based data of such projects. Therefore, this study not only maps the current state of practice but also serves as a call to action for more rigorous research. Future work must prioritize in-depth case studies with on-site verification and post-occupancy evaluations to generate the precise data required to validate, refine, and ultimately mainstream circular, reuse-driven methodologies in architecture

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DAYLIGHT PERFORMANCE OF TURKISH RESIDENTIAL BUILDINGS IN THE CONTEXT OF EN17037

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Daylight Performance of Turkish Residential Buildings in the Context of EN17037

Abstract: The TS EN 17037:2019 standard is the Turkish version of the European Standard EN 17037, which was first published in 2018. The standard is not yet included in the Turkish building regulations and covers residential and non-residential buildings. The requirements stated by EN 17037 have been found hard to reach for existing residential spaces in Northern Europe, while assessments for southerly countries like Türkiye are currently limited. This article assesses the daylight provisions of 115 spaces in a total of 5 Turkish residential buildings representing typical newly constructed apartment buildings constructed in the last 2 years in Türkiye. The results show that none of the spaces reach compliance with the minimum requirements from EN 17037. This opens a discussion on both the quality of daylight in Turkish dwelling and the feasibility of current EN 17037 for existing buildings.

Keywords: residential buildings; daylight performance; EN17037; urban density.

Introduction

Daylight in buildings improves health and wellbeing in buildings, can reduce the energy use (Sepúlveda et al., 2022), and increase the economic value of spaces (Turan et al., 2020; Pizarro & Gentile, 2019). On this basis, the first European Daylight in Buildings standard (EN 17037) was published in 2018 and adopted as Turkish national standard TS EN 17037:2019. The standard covers four quality aspects of daylight: (1) daylight provision, (2) view out, (3) sunlight exposure, and glare protection, with (1) being at the focus in this article. The standard is not yet included in the national binding building regulation (Kılıç & Yener, 2025). Research conducted mainly in the northern European context suggests that the criteria for daylight provision established by EN 17037 are difficult to reach. Information from southern climates is scarcer. In addition, the Turkish national regulation recently dropped existing daylight requirements based on Window-to-Floor area Ratio (İzmir Metropolitan Municipality [IMM], 2013; IMM, 2021) With daylight gaining importance in sustainable buildings, it is expected that the requirements will be reintroduced. As TS EN 17037:2019 may serve as an excellent framework for new requirements, it is of utmost importance to verify whether such requirements can be complied in the local context.

To the scope, this article investigates the daylight provision in five existing residential buildings located in Izmir, Türkiye and relates that to the current TS EN 17037:2019 recommendations.

Literature Review

Daylight requirements in European building codes remain limited and often rely on simplified metrics. While some regulations apply across building types, others focus mainly on residential applications. The most common compliance path is based on the window-to-floor ratio (WFR), due to its ease of use and measurement.

Several countries continue to use WFR as the primary indicator. For example, Italy mandates a WFR greater than 12.5% or an average daylight factor (DF) above 2% for residential spaces. Poland and Slovenia require WFRs of over 12.5% and 20%, respectively, while the Netherlands sets the threshold at 10% (Jin et al., 2025). Denmark introduced a WFR requirement in 1995 and later added an optional DF-based compliance route in 2008. In 2018, Denmark incorporated target illuminance as a third option, although reliance on WFR persists (Rogers et al., 2025).

Norway integrated daylight into its building code in 1997, originally following Swedish standards, which offered compliance via WFR or point daylight factor (DFp). By 2017, Norway required an average DF of 2% for non-residential buildings, while retaining WFR for residential use. Sweden adopted daylight requirements in 1976, initially using DFp and later incorporating WFR through the SS 914201 guideline. Though DF remained relevant between 1993 and 2014, it was not explicitly mentioned in the code. More recently, median DF has gained industry acceptance as a more robust metric (Rogers et al., 2025).

Overall, reliance on WFR dominates across Europe, limiting the adoption of more advanced methods such as DF or climate-based metrics. Most practitioners are unfamiliar with dynamic daylight analysis, and DF calculations are not standard in daily workflows.

The European Standard EN 17037 sets three levels of daylight provision—minimum, medium, and high—with two assessment methods: daylight illuminance and daylight factor (DF).

The illuminance-based method requires that at least 50% of the floor area must receive a target illuminance (ET) for 50% of daylight hours, and 95% must meet a lower threshold (ETM). For example, the minimum level requires 300 lx and 100 lx for respectively 50% and 95% of the floor area. The DF-based method translates the illuminance criteria into DF thresholds that vary by location, although discrepancies between the two methods have been identified (Konuk Taştan et al., 2024). For instance, in Istanbul, climate data would yield

specific DF values (e.g., D ≥ 0.6% for 100 lx, D ≥ 1.8% for 300 lx), which must be met across 95% and 50% of the floor area, respectively.

Although EN 17037 is not yet formally adopted in Türkiye, it provides a clear performancebased framework that could guide national Turkish regulations. In such context, it becomes fundamental to understand how the Turkish building stock would perform if compared to the current EN 17037 recommendations.

Methods

Five residential models representing different building typologies were analysed to evaluate the compliance of EN 17037 daylight standards with current residential building practices in Türkiye.

Selection of models

First, according to the Planned Areas Zoning Regulation (2021) detached buildings (ayrık nizam) are those that do not adjoin neighbouring structures on any side; attached buildings (bitişik nizam) are adjacent to one or more buildings on neighbouring parcels and often share walls; block buildings (blok nizam) refer to buildings with predetermined frontage length, depth, and height that span across multiple parcels, and may include semi-detached or twin building configurations (IMM, 2021). Since these typologies directly influence the availability and distribution of daylight in interior spaces, incorporating a representative sample from each type is essential to assess the applicability of the EN 17037 standard in the urban context.

Second, the housing stock data for the city of İzmir was analysed based on information retrieved from a widely used real estate listing platform for sales and rentals in Türkiye. According to the data at the time of the search (03.06.2025), 27 503 of the 55 422 units listed for sale, and 16 607 of the 25 965 units listed for rent, were either 1-bedroom (1+1) or 2-bedroom (2+1) apartments (Endeksa, 2025). These figures indicate that such unit types constitute a significant portion of İzmir's housing market.

Eventually five residential models were selected to represent both the predominant building typologies and common apartment configurations.

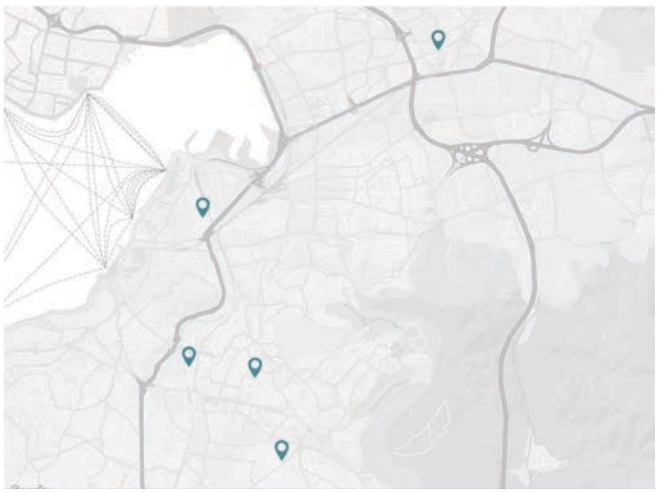

Figure 1. Location map of the selected buildings.
Notes. This map covers the area of İzmir between latitudes 38.365° and 38.474° North, and longitudes 27.096° and 27.268° East.

Simulations

The five residential buildings were modelled in Rhinoceros 3D following best practice for daylight modelling (Dubois et al., 2024). Surrounding buildings were modelled as blocks based on data from municipal maps and the Turkish Land Registry and Cadastre Information System (Tapu ve Kadastro Genel Müdürlüğü [General Directorate of Land Registry and Cadastre – TKGM], 2025), while the building plans were based on original approved architectural drawings sourced from the relevant municipal authorities. The interior spaces analysed in the simulation were labelled by function as living room, bedroom (room), and kitchen, if the kitchen and living room are not combined. These summed up to a total of 115 regularly occupied daylit rooms that were further analysed.

Climate-based daylight simulations were performed using Ladybug and Honeybee plugins within the Grasshopper. The simulations were structured in accordance with the illuminance method of EN 17037, where the minimum criteria for daylight provision requires that 100 lx and 300 lx are reached for 95% and 50% of the floor area for 50% of the daylight hours. The surface reflectance values, and Radiance simulation parameters used in the analysis are presented in Table 1.

Table 1. Settings used in simulations.

Surface properties					
Reflectance values					Transmittance
Ceiling	Ground	Wall	Floor	Surrounding	Glazing
0.7	0.2	0.5	0.2	0.2	0.7

Radiance settings												
-ab	-ad	-as	-c	-dc	-dp	-dr	-ds	-dt	-lr	-lw	-ss	-st
6	25000	4096	1	0.75	521	3	0.05	0.15	8	4e-07	1	0.15

All simulations were configured under comparable conditions across the different building models to ensure consistency. Details of the 3D models and the associated apartment and room IDs are provided in Figure 2 and Figure 3.

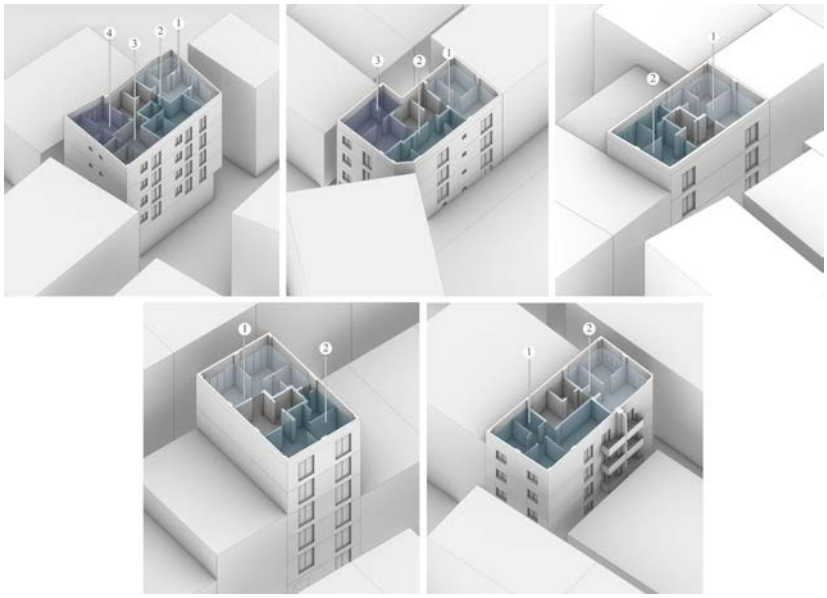

Figure 2. Spatial distribution and identification of apartments in selected buildings (3D models).

Figure 3. Layout plans showing room identification in selected buildings.

The models were further checked in terms of Window-to-Floor area Ratio (WFR). The urban context and building density were assessed using two key urban density indicators: Floor Area Ratio (FAR) and Building Coverage Ratio (BCR). FAR represents the ratio of a building's total floor area to the plot area, while BCR indicates the proportion of the plot area covered by the building's footprint (Godoy-Shimizu et al., 2021). According to Bolen et al. (2007), FAR values up to 1.80 and BCR values around 0.25 to 0.30 are recommended. Exceeding these limits, especially when FAR goes beyond 2 and BCR surpasses 0.30, can negatively impact residential quality.

Findings

A total of 115 rooms across five buildings in İzmir were evaluated according to the daylight illuminance thresholds of 100 lx and 300 lx as defined in EN 17037 (Figure 4). The findings indicate that none of the rooms in any of the buildings met the 100 lx criterion for 95% of the area. This suggests a generally insufficient access to natural daylight within the examined residential units.

Regarding the 300 lx level, limited compliance was observed. Only 14% of the 36 rooms in the first building, 32% of the 22 rooms in the second, 6% of the 16 rooms in the third, 50% of the 22 rooms in the fourth, and 21% of the 19 rooms in the fifth building met the standard. These results demonstrate significant variability in daylight performance among the buildings, with an overall low compliance rate.

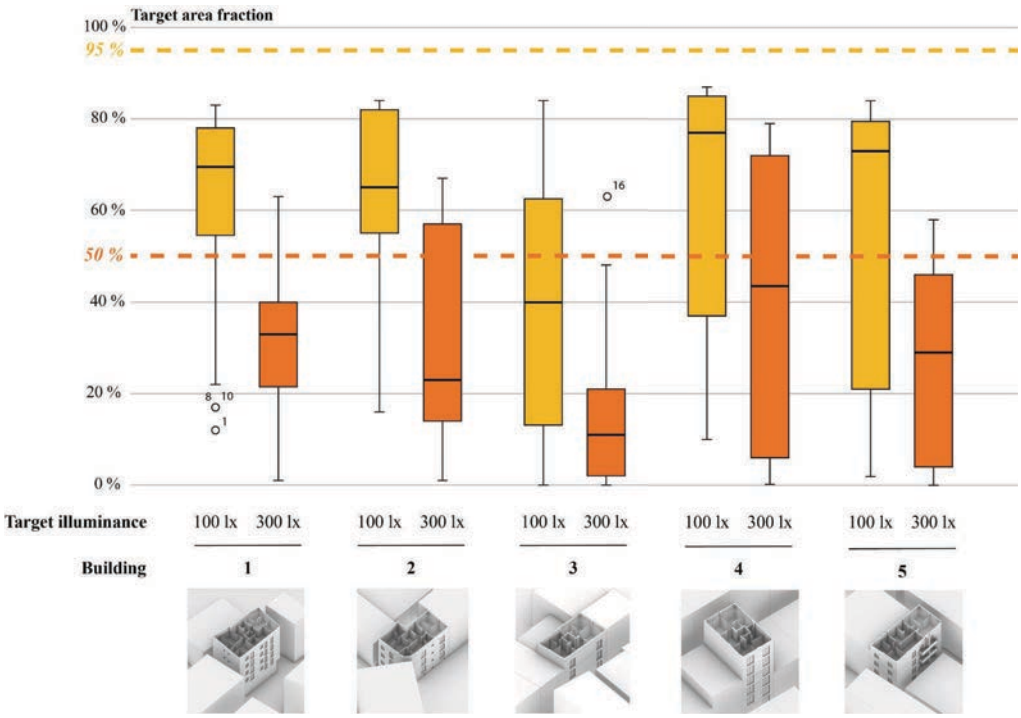

Figure 4. Reached area fraction per room in buildings according to the minimum target illuminance requirements provided by EN17037 (E_{TM} = 100 lx and E_T = 300 lx).

To investigate the underlying reasons for this limited performance, window sizes were analysed against the 1/8 window-to-floor area ratio stipulated in the national regulation from 2013. The analysis revealed that 92% of the 115 rooms met this requirement, indicating that inadequate daylight access cannot be attributed solely to insufficient window dimensions.

According to the analysis results, the BCR values in all five buildings exceeded the suggested threshold. The highest BCR was recorded in Building 4 (0.66), while the lowest was observed in Building 2 (0.39). These findings indicate that the buildings occupy a large portion of their plots, which may create significant shading effects both on their own interiors and on surrounding buildings, thereby limiting daylight access.

When the FAR values are examined, it is seen that the first three buildings remained below the limit, with values of 1.88, 1.46, and 1.66, indicating that they are still close to the threshold. In contrast, the last two buildings exceeded the limit, with FAR values of 2.87 and 2.02. This comparative assessment reveals that high BCR and FAR values, due to their impact on urban density, play a significant role in shaping daylight performance.

Discussion and Conclusion

The analysis of five buildings located in İzmir provides useful insights regarding daylighting in the local building stock. First, the stringent daylight requirements outlined in EN 17037 prove to be challenging to meet under current urban conditions.

The lower compliance with the E_{TM} target in respect to the E_T target suggests that rooms are probably quite deep in respect to the window size. Balconies may play a role here too. The E_{TM} = 100 lx target is reached for about 75 % of the space area for half of the daylight hours in all buildings but building 3. These mean that some areas of the rooms in whole buildings are generally dark, with building three having several rooms with more than 60 % of the area below 100 lx.

The poor compliance rates raise questions about the practicality and applicability of these standards in the context of typical mid-rise residential developments in İzmir, where developments have been guided for years by simple WFR approaches. On the other hand, the WFR approach, which is independent from climate and urban context, does provide a very limited understanding of actual daylight conditions. Current daylight provisions, as regulated by window dimensions alone, are insufficient to ensure adequate natural lighting.

A better understanding of context, including the urban one, is needed. In this perspective, one key observation is that Floor Area Ratio (FAR), commonly used as an indicator of urban density, does not fully capture the factors influencing daylight penetration. Although three of the buildings remained below the FAR limit, their daylight performance was still poor, indicating that FAR alone is not a sufficient descriptor of daylight access.

While the daylight performance of the investigated buildings is certainly poor, local needs and specific climatic conditions should still be understood and discussed. For example, are buildings designed to provide shelter from daylight - and thus solar gains - rather than accommodating daylight provision? Given the specific context, increasing daylight provision would certainly mean increasing the light quality of buildings, but it would also affect energy and environmental performance, as well as, potentially, thermal comfort.

The European standard EN17037 provides definitions of good daylight, and it harnesses them with target values that are applied throughout Europe and for all building typologies. The standard may provide a basis for calculating good daylighting in national and European regulations. Depending on which regulation is concerned, legislators should be aware that some targets in the standard are hard or impossible to be reached in some situations.

It is worth discussing whether such targets should be adapted to different contexts, for example acknowledging the *status quo* in some areas, facilitating a slow transition towards better daylit buildings. This should not be interpreted as to yield to poor urban development and building design, rather as a recognition of good daylighting. One suggestion could be to introduce additional lower targets in the standard, describing them as leading to poor daylighting and that could be accepted only in specific conditions - e.g. existing buildings in existing dense urban environments or urban context. That would not undermine the definition of good daylighting but would facilitate a wider adoption of the standard in national regulation, eventually raising awareness about daylighting among practitioners.

To conclude:

- the current building stock in İzmir largely fails to comply with the current EN17037 requirements for daylight provisions, but it does largely comply with a simple WFR approach;
- inconsistencies between the EN17037 and WFR compliance are possibly related to urban densities;
- a recognition of local contexts and situations is perhaps needed in the EN17037.

Acknowledgments

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DESIGNING WITH DAYLIGHT: NATURAL LIGHT STRATEGIES IN LOUIS I. KAHN'S EDUCATIONAL BUILDINGS

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Designing with Daylight: Natural Light Strategies in Louis I. Kahn's Educational Buildings

Abstract: This study aims to reveal how Louis I. Kahn employed daylight as a spatial design device in his educational buildings. The research offers a comparative analysis of the Exeter Library, the Indian Institute of Management Ahmedabad, and the Salk Institute for Biological Studies based on six criteria: system of daylight entry, light control strategies, interior placement, spatial impact, climatic responsiveness, and poetic use of light. The findings indicate that Kahn conceived daylight not merely as a functional lighting element but as a poetic and directive force that shapes architectural identity. Despite contextual and programmatic differences, Kahn's daylight strategies demonstrate a strong ability to generate holistic, meaningful, and inspiring spatial experiences in educational environments. Thus, the study underscores the continued relevance of daylight as a critical reference for contemporary educational design.
Keywords: Louis I. Kahn; natural light; educational buildings; architectural design; daylighting strategies.

Introduction

As one of the foremost architects of the twentieth century, Louis I. Kahn regarded natural light as a fundamental design element shaping his architecture. Kahn begins architecture with the "making of a room" and asserts that "a room is not a room without natural light," defining the very existence of space through light (Uddin, 2008). Throughout his career, he developed a wide range of solutions — from small lighting devices to complex dome systems — to bring light into interiors in the most creative ways. In Kahn's architectural practice, light functions not only as an atmospheric and meaning-enhancing element, but also as a deeply integrated design strategy connected to structure, material, and function (Liu et al., 2025). His orchestration of light transforms space into both a functional and spiritual experience, playing a decisive role in the formation of architectural identity. Accordingly, one of the most significant building types in which light must be experienced through both functional and spiritual dimensions is educational architecture (Heschong, 2002). While providing physical comfort within learning environments, it also carries the responsibility of creating an inspiring and motivating atmosphere for users. In spaces of differing functions such as libraries, laboratories, classrooms, and research areas, the quality, distribution, and continuity of light define spatial perception and performance. Therefore, the integration of daylight into design should be considered not only a technical requirement but also an educational strategy in school buildings (Acosta et al., 2019; Mehta, 2020).

The central research question of this paper is: How did Louis I. Kahn configure the use of natural light in the educational buildings he designed? Accordingly, the aim of this study is to comparatively examine daylight use strategies in three of Kahn's award-winning projects classified within the educational typology. The study evaluates daylight entry systems, light

control methods, interior use, spatial effect, climatic appropriateness, and poetic use of light. The scope is limited to the Exeter Library (Phillips Exeter Academy Library), the Indian Institute of Management (IIM) Ahmedabad, and the Salk Institute for Biological Studies. The analysis is based on literature review, plan–section examination, and interpretation of photographic documentation.

Literature Review

In Louis I. Kahn's architecture, natural light is considered not only as a means of illumination, but also as a defining element of architectural meaning, spatial atmosphere, and functionality. Kacel and Lau (2018) examined the collaboration between Kahn and lighting designer Richard Kelly from both theoretical and technical perspectives, demonstrating how daylighting solutions implemented in the Yale University Art Gallery, the Kimbell Art Museum, and the Yale Center for British Art contributed to spatial quality. Jansen (2012) discussed the universal role and changing nature of natural light in architectural design, emphasizing how window openings and spatial organization transform user experience — a fundamental aspect in understanding Kahn's light-space interaction. Fordham (2018) analyzed passive solar control strategies in Kahn's Radbill addition to the Philadelphia Psychiatric Hospital, revealing how elements of natural ventilation and shading balance daylight with thermal comfort, and highlighting Kahn's sensitivity to climatic performance as well as aesthetics. Rahman (2020), through the Kimbell Art Museum, evaluated Kahn's relationship between light and form using both qualitative and quantitative methods, illustrating how top-lighting and borrowed light from inner courts create a balanced luminous environment. While existing literature offers in-depth analyses of Kahn's use of light across various building types, comparative studies specifically focused on daylighting in award-winning educational buildings remain limited. This study aims to address this gap by systematically comparing daylight strategies in projects such as the Exeter Library, IIM Ahmedabad, Yale Center for British Art, and the Salk Institute.

Indian Institute of Management (IIM)

In 1962, after designing the National Assembly Building in Bangladesh, Louis I. Kahn was invited by Indian architect Balkrishna Doshi to design the 60-acre campus for the Indian Institute of Management (IIM) in Ahmedabad. Kahn argued that learning does not begin and end in the classroom alone, but continues in corridors, courtyards, and particularly in communal

areas such as the “Kahn Plaza” that he created in this project. He blended modern architecture with Indian architectural tradition, using local materials such as brick and concrete and designing large geometric façade openings inspired by abstract patterns found in Indian culture. These openings functioned not only as aesthetic elements, but also as light wells and natural cooling devices, protecting the interior from the harsh desert climate. The porous façade filtered sunlight and air while also creating new social gathering spaces for students and faculty. By reinterpreting the principles of India’s traditional education system, Kahn extended learning beyond the classroom and introduced an institute concept based on interdisciplinary collaboration. Thus, not only classrooms but also transitional zones and open spaces supporting continuous learning were placed at the heart of the design. Although Kahn passed away in New York in 1974 before the project was completed, the design is considered a significant example of how modern architecture can be positioned within a specific cultural context (Kroll, 2025). The diagrammatic representation of daylighting strategies in the Indian Institute of Management (IIM), using plan and photographic illustrations, is provided in Figure 1.

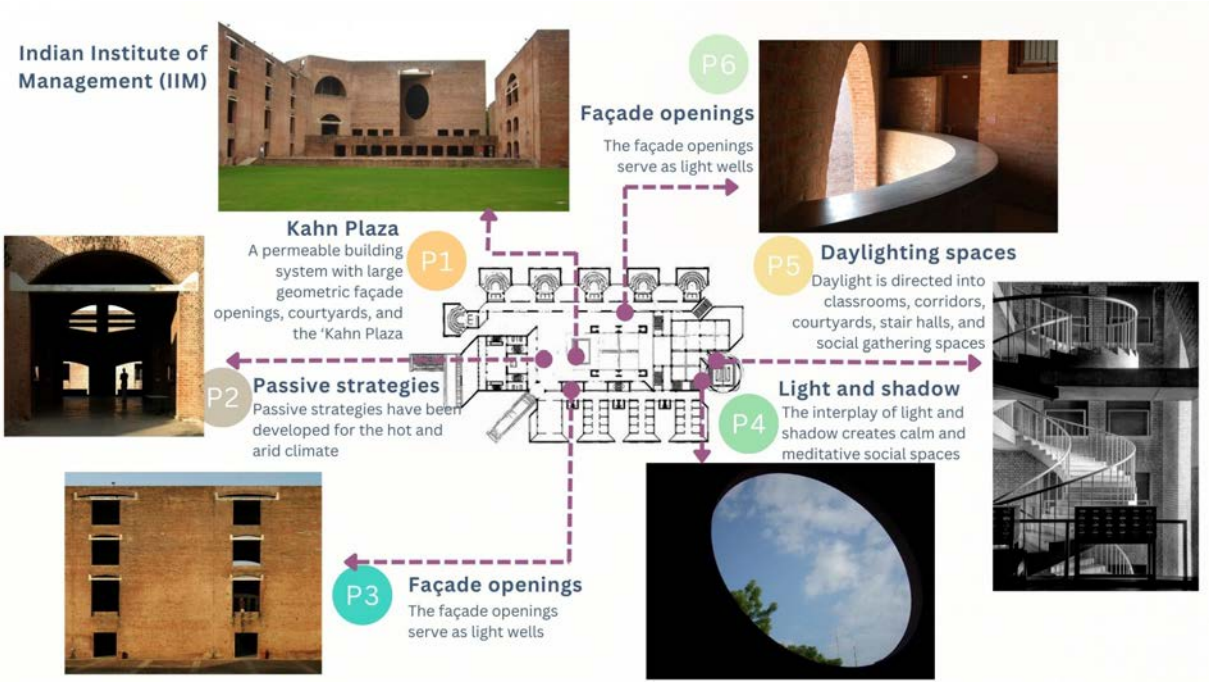

Figure 1. Diagrammatic representation of daylighting strategies in the Indian Institute of Management (IIM) based on plan and visual documentation (images adapted from Kroll (2025) online source).

Exeter Library

In 1965, Phillips Exeter Academy commissioned Louis I. Kahn to design a new library for the school. The main requirements were a brick exterior compatible with the Georgian-style

campus buildings and an interior environment ideal for study. With his mastery of brickwork and commitment to natural light, Kahn successfully met these expectations. The library follows a square plan measuring 111 × 111 ft. From the ground floor, broad stone stairs lead to the first floor, where the entrance immediately reveals the spatial relationship between the reference area, circulation desk, and book stacks. The main reading room rises to a height of 21 meters and receives daylight through a large skylight and broad northwest-facing façade openings. The upper floors house book stacks for 250,000 volumes, computer laboratories, multimedia viewing and listening areas, faculty offices, and 210 private study carrels. Exeter-made brick on the exterior and stone, slate, and natural wood inside create a warm atmosphere, enhanced by daylight. Completed in 1972, the building reflects Kahn's design approach, which integrates spatial quality with functionality (Perez, 2025). The diagrammatic representation of daylighting strategies in the Exeter Library, using plan and visual illustrations, is presented in Figure 2**.**

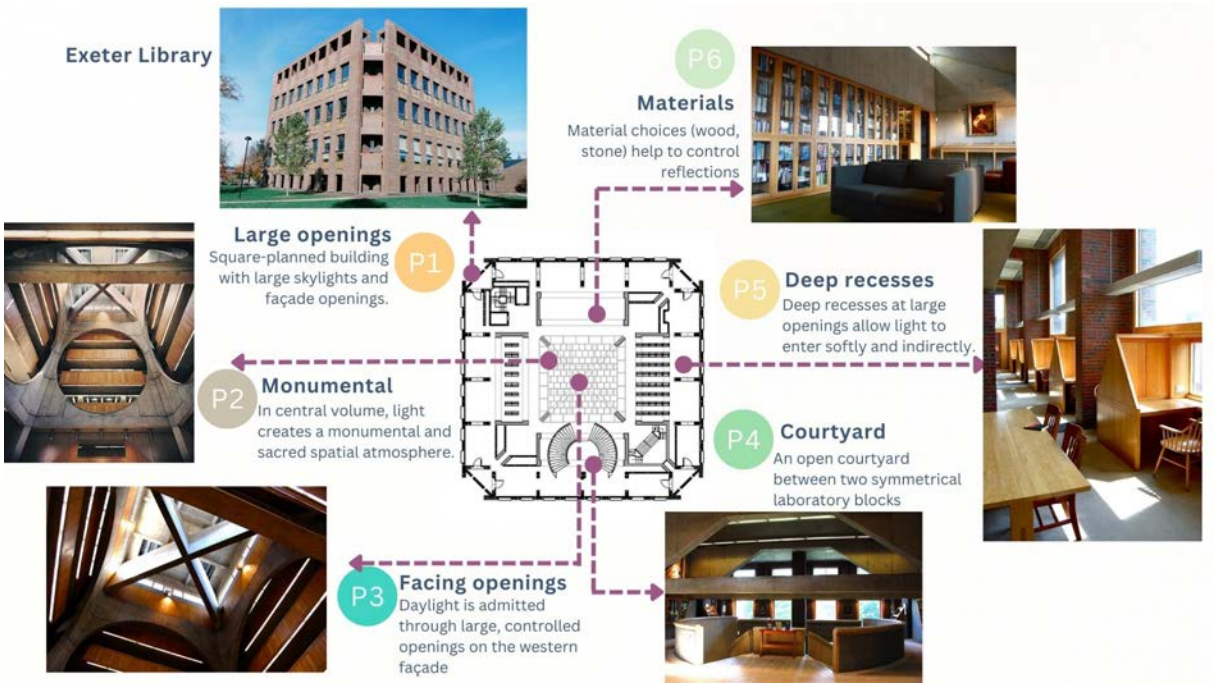

Figure 2. Diagrammatic representation of daylighting strategies in the Exeter Library based on plan and visual documentation (images adapted from the online source Perez (2025)).

Salk Institute for Biological Studies

In 1959, Jonas Salk commissioned Louis I. Kahn to design a research facility on the Pacific coast in La Jolla. Salk requested an architecture that emphasized the humanistic dimension of scientific progress while also possessing a striking aesthetic quality. Kahn's

design was organized around two symmetrical laboratory blocks separated by a stone-paved courtyard; the project is notable for its monastic layout, daylight-drawing courts, and spatial configuration oriented toward the sea. The laboratories were designed to be flexible, open, and easily reconfigurable, with service floors separated from research floors, allowing for technological updates and maintenance without disrupting scientific work. Materials such as concrete, travertine, and teak generate a minimal yet monumental architectural identity. The water channel in the central void visually connects the interior to the horizon. Opened in 1965, the Salk Institute demonstrates the potential of architecture to create an inspiring and enduring environment for scientific research through the unity of functionality and aesthetics (Fiederer, 2025). The diagrammatic representation of daylighting strategies in the Salk Institute for Biological Studies, using plan and visual illustrations, is presented in Figure 3.

Figure 3. Diagrammatic representation of daylighting strategies in the Salk Institute for Biological Studies based on plan and visual documentation (images adapted from the online source Fiederer (2025)).

Methods

This study conducts a comparative daylight analysis of three award-winning educational buildings designed by Louis I. Kahn: the Indian Institute of Management Ahmedabad (1962–1974), the Exeter Library (1965–1972), and the Salk Institute for Biological Studies (1959–1965). As a method, a qualitative literature review was first carried out; subsequently, the

relationship between space and light was examined through spatial analysis, plan–section studies, and photographic interpretation. During the investigation, Kahn's daylight-oriented design approaches were evaluated through architectural documents, secondary sources, academic publications, and archival materials.

The buildings were analyzed according to methodological criteria established to evaluate the multidimensional integration of natural light into architectural composition. In this context, the systems through which daylight enters the buildings — such as skylights, façade openings, and courtyards — were examined first; then, architectural strategies that control the quality and intensity of light, such as shading elements, deep window recesses, and light filters, were evaluated. Daylight placement within interiors was considered based on its use in spaces with different functions, such as reading rooms, circulation areas, and laboratories. In parallel, the atmospheric effects of light on spatial perception, functionality, and spiritual experience were analyzed under the heading of "spatial effect." Additionally, each building's geographical and climatic context was evaluated in terms of the suitability of its daylight strategies to local environmental conditions; finally, how Kahn used light as a poetic, structural, or directive design tool was interpreted under "mode of light utilization." Each building was assessed individually within these criteria, after which the findings were tabulated and a comparative interpretation was made.

Findings and Discussion

The three buildings examined reveal how Louis I. Kahn diversified the use of daylight according to different contextual and functional requirements within the scope of educational architecture. Accordingly, the buildings were evaluated in terms of daylight entry systems, light control strategies, interior placement, spatial effects, climatic suitability, and the use of light as an architectural device, and the strategies unique to each project were systematically compared. The findings obtained according to these evaluation criteria are presented in Table 1.

Tablo 1. Evaluation of Daylight Use in Louis I. Kahn's Buildings

	Indian Institute of Management Ahmedabad	**Exeter Library**	**Salk Institute for Biological Studies**
Daylight Entry System	Geometric façade openings, courtyards, "Kahn Plaza"	Skylights and large northwest-facing glazing	Courtyard between two laboratory blocks, light wells, bridges

Daylight Control	Façade openings as light wells Porous surfaces filtering light.	Deep window recesses Wood–stone materials reducing reflections	Controlled west-facing openings Courtyard with reflective stone colour Water channel as guiding element
Interior Placement of Daylight	Classrooms, corridors, courtyards, social spaces	Reading hall, individual study carrels, circulation areas, gallery voids.	Laboratories, meeting rooms, circulation spaces, central courtyard
Spatial Effect	Light–shadow interplay creating meditative social spaces Extending learning beyond classrooms	Monumental 21 m-high reading hall, sacred spatial atmosphere	Monastic layout creating an inspiring atmosphere through light
Climatic Appropriateness	Passive cooling and ventilation adapted to hot-arid climate Daylight supports ventilation	Indirect daylight suitable for cold climate, glare-free illumination	Passive strategies for mild climate, openings oriented toward the sea for maximum daylight.
Mode of Light Utilizatio	Structural and directive: light spread across learning spaces	Poetic and functional: light as a representation of knowledge, enhancing the spirit of the space	Poetic and directive: light as an inspiring tool for scientific research

The three buildings examined in this study demonstrate how Louis I. Kahn balanced functionality, symbolism, and climatic sensitivity when integrating daylight into the architectural organization of his educational works. The findings reveal that although different instruments are employed in each building, Kahn considered light not merely as an illuminating element but as a fundamental form-giving component shaping the spirit of space.

The Indian Institute of Management Ahmedabad features a permeable building system that receives daylight through large geometric façade openings, courtyards, and the "Kahn Plaza," constructed with local brick and concrete (Kroll, 2025). The façade openings act as light wells; porous geometric surfaces filter and diffuse daylight while simultaneously providing natural ventilation. Daylight is directed not only into classrooms but also into corridors, courtyards, stair halls, and social gathering spaces. The interplay of light and shadow creates calm, meditative social spaces, extending learning beyond the classroom and fostering a collaborative and inspiring environment. Passive cooling strategies have been developed for India's hot and arid climate, with daylight also supporting ventilation to enhance indoor climatic

comfort. In this building, light is treated as a structural and directive element; it permeates all areas of learning, serves as a tool that interprets local culture within modern architecture, and defines the spatial character (Kroll, 2025).

Exeter Library, as noted by Perez (2025), was designed as a square-plan building that receives daylight through skylights and large northwest-facing glazing, with the tall central reading hall functioning as the main gathering space for light. The large façade openings are shaped with deep recesses, allowing daylight to enter softly and indirectly. The choice of interior materials—particularly wood and stone—helps control reflections while harmonizing the diffusion of natural light throughout the space. Daylight is most intensely used in the central reading hall, individual study carrels, circulation areas, and gallery voids that visually connect the different floors. In this way, daylight is not only an illuminating device but also a means of ensuring visual continuity between spaces. The central reading hall, rising to a height of 21 meters, creates a monumental and almost sacred spatial perception through the presence of light. Combined with wooden surfaces, light adds warmth to the atmosphere and fosters an environment that invites mental focus and concentration. The northwest-facing openings admit daylight without producing glare, while the skylights provide controlled light to the interior despite the cold climate. Ultimately, in the Exeter Library, light is employed as both a poetic and functional design tool. Positioned as a central architectural element, light represents knowledge while also reinforcing the spiritual effect of the volume, thereby functioning as a symbolic and defining feature of the architecture (Perez, 2025).

The Salk Institute for Biological Studies, designed by Louis I. Kahn, is organized around an open courtyard situated between two symmetrical laboratory blocks. The architectural composition includes west-facing openings, sunken light wells, and a system of towers and bridges, all of which allow daylight to penetrate effectively into the lower levels of the building. Daylight is introduced through large, carefully controlled western apertures. The stone-colored courtyard acts as a reflective surface, while the central water channel further directs and disperses the light across the space (Fiederer, 2025). Natural illumination is not confined to the exterior zones but is actively integrated into laboratories, meeting rooms, circulation areas, and the central courtyard, ensuring a cohesive distribution of light throughout the complex. The monastic character of the courtyard layout creates a meditative, inspiring, and timeless spatial atmosphere, where daylight plays a central role in spiritually reinforcing the research environment. This quality transforms the building into more than a functional research facility, endowing it with a contemplative and symbolic dimension. Climatically, the design employs

passive daylighting and ventilation strategies suited to California's mild environment. The building's orientation toward the sea enhances natural airflow while maximizing the use of daylight. In Kahn's approach, light is treated not only as a functional necessity but also as a poetic and directive architectural tool. It represents the spirit of scientific activity, serving simultaneously as an inspiring element and as a fundamental generator of spatial and symbolic meaning (Fiederer, 2025).

In comparison, it can be seen that Kahn developed context-specific daylight strategies adjusted to different climates and building programmes; yet in every case, light becomes a constitutive element of architectural identity. His daylight approach should thus be understood as a layered design strategy that cannot be reduced to a single technical solution and that evolves according to the meaning of space.

Conclusion

This study has comparatively examined Louis I. Kahn's architectural approach to daylight through three different buildings and revealed that light was employed not merely as a physical means of illumination but as a fundamental element shaping spatial identity. In the Exeter Library, daylight is carefully integrated into the spatial organization to evoke concentration, contemplation, and a sense of monumentality. At the Indian Institute of Management Ahmedabad, daylight encourages social interaction, continuity, and collective learning, reflecting Kahn's vision of education as an interdisciplinary and ongoing activity. In the Salk Institute, light is transformed into a poetic and symbolic medium, creating an inspiring atmosphere that resonates with the spirit of scientific exploration.

Although the method of introducing light, its control strategies, interior applications, and climatic responsiveness differ in each project, a common architectural attitude is evident: daylight is consistently elevated to a poetic and structural design tool that deepens the relationship between building, space, and human experience. This comparative analysis also demonstrates Kahn's sensitivity to local climatic and cultural conditions, showing that his daylight strategies were not only universal design principles but also contextually adapted solutions.

In this respect, Kahn's daylight philosophy in educational and research architecture stands as an inspiring reference for contemporary design practice. It highlights how light can transcend its functional role and become a formative force in shaping spatial meaning, atmosphere, and human interaction. Future architectural approaches can benefit from this

layered understanding of light as both a technical and symbolic design instrument, offering valuable insights for creating spaces that are climatically responsive, socially engaging, and experientially profound.

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EVALUATING DAYLIGHT PERFORMANCE IN A CULTURAL HERITAGE LIBRARY: A COMBINED SIMULATION AND MEASUREMENT APPROACH AT APİKAM

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Evaluating Daylight Performance in a Cultural Heritage Library: A Combined Simulation and Measurement Approach at APİKAM

Abstract: This study aims to evaluate the daylight performance of the cultural heritage APIKAM Library and to test the accuracy of digital simulation tools through comparison with on-site measurement data. Real-time illuminance measurements conducted between 08:00 and 12:00 on May 23, 2025, were digitally modelled using the Velux Daylight Visualizer software for the same time intervals. The simulation outputs and actual field data were comparatively analysed in terms of illuminances, spatial light distribution, and uniformity. The findings revealed that deviation rates ranged from as low as 1.7% to as high as 12.6%, depending on the time of day. These variations were primarily attributed to the limited capacity of the simulation software to accurately represent dynamic sky conditions, particularly during periods when direct sunlight is dominant.
This study exemplifies how validated digital simulations can effectively inform decision-making processes in the assessment of natural lighting strategies, especially in heritage buildings.

Keywords: daylight simulation, heritage buildings, lighting validation

Introduction and Background

Sustainable strategies for cultural heritage buildings increasingly focus on indoor environmental quality and user experience alongside physical factors like energy use (Balocco & Cecchi, 2020). In repurposed public spaces such as libraries and museums, lighting that supports user comfort is a key design aspect (Prihatmanti & Susan, 2016). Natural lighting in heritage buildings has been widely assessed using simulation and measurements, with metrics such as Spatial Daylight Autonomy (sDA), Daylight Factor (DF), and Annual Sunlight Exposure (ASE) (Marzouk et al., 2021; Piraei et al., 2022). Tools like Radiance, Honeybee, Diva, and Velux Daylight Visualizer are commonly used to analyze lighting's impact on comfort and energy use.

Examples from the literature demonstrate how sustainable interventions can improve daylight conditions while respecting conservation principles. For instance, adding an atrium increased sDA from 14.2% to 50.2% in a 17th-century Norwegian warehouse (Piraei et al., 2022), while skylight optimization at Egypt's Tosson Palace reduced ASE by 38% (Marzouk et al., 2021). Similar approaches include reversible window modifications (Prihatmanti & Susan, 2016), optical fiber textiles (Balocco & Cecchi, 2020), LED dimming, and advanced glazing strategies. Studies on Italian monasteries and libraries also highlight energy-efficient lighting improvements guided by standards like LEED v4.1 and EN 17037 (Balocco & Volante, 2019; Balocco et al.,2019; Shirzadnia et al., 2023), aiming for maximum daylight with minimal physical impact (Nocera et al., 2018).

Parallel research in educational environments has linked daylight to user comfort, physiological responses, and academic performance. The HEAD Project (Barrett et al., 2015) found lighting accounts for 21% of factors influencing student achievement, while other studies report variations in user preferences and comfort under different lighting conditions (Gkolompia, 2024; Kong & Jakubiec, 2021). These findings underline the importance of considering both performance metrics and human experience in lighting design.

However, simulation accuracy remains variable and depends on factors such as sensor placement and sky model calibration (Quek & Jakubiec, 2019; Reinhart & Breton, 2009). Reported deviations range from 0.6% to 45.5%, depending on methodology and software (Febriyursandi et al., 2019; Dabe & Adane, 2020). While precise modeling of lamps, surfaces, and material reflectance improves reliability, varied validation methods complicate direct comparisons across studies (Pacheco Diéguez et al., 2016; Drosou et al., 2016).

Within this context, the present study investigates daylight performance in the 272.81 m² upper-floor library of APIKAM, a historic modernist building in İzmir serving as an archive and museum (İzmirART, n.d.). The space, characterized by wooden floors, white walls, and fixed bookcases, receives natural light from the northeast façade. By comparing on-site illuminance measurements with Velux Daylight Visualizer simulations, this research not only evaluates simulation accuracy but also demonstrates how validated digital tools can inform user-centered, conservation-sensitive daylight design strategies for cultural heritage buildings.

Fig.1. APIKAM Library Photos

Methods

This study evaluates the accuracy of daylight simulation tools by comparing in-situ luminance measurements with simulation results. The selected case is the upper-floor library

(approx. 272.81 m²) of the Ahmet Piriştina City Archive and Museum (APIKAM) in Izmir, which receives natural light from the northeast facade and is used for both individual and group activities. (Fig.2.)

Fig.2. APIKAM Library

On-site illuminance measurements were conducted between 08:00 and 12:00 on May 23, 2025, when the eastern-oriented library receives the most effective natural light. This time frame was chosen to capture the dynamic changes in daylight during morning hours. Measurements were taken at a height of 0.75 m on the horizontal surfaces of reading desks near the windows to reflect typical user behavior. Separate data sets were created for each hour, allowing a time-based evaluation of lighting conditions across different user zones. Measurement points were selected based on interior use scenarios to enable a user-centered analysis.

To evaluate the accuracy and digital applicability of the measured data, the library space was modeled in Velux Daylight Visualizer. The model included accurate definitions of geometry, window openings, floor height, and orientation based on architectural plans. Surface reflectance properties were defined to match on-site materials: wooden parquet flooring, white-painted walls, and wood-textured fixed furniture—key elements influencing light reflection and diffusion.

The east-facing windows were rotated -90° to match real orientation, and Izmir's EPW file (latitude, longitude, UTC+3, annual climate) was integrated. Simulations were aligned with field measurement times, using the CIE Intermediate Sky to represent the morning’s diffuse, overcast light. Each hour was modeled as a separate scenario.

Simulation outputs, including numerical illuminance values and false-color visualizations, were analyzed for light distribution and intensity. These results were compared with actual measurements in terms of average illuminance and uniformity. The following image illustrates the lx meter positions used for real-time measurements in the space.

Fig.3. Locations of Lux Measuring Devices

This methodological approach aims not only to test the representation of the data collected in the field in the digital environment, but also to examine the reliability of light-based design strategies that can be applied in cultural heritage structures and their applicability in the decision support process. The parameters affecting the simulation accuracy (material reflectivity, furniture placement, window openings, orientation, etc.) thanks to careful modeling, inferences have been made about the potential of digital tools to contribute to the design process. In this context, the study proposes both a verification-based method and provides a qualified example for cultural heritage structures in terms of daylight design that prioritizes user comfort.

Table.1. Hourly Illuminance Measurements (Real Data – 23 May 2025)

Time	Min (lx)	Max (lx)	Average (lx)	Std. Deviation	Number of Measurements
08:00	0.0	485.0	131.8	214.1	321
09:00	0.0	485.0	125.4	209.7	273
10:00	0.0	485.0	128.8	212.3	314
11:00	0.0	485.0	118.7	206.3	375
12:00	0.0	485.0	132.1	213.9	284

Results and Discussion

On May 23, 2025, on-site illuminance measurements and simulation results from the APIKAM library were compared for the 08:00–12:00 interval, when the east-facing space receives the most intense natural light. Although measurements were not taken directly on user desks, selected points near the windows accurately represented typical reading and working zones at a height of 0.75 m.

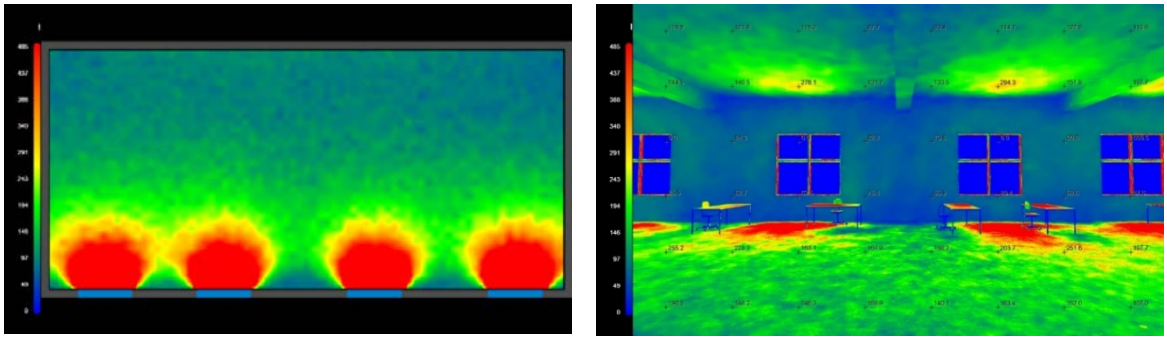
Measured average illuminance levels ranged from 129 to 137 lx, with a peak of 485 lx. These were compared with Velux Daylight Visualizer simulation outputs for the same hours.

The comparison focused on both average illuminance values and spatial light distribution. Differences ranged between 1–4% for most hours, reaching 12.6% at 11:00, indicating that while the simulation provided high accuracy overall, it showed reduced reliability during peak light conditions.

Table.2. Simulation vs Real Measurement Comparison

Time	Real Avg.(lx)	Real Max. (lx)	Simulation Range (lx)	Simulation Notes
08:00	131.8	485	0 – 450	Narrow red zones near windows; blue-green in inner zone
09:00	125.4	485	0 – 460	Expanding red areas; wider light diffusion
10:00	128.8	485	0 – 470	Most uniform distribution; balanced red-green pattern
11:00	118.7	485	0 – 480	Maximum red spread; light reaches deep into the room
12:00	132.1	485	0 – 485	Strong light on upper surfaces, fading toward rear interior

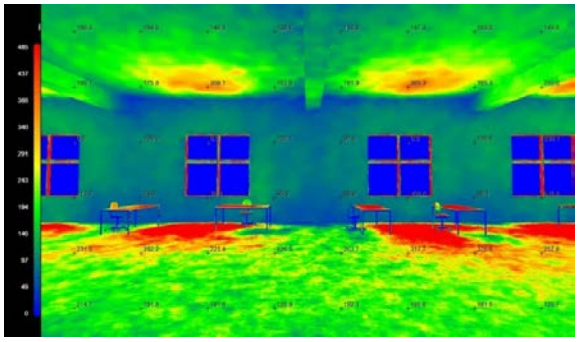
08:00 – As can be seen from Figs. 4–5., simulation showed low illuminance concentrated near window edges with limited spread inward, typical of low-angle or diffuse morning light. Measured illuminance was 137.3 lx; simulation was 131.8 lx (4% deviation). This close match indicates accurate modeling of key physical parameters and appropriate sky conditions, though limited horizontal light spread may affect visual comfort.

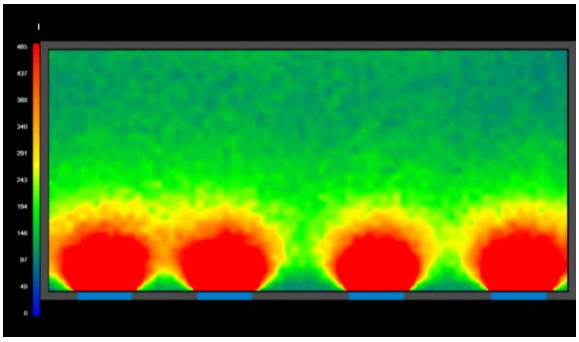


Figs. 4–5. 08:00 Simulation views of plan and elevation

09:00 – Simulation outputs at this hour show a noticeable increase in illuminance near the windows, with high lx values (indicated by red shades) on the floor. Light also begins to affect vertical surfaces, especially the ceiling, indicating a broader and more diffuse spread (Figs. 6–7.).

Measured average illuminance was 129.7 lx, while the simulation yielded 125.4 lx—a deviation of approximately 3.3%. This close match reflects the accurate definition of physical parameters (surface reflectance, window orientation, furniture layout) and the simulation tool's effectiveness in capturing morning light behavior. This hour marks a transition when daylight begins to enter more directly and uniformly, reaching deeper into the space and contributing to improved visual comfort and lighting uniformity.



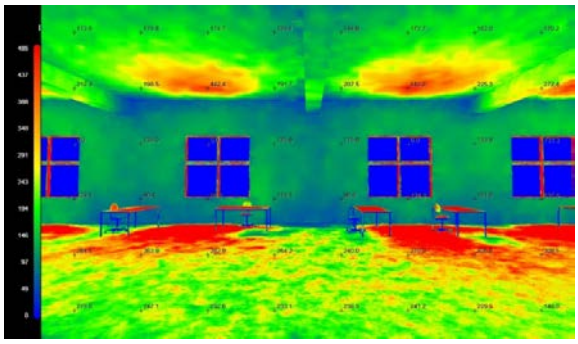
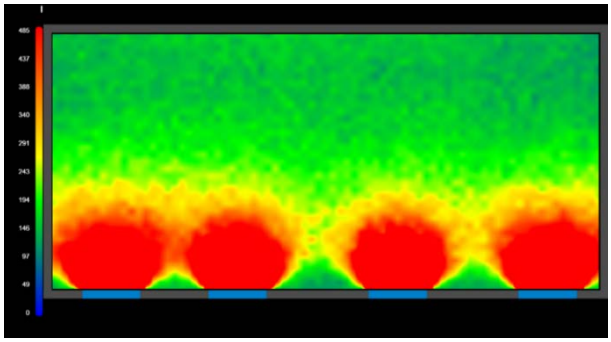


Figs. 6–7. 09:00 Simulation views of plan and elevation

10:00 – Figs. 8–9. indicate the most balanced light distribution at this hour, with homogeneous illumination on the floor and a warm yellow–orange spread on the ceiling, reflecting both adequate intensity and spatial uniformity.

Measured average illuminance was 137.3 lx, compared to 128.8 lx in the simulation—a deviation of approximately 6.2%. Although slightly higher than previous time periods, this difference still confirms the model's overall accuracy in integrating key physical parameters (surface reflectance, window orientation, furniture layout).

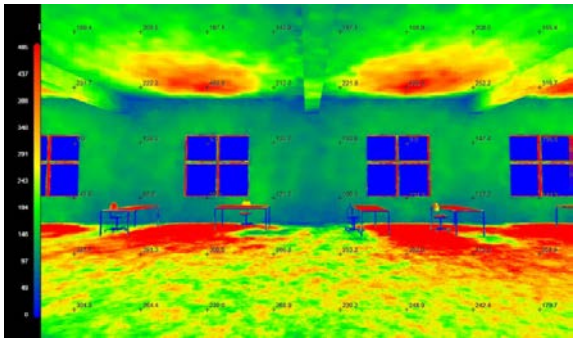
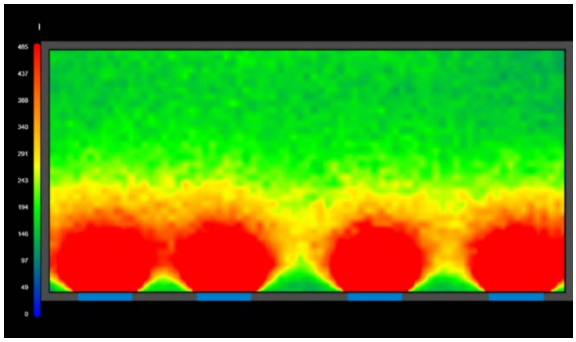
The even distribution of light across both horizontal and vertical planes at this time supports optimal visual comfort, enhancing conditions for focused and task-based activities (Roy et al., 2023). Thus, 10:00 stands out as one of the most favorable hours in terms of daylight performance for the studied space.

Figs. 8–9. 10:00 Simulation views of plan and elevation

11:00 – Simulation outputs show a sharp increase in illuminance, with extensive areas reaching 450–485 lx, especially on the floor (Figs. 10–11). These high values reflect strong direct sunlight entering the space. Measured average illuminance was 135.9 lx, while the simulation yielded 118.7 lx-a 12.6% deviation.

This larger discrepancy suggests the simulation's limited accuracy under intense light conditions. However, the general distribution patterns and luminous zones were still represented qualitatively well. At this hour, daylight reaches its peak, especially enhancing task lighting on desks near the windows and supporting visual comfort despite the numerical variation.

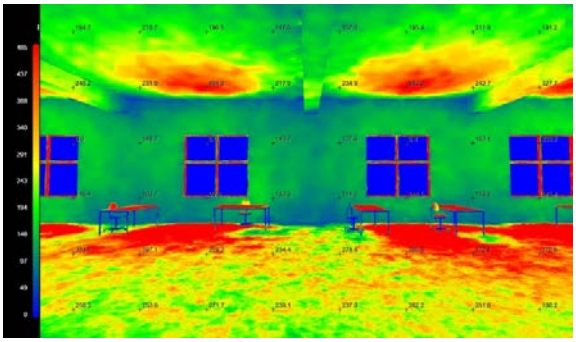



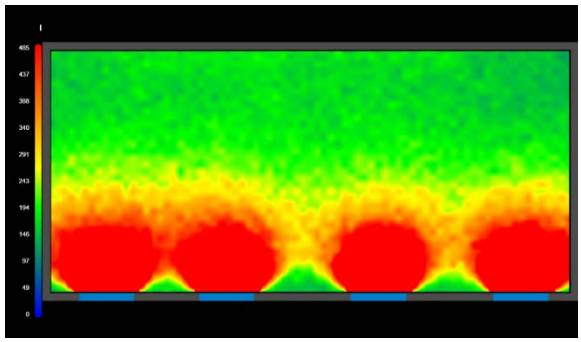
Figs. 10–11. 11:00 Simulation views of plan and elevation

12:00 – Simulation visuals show intense warm tones on the ceiling and continued horizontal light spread on the floor, though with reduced depth penetration. This is likely due to steeper solar angles, concentrating light on upper surfaces (Figs. 12–13).

Measured average illuminance was 134.4 lx, and the simulation result was 132.1 lx, yielding a minimal deviation of 1.7%. This close match confirms the effectiveness of the physical model parameters. Although light uniformity slightly decreases compared to earlier

hours, both task lighting and general visual comfort remain satisfactory. The simulation accurately captures the intensity and orientation of daylight for this time frame.





Figs. 12–13. 12:00 Simulation views of plan and elevation

Table.3. Summary of Light Spread and Distribution by Hour

Time	Light Spread	High-Intensity Area	Interpretation
08:00	Low spread	Small red zone near the wall	Sun is still low in the sky
09:00	Increasing spread	Expanding red areas	Daylight impact starts to increase
10:00	Most balanced spread	Smooth red-green transitions	Daylight hits from the most optimal angle
11:00	Maximum spread	Large red zone, deep green-blue	Strong light penetration
12:00	Spread decreasing	Red zones shrink, green dominates	Sun gets steeper; light doesn't reach the back

The comparison between simulation outputs and on-site measurements revealed that the deviation rates varied across different time periods. Notably, at 09:00 and 12:00, the differences remained low—3.3% and 1.7%, respectively—indicating that the physical parameters used in the digital model (e.g., surface reflectivity, window geometry, furniture placement, spatial orientation) were accurately defined and effectively processed by the simulation software (Quek & Jakubiec, 2019; Febriyursandi et al., 2019).

However, larger deviations were observed at 10:00 (6.2%) and particularly at 11:00 (12.6%). The latter suggests that under intense daylight and direct solar radiation, the model's accuracy is reduced. This may stem from limitations in the CIE Intermediate Sky model and the EPW file, which may inadequately represent low-angle solar radiation and sky luminance distribution. During early morning hours, the low solar angle leads to more complex light interactions in terms of both intensity and directionality, making accurate modeling more challenging.

These findings suggest that while daylight simulation tools generally provide reliable results, their accuracy may decline under conditions of high light variability or intense

directional sunlight. In such cases, the use of more advanced or calibrated sky models is recommended for improved precision.

Table.4. Hourly Comparison of Real-Time and Simulated Illuminance Values with Deviation Rates

Time	Real Average (lx)	Simulation Average (lx)	Deviation (%)
08:00	137.3	131.8	~4.0%
09:00	129.7	125.4	~3.3%
10:00	137.3	128.8	~6.2%
11:00	135.9	118.7	~12.6%
12:00	134.4	132.1	~1.7%

Conclusion

This study contributes to the growing body of research on daylight performance in cultural heritage buildings by demonstrating that accurate digital simulation tools, when calibrated with precise physical parameters, can reliably replicate natural lighting conditions in complex historical interiors. The strong agreement between on-site measurements and Velux Daylight Visualizer simulations during key morning hours supports the practical applicability of such tools in heritage-sensitive lighting design. However, the noted limitations under intense direct sunlight emphasize the need for advanced sky modeling to improve simulation accuracy in dynamic lighting conditions.

By integrating user-centered illuminance analysis with detailed simulation validation, this research highlights the potential of simulation-based strategies to balance visual comfort, energy efficiency, and preservation principles. These findings align with and extend previous work emphasizing the importance of indoor environmental quality on user well-being and task performance (Barrett et al., 2015; Gkolompia, 2024; Kong & Jakubiec, 2021). Ultimately, this study advocates for the thoughtful use of simulation technologies as essential tools in sustainable, user-oriented lighting interventions within cultural heritage contexts, thereby bridging the gap between conservation and modern environmental performance goals.

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USE OF DAYLIGHT IN MİMAR SİNAN'S ŞEHZADE AND SELİMİYE MOSQUES: FUNCTIONAL, SYMBOLIC, AND LEED CERTIFICATION CRITERIA PERSPECTIVES

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Use of Daylight in Mimar Sinan's Şehzade and Selimiye Mosques: Functional, Symbolic, and LEED Certification Criteria Perspectives

Abstract: Light in architecture is used both functional and to add character, depth, and meaning to a space. In religious buildings, the use of light takes on a particularly sacred dimension. Mimar Sinan employed daylight in his mosques both functionally and symbolically by developing innovative solutions. These solutions can be analysed today from the perspectives of contemporary sustainability strategies, yielding significant insights and potentially inspiring advancements in modern construction technologies. In this context, the planning, structural systems, spatial arrangements, and material usage in Mimar Sinan's mosques align with contemporary principles of sustainability. This study will comparatively analyse the functional and symbolic daylighting in the Şehzade and the Selimiye Mosque, in terms of sustainability and energy efficiency. An evaluation was made according to the LEED certification IEQ Daylight Requirements based on literature review.

keywords: lighting design, Mimar Sinan, Ottoman mosques, symbolic lighting, functional lighting

1. Introduction

Light has been one of the most important elements in architecture for centuries, shaping the character of buildings and defining spaces. Light is the factor in the formation of architectural forms and spaces, contributing to the space in many ways from the smallest detail to the largest. (Hadrovic, 2022) The activity to be performed, the way the space is used, and its dimensions are among the factors that affect the amount of light to achieve indoor visual comfort. Today, visual comfort is ensured through passive and active systems; however, long before the technological advancements of the modern era, it was achieved through architectural arrangements. Arel& Öner (2017) points that Mosques are among the buildings where the use of daylight is particularly significant and utilize daylight most effectively. They add that "Well-illuminated mosques are inarguably the dreamiest and peacefully manipulated spaces that guide prayer towards the heavens." Daylight usage in mosques creates an impressive atmosphere. Furthermore, the daylight used in mosques carries symbolic meanings while also being functional. Worship activities demand clarity and comfort. "While performing namaz (prayer), the imam's ritual movements should be easy to follow, and while he is reading (reciting) the Qur'an on a low table called a 'qurs', daylight must be sufficient to meet reading standards." (Hadrovic, 2022)

In Ottoman architecture Mimar Sinan was the architect who manipulates the structural system and created spaces filled with daylight. Therefore, there is not necessity of artificial light during daytime. By evolving that structural system, he integrated natural daylight into the form and interior, in a process that progressed from the Şehzade Mosque to the Selimiye Mosque. Sinan's mosques can be grouped as three periods which are pre-classical, classical, and anti-classical periods. (Erzen, 1988) These two mosques from his apprenticeship (Şehzade Mosque)

and mastership (Selimiye Mosque) period will be assessed comparatively in terms of their daylight integration and based on contemporary standards to reveal sustainability potentials of historical buildings by means of indoor environmental quality and need for artificial lighting.

2. Theoretical Framework

Light is an important element in shaping the identity of a space. Both symbolic and functional uses of light play a significant role in mosque interior, daylight represents the concept of *nur* (divine light), while its use also makes the space functional for worship. The use of daylight provides visual comfort for users. Visual comfort depends on numerical values such as glare, illumination level (lux), and homogeneous light distribution. Passive strategies that minimize energy consumption, reduce the use of active systems and providing visual comfort have been employed by architects both in the past and in the present.

Mimar Sinan was an architect who elevated the use of daylight in Ottoman Mosque architecture to its highest level. The approach to illumination in Ottoman Mosque progressed in parallel with the development of architectural solutions. In Sinan's works, light was used in the most effective way, introducing innovations to Ottoman Mosque architecture (Doğan, 2013). Sinan integrated dome and space, achieving unity and light flow inside the space. Sinan's structural innovations allowed light to enter the mosque's interior. "The increase of arches in the interior, to support the galleries, results in an increase in the numbers or sizes of windows to provide the abundant daylight that Ottoman mosques always required." Erzen (1986). "The great architect who initiated the Classical period, Sinan, always changed the old massive and windowless understanding completely in the way the dome sat on the body walls or in the construction of the body walls. he created openings and paid great attention to making the interior spacious and luminous" (Doğan, 2013).

Windows were the most important tool for Sinan's lighting strategy. "In Sinan's hands, the window was used as an extraordinary design tool beyond simple sequences and rhythms." (Doğan, 2013). It is clearly seen that through the structural evolutions that Sinan made also influences the daylight integration to the mosques. His development from Şehzade to Süleymaniye and Selimiye reflects this evolution. In these mosques, increasing numbers and sizes of windows allowed more light in, transforming its quality from raw to refined: "The raw light in the Şehzade Mosque softens somewhat in the Süleymaniye, and reaches a level of maturity in the Selimiye." (Doğan, 2013)

3. Evaluation of Şehzade Mosque and Selimiye Mosque in terms of use of Daylight and LEED certification Criteria

Mimar Sinan's masterful use of daylight, both functionally and symbolically will facilitate their reinterpretation within the framework of modern sustainability standards, facilitating their use as exemplary models in contemporary buildings. The fact that daylight is an energy-efficient element, provides visual comfort, and reinforces the meaning of space demonstrates that the proper use of daylight requires a multifaceted approach. Both mosques differ in terms of light distribution, visual comfort, spatial meaning, and LEED certification criteria.

3.1. Şehzade Mosque Daylight Usage

The Şehzade Mosque (1543) was Sinan's first trial with a central domed structure. A central dome sitting on pendentives above four large piers is surrounded on four sides by semi domes. Quarter domes were added to support the semi-domes (Ünlütürk, 2021).

3.1.1. Functional Dimension

In the Şehzade Mosque, the central dome directs light toward the center of the space, while the mihrab and minbar are emphasized with daylight. Thus, the interior space has the daylight both functionally and symbolically.

According to Kuban: "In Ottoman architectural history, the transformation of façades from having a structural identity defined by windows into gallery-like palace façades begins with the Şehzade Mosque. The mass of the wall disappears in the brightness of the windows, and the buttresses of the roofing system lose their visual weight in the shadows of the galleries." This shift softened the perception of structural weight and increased light flow (Kuban 1988). Daylighting is achieved through double-walled structural elements composed of lower windows and the *içlik* and *dışlık* openings located at the upper levels of the domes and walls. The lower windows are generally designed to be transparent, allowing views of the outside. At the upper levels, there are windows called *içlik* or *revzen*, in which colored or colorless glass pieces are set between plaster frames. (Dişli, Kaygısız& Semerci 2023) These elements were also used for lighting control where the sun is 90 degrees.

Approximately 200 windows in the drum of the dome and on the facades distribute daylight evenly (Goodwin, 1971). Daylight analyses of the Şehzade Mosque have highlighted the uneven distribution of light. It has been noted that the mihrab, as the spatial focal point, and

central space are designed to be brighter, while lower light values are obtained at the edges and in the column shadows (Mumcuoğlu Türker, Z. & Karamağaralı, Z., 2025; Tuncer, S., 2024). This suggests that the direct incoming light has the potential to create a glare.

3.1.2. Symbolic Dimension

The natural light entering the space from the dome, through the openings on facades, and from above the dome at different levels, gains diverse qualities through the stained glass and latticework of the windows. This creates an atmosphere of divine light, enriching the worship experience.

In Şehzade Mosque, daylight was orchestrated not only for visual comfort but also as a symbolic medium: guiding spiritual orientation, creating a hierarchy of sacred space, and evoking transcendence through the dome. Light thus acts as a theological statement, binding the worshipper to divine presence through architecture (Necipoğlu, 2005; Kuran, 1987).
Shaded areas remain under the columns and half-domes. This contrast between shadow and light creates a layered sense of sanctity in the space (Kuran, 1987).

3.2. Selimiye Mosque Daylight Usage

Architecturally, Selimiye (1567-1574) features an octagonal system supported by eight massive piers. The eight piers form an octagonal shape in the square ground floor, creating the effect of an uninterrupted upward transition, from the square on the ground to the octagonal lower level and finally to the round domed roof hence. Selimiye has total 384 openings. Therefore, light in the space is homogeneous and even. (Takikawa, 2013)

3.2.1. Functional Dimension

The eight-pier structural system, which reduced the need for load-bearing walls, a greater number of openings could be created on the facades. The central dome, drum windows, and numerous openings on the facades ensure the homogeneous distribution of light, optimizing both functional and symbolic illumination.
The number and size of the windows on both walls and the dome give the same lighting effect without any feeling of directionality as if it would be impossible for one to guess where the sun is. Illuminance reaches a level of maturity in the Selimiye Mosque with the most generous use of light. The dome becomes both a functional and symbolic focus: “Daylight flowing down

from the dome signifies the light of God under which the worshippers gather" (Arel & Öner, 2017).

Analyses conducted by Mumcuoğlu Türker & Karamağaralı (2025, p. 171) revealed that despite having the lowest transparency ratio (~15%), the Selimiye Mosque is one of the structures that distributes light most evenly. This is a strong indication that Sinan was no longer pursuing the maximum amount of light but was instead focusing on the quality and control of light. Furthermore, as emphasized by Tuncer (2024, p. 219), the controlled admission of light from higher levels minimized direct and disturbing light entering the qibla wall, thereby achieving visual comfort.

3.2.2. Symbolic Dimension

By dispersing the light on the qibla wall and channeling it to support the daylight gathered on the central dome, a complete atmosphere of sacred light was created in the Selimiye Mosque. The uniform brightness reflects the union of religious elements with architecture. Sinan completely illuminates the interior with more windows opened onto the dome drum and its surroundings. Here, light surrounds the entire space, symbolizing the equal distribution of divine light. The lighting is more holistic and directionless. Every point in the space receives an equal amount of light, which reinforces the idea of God's omnipresence and unites worshippers in a single space (Necipoğlu, 2005).

3.3. LEED certification criteria for Daylight use of Şehzade and Selimiye Mosques

The United States Green Building Council (USGBC) defines green buildings as "buildings that aim to establish a healthy and dynamic balance between environmental, social, and economic benefits, significantly reducing any potential negative impacts on the environment and the user" (USGB 2021). In this context, LEED, developed by the USGBC in 1998, provides a framework for healthy, highly efficient, and cost-effective buildings.

According to LEED certificate daylight usage reduces electric loads, reinforces circadian rhythms, and "connect" users to the outdoors. In the LEED Certification system, daylighting is included in the environmental quality section. There are two main evaluation criteria to determine whether daylighting is used effectively.

Daylight has played a central role in the architectural identity of religious buildings. In the context of Ottoman mosque architecture, particularly in the works of Mimar Sinan, the relationship between space and light becomes a matter of visual comfort and a representation

of spiritual symbolism. LEED v4.1 (Building Design and Construction) provide measurable criteria—such as Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)—that allow for a systematic evaluation of daylight performance in spaces. In addition to complying with either option, glare-control devices must be provided everywhere. (U.S. Green Building Council, 2021)

Although no study was found in the literature evaluating these two mosques in terms of LEED criteria, a preliminary evaluation was carried out using the data obtained from the literature review.

Measurements and simulations conducted at the Şehzade Mosque indicate that it can meet the sDA300/50% criterion (Mumcuoğlu Türker & Karamağaralı, 2025); however, the distribution of light is not homogeneous. Measurements show that the Şehzade Mosque exceeds the 100 lux value recommended by the International Commission on Illumination (CIE) for general worship areas (Mumcuoğlu Türker & Karamağaralı, 2025). Thanks to the strategies Mimar Sinan applied in the structure, architectural elements, and openings, the use of daylight during daytime hours ensured visual comfort, reduced the need for artificial light, and provided energy efficiency. In particular, while the mihrab area is significantly brighter, the peripheral areas and sections under the column shadows remain dimmer (Tuncer, 2024). Although this situation meets the SDA criteria from a functional perspective, it creates a non-homogeneous lighting, which may cause glare due to high contrast. This suggests that the issue of whether the ASE value is within acceptable limits should be investigated.

Selimiye Mosque, on the other hand, provides a homogeneous lighting arrangement thanks to its large dome and windows. The structure strongly meets the sDA criteria and prevents glare by keeping ASE values within acceptable limits (Mumcuoğlu Türker & Karamağaralı, 2025).

4. Findings and Discussion

While the structural organization of Şehzade causes light to concentrate in certain directions, Selimiye's systematic design optimizes visual comfort and symbolic integrity. Sinan attempted to increase the light and its symbolic meaning in Şehzade, while in Selimiye he emphasized light quality and visual comfort, aiming for a homogeneous light distribution but not abandoning symbolic use. The symbolic dimension of daylight use is revealed through a literature review, showing that in Şehzade, he create a spatial hierarchy by directing light toward specific focal points (mihrab, minbar) and emphasizing hierarchy with sharp light and

shadows; in Selimiye, he create an equality and unity encompassing the entire space. It is thought that both structural development and changes in functional and symbolic needs have created differences between the LEED criteria. The sharp differences that emerged in the Şehzade Mosque due to symbolic concerns and structural requirements suggest that the mosque does not meet ASE standards.

As a result, both mosques are acceptable in terms of LEED v4.1 daylighting criteria; however, Şehzade Mosque reflects a design that is functionally adequate but distributes light heterogeneously, Selimiye Mosque distributes light homogeneously and meet the criteria more than Şehzade Mosque.

5.Conclusion

In this study, the functional and symbolic dimensions of daylight use in the Şehzade and Selimiye Mosques, and their relationship with LEED criteria were examined. In this context, it has been observed that the use of natural light and LEED criteria must be considered together, and that the glare criterion must be included under the LEED 4.1 DAYLIGHTING heading. The symbolic and cultural meanings of buildings, as well as spatial needs, must not be overlooked in green building certification systems, as they are an important factor (U.S. Green Building Council, 2021).

Historical buildings should be evaluated in terms of LEED standards and criteria, which are currently applied for standardizing contemporary structures, and perhaps a dedicated category could be created for these buildings to establish a database. Proper analysis and documentation of these structures could further develop the system for contemporary architecture. Additionally, conservation experts should collaborate with other disciplines to work on this collectively.

Conducting numerical calculations and analyses specifically for these mosques could provide a starting point for future studies. Research in this direction would be highly valuable both for understanding the past and guiding the future. The past should feed the future, and the future should feed the past.

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BUILDING MATERIALS AND INDOOR AIR QUALITY: EMISSION PROFILES, ENVIRONMENTAL SENSITIVITY, AND POLLUTION AGE CONCEPT

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Building Materials and Indoor Air Quality: Emission Profiles, Environmental Sensitivity, and Pollution Age Concept

Abstract: Indoor air quality (IAQ) is a critical determinant of human health, given that individuals spend more than 80% of their time indoors. Poor IAQ has been directly associated with respiratory illnesses, allergies, asthma, and premature mortality. Among the most significant indoor pollutants are volatile organic compounds (VOCs), emitted from finishing materials, paints, adhesives, flooring, and furniture. These emissions are particularly elevated in newly constructed or renovated buildings, where they may persist for long periods and interact with indoor ozone to generate secondary pollutants, further degrading IAQ. Such evidence highlights the pivotal role of material selection in architectural design. Implementing low-emission materials, optimizing ventilation systems, and reducing VOC sources are essential strategies for safeguarding occupant health. Beyond health protection, the integration of IAQ considerations enhances comfort, sustainability, and building performance. Therefore, understanding emission profiles and managing indoor pollutants represent fundamental responsibilities in contemporary architectural practice

Keywords: air quality, building materials, low-emission materials, health effects, architecture

Introduction

Indoor air quality (IAQ) has emerged as a fundamental dimension of public health and building performance, particularly in modern societies where individuals spend more than 80% of their lives indoors (WHO, 2010; Gonzalez-Martin et al., 2021). Increasing evidence demonstrates that poor IAQ contributes to respiratory diseases, asthma, allergies, neurodevelopmental disorders, and millions of premature deaths annually (Roser, 2021). The World Health Organization reported that in 2020, household air pollution was responsible for approximately 3.2 million global deaths, including more than 237,000 children under the age of five (WHO, 2022). These statistics highlight the urgency of addressing indoor pollutants within both health policy and sustainable building design frameworks.

Among indoor contaminants, volatile organic compounds (VOCs) are of particular concern due to their abundance, chemical diversity, and toxicological effects. VOCs—including hydrocarbons, aldehydes, ketones, alcohols, and esters—are emitted from paints, adhesives, flooring, furniture, cleaning products, and fuel combustion (Ayri et al., 2020; Pei et al., 2020). Short-term exposure is linked to acute symptoms such as headaches, fatigue, and eye or throat irritation, while long-term exposure increases the risk of chronic respiratory disease, allergies, asthma, and carcinogenic effects (Tsai, 2019). Furthermore, odors associated with VOC emissions can impair psychological well-being and reduce perceived comfort (Wolkoff et al., 2001; Liu et al., 2007).

Empirical evidence consistently shows that indoor VOC concentrations often exceed outdoor levels by several orders of magnitude (Harb et al., 2018). This is particularly

pronounced in newly built or renovated spaces, where finishing and furnishing materials emit substantial quantities of VOCs (Pei et al., 2016; Zhang et al., 2021). For example, Liang et al. (2014) reported significant increases in toluene, α-pinene, and total VOCs following door and doorframe installation, while wall paint application elevated propylene glycol concentrations. Similarly, Ochs et al. (2016) observed that varnishing and painting processes substantially increased acetone and carbonyl compounds during apartment renovations. Such findings reveal that construction materials are not passive design elements but active contributors to indoor chemical environments.

Material-specific emission patterns further illustrate the complexity of IAQ management. Gallon et al. (2020) identified paints, flooring, and decorative finishes as major VOC sources, with aldehyde levels peaking after painting. However, field measurements often reflect cumulative emissions from multiple stages rather than isolated material effects. To overcome these limitations, environmental chamber studies have measured emissions under controlled conditions. For instance, Park et al. (2018) tested 15 building materials, finding that furniture significantly increased toluene and formaldehyde concentrations, whereas natural additives such as diatomite and charcoal reduced emissions. Plaisance et al. (2017) further demonstrated that adhesives, coatings, and engineered woods can serve as significant sources of xylene, ethylbenzene, and formaldehyde.

Despite advances, knowledge gaps remain. Most studies either identify pollutant sources qualitatively or report steady-state concentrations without integrating two crucial aspects: (1) hazard classification of materials based on toxicity and (2) emission age, referring to the duration of significant pollutant release. Without incorporating both factors, architects and policymakers lack a comprehensive framework for material selection that safeguards IAQ across both short- and long-term horizons.

To address this gap, the present study introduces a dual-criteria framework combining hazard-based classification of construction materials with an assessment of emission ages. Materials were categorized into non-hazardous, low-hazard, and hazardous groups according to emission intensity and health risks. Additionally, emission dynamics were analyzed under varying environmental conditions, with a particular focus on renovation and retrofitting contexts where long-term emissions may compromise IAQ even after project completion.

From an architectural perspective, these insights underscore that material selection is not merely a technical decision but also a design responsibility directly affecting spatial quality, user comfort, and sustainability. By integrating emission profiles into design practice, architects

can contribute to healthier living environments that align with aesthetic, functional, and environmental objectives. The ultimate goal of this research is to provide evidence-based guidelines that enable architects and practitioners to make informed material choices, thereby advancing sustainable design and improving indoor environmental quality.

Literature Review

Indoor air quality (IAQ) has become a critical concern in the built environment, particularly due to emissions of volatile organic compounds (VOCs) from construction and finishing materials. The study Material VOC Emissions and Indoor Air Quality Simulation (2019) investigated the interplay between VOC emissions, ventilation strategies, and occupant activities. Results highlighted that material selection and ventilation are central determinants of IAQ, especially during the first weeks of building use, when emissions are typically highest. Simulation models such as IA-Quest demonstrated that integrating low-emission materials with appropriate ventilation can significantly reduce VOC concentrations, without compromising energy efficiency. These findings underscore the possibility of achieving both sustainable and healthy indoor environments.

Complementary evidence was provided by Volatile Organic Compounds and Odor Emissions Characteristics of Building Materials and Comparisons with On-Site Measurements during Interior Construction Stages (2024), which reported aldehydes—particularly formaldehyde—as the dominant VOC group in newly constructed buildings. Wet-applied materials such as paints and adhesives contributed to short-term emissions, while wood flooring emerged as a persistent long-term source. The study also emphasized that odor activity values (OAVs), especially from aldehydes such as octanal, decayed more slowly than VOC concentrations, thus maintaining sensory relevance for extended periods. Moreover, variations in substrate type, temperature, humidity, and ventilation produced considerable discrepancies between laboratory chamber results and on-site measurements, highlighting the need for integrated IAQ management strategies.

Further research, such as Impact of Indoor Surface Materials on Perceived Air Quality (2014), showed that perceived IAQ depends not only on chemical concentrations but also on sensory responses. Using glass chamber experiments, the study combined chemical testing with odor assessments, finding significant variability among different materials and material combinations. Some combinations even reduced odor intensity and improved perceived air acceptability, demonstrating that synergistic effects can positively influence IAQ. The dual

approach of chemical and sensory analysis was shown to be essential for comprehensive IAQ assessment.

Carpets, as explored in Impact of Carpets on Indoor Air Quality (2022), represent another major factor in indoor environments. Due to their multilayered structure and extensive surface area, carpets function both as pollutant sources and as reservoirs that adsorb and later re-emit VOCs and particulate matter (PM). Human activity exacerbates this issue by resuspending particles, particularly larger ones, into the air. Laboratory studies confirmed the sorption and re-emission dynamics of carpets, yet the long-term impacts in real-world conditions remain underexplored. Future research is needed to assess differences between natural and synthetic fibers and optimize carpet design to mitigate emissions while preserving their functional benefits.

In summary, the reviewed literature highlights the central role of building materials, surface finishes, and carpets in shaping IAQ, alongside the moderating effects of ventilation and environmental conditions. While substantial progress has been made, significant research gaps remain. These include the lack of long-term field studies, limited assessment of multi-material interactions, and insufficient integration of sensory evaluation into IAQ studies. Addressing these gaps requires systematic examination of emissions over time, under varying environmental scenarios, and across diverse material categories.

Methods

This study adopted a mixed-method approach, combining systematic literature analysis with empirical field investigations. Peer-reviewed articles, international standards, and technical reports provided the scientific basis for identifying critical emission factors. Concurrently, real samples of common building materials were collected and evaluated under both controlled chamber conditions and real-world environments, enabling direct comparison between theoretical and empirical findings.

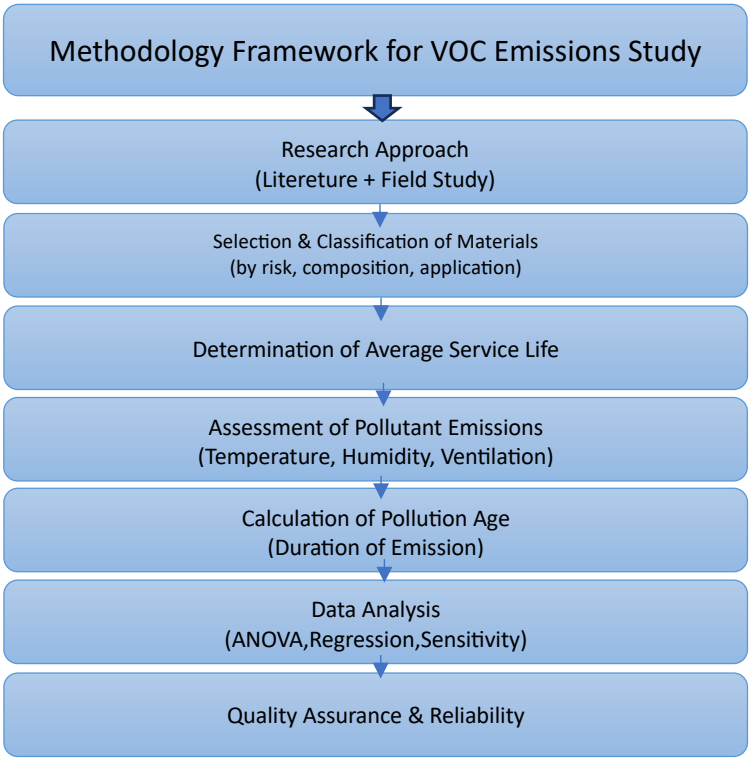

Figure1. Methodology framework for VOC emissions study

(1) Selection and Classification of Building Materials

A systematic list of commonly used residential and commercial construction materials was compiled. In contrast to earlier studies that often considered a limited subset of materials (e.g., only flooring or paints), this research adopts a holistic classification framework that integrates three dimensions:

- Pollution potential (low, medium, high), determined by reported VOC emission intensity.
- Chemical composition (organic-based, mineral-based, composite).
- Application type (flooring, wall coverings, paints, adhesives, furniture).

This multidimensional classification enables a more comprehensive comparison of material categories and facilitates cross-referencing with international standards such as ISO 16000 (indoor air quality) and ASTM D5116 (VOC emissions).

(2) Determination of Average Service Life

The average service life of each material category was established using peer-reviewed scientific sources, industry reports, and field datasets. While prior research has largely focused on short-term emission behavior, our study introduces service life as a long-term parameter that directly links material durability to cumulative pollutant release potential. This approach offers a novel perspective on the sustainability of material choices by incorporating time-dependent exposure risk.

(3) Assessment of Emissions under Environmental Conditions

VOC emissions were examined under varying indoor conditions, reflecting realistic residential and commercial environments:

- Temperature: standard indoor (20–25°C) vs. elevated (>30°C).
- Relative humidity: low (30–40%), medium (50–60%), high (70–80%).
- Ventilation modes: mechanical, natural, and absence of ventilation.

Unlike previous works that rely primarily on controlled laboratory conditions, this research combines laboratory results with empirical field data, ensuring ecological validity. This dual approach increases the generalizability of findings and strengthens alignment with international IAQ standards (e.g., WHO guidelines for indoor pollutants).

(4) Pollution Age of Materials

This study introduces a novel indicator, the Pollution Age of Materials, which represents the effective time span during which a material functions as an active pollution source indoors. The index is computed by integrating:

- average service life,
- emission intensity, and
- environmental sensitivity factors.

To the best of our knowledge, no previous studies have formalized this concept. Existing frameworks typically assess emissions at a fixed point in time, whereas the Pollution Age provides a dynamic, time-based perspective that reflects both material degradation and indoor environmental variability.

(5) Data Analysis

All collected data were categorized and analyzed using descriptive and inferential statistical methods. Sensitivity analyses quantified how variations in temperature and humidity influenced VOC release rates. This step moves beyond prior qualitative studies by offering a quantitative model of indoor emission dynamics.

(6) Quality Assurance and Data Reliability

To ensure scientific rigor, the study adopted the following measures:

- Reliance exclusively on ISI-indexed, peer-reviewed sources for baseline data.
- Inclusion of diverse material samples from real-world projects, rather than relying solely on laboratory-produced specimens.
- Rigorous documentation of indoor environmental parameters during both laboratory and field measurements.

Together, these measures provide a level of methodological transparency and replicability that exceeds many earlier investigations, thereby reinforcing the reliability of the results

Table 1. Steps of the study.

Step	Previous Studies	This Study (Novelty & Contribution)
1. Selection & Classification of Materials	Focused on limited material groups (e.g., only flooring, paints).	Developed a multidimensional framework (pollution potential, chemical composition, application type). Provides broader comparison and aligns with international standards (ISO 16000, ASTM D5116).
2. Average Service Life	Emissions typically studied in short-term laboratory tests.	Introduced service life as a factor to assess long-term pollutant release, linking durability with cumulative exposure risk.
3. Emission Assessment under Conditions	Mainly controlled laboratory tests, limited environmental variation.	Combined lab data with field data; tested across temperature, humidity, and ventilation modes → more ecologically valid and realistic.
4. Pollution Age of Materials	No formal concept; emissions usually measured at a fixed point in time.	Introduced the Pollution Age indicator (integration of service life, emission intensity, environmental sensitivity) → dynamic, time-based perspective.
5. Data Analysis	Mostly qualitative or descriptive statistics.	stronger evidence of correlations and causal relationships.
6. Quality Assurance	Often based on small sample sizes or lab-only specimens.	Ensured rigor via ISI-indexed sources, real-world material samples, and systematic environmental documentation → improved replicability and reliability

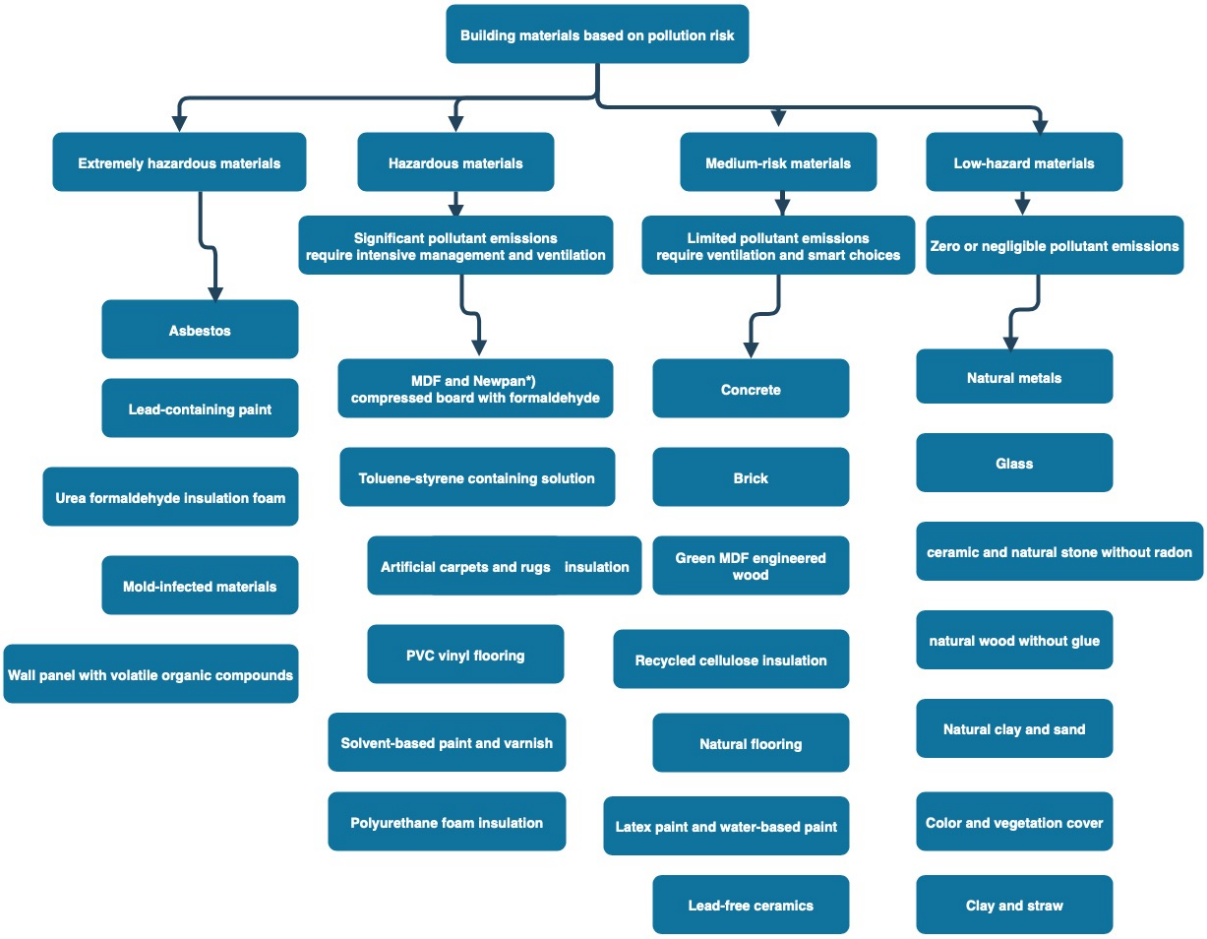

Figure 2. Classification of building materials based on indoor air pollution potential

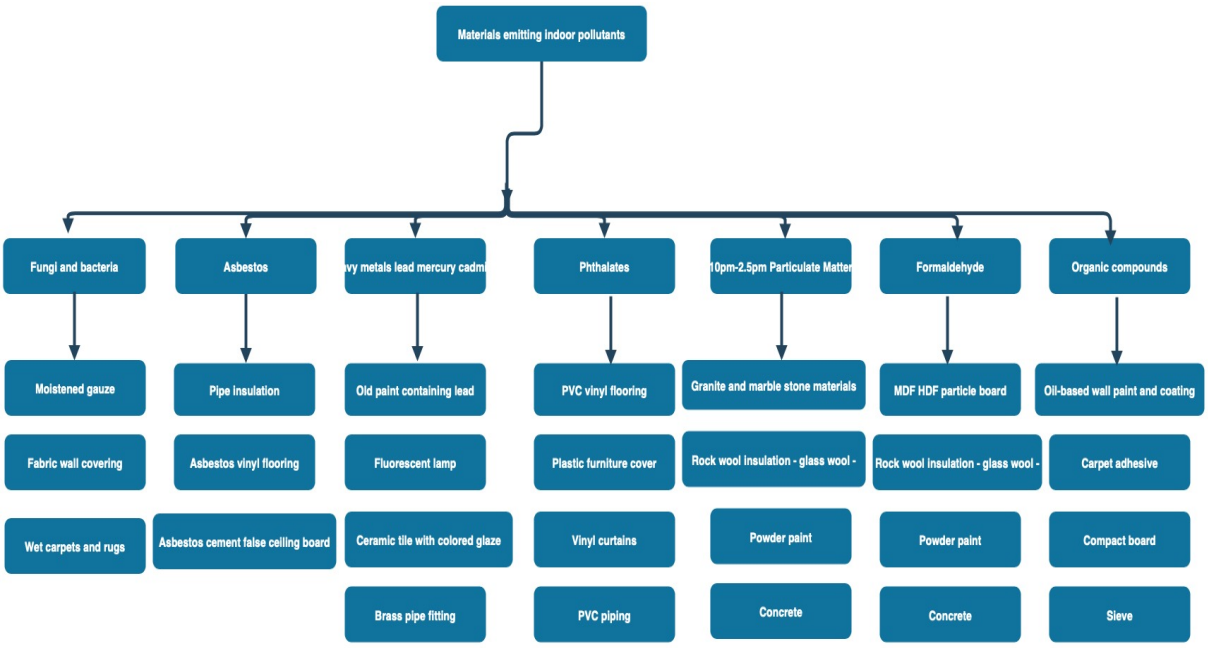

Figure 3. Classification of building materials based on type of pollution

Findings and Discussion

(1) Classification of Building Materials by Pollution Risk

The findings of this study revealed that building materials can be systematically categorized into three groups based on their VOC emission potential:

- Low-risk materials, such as mineral-based elements (e.g., ceramics, concrete), which showed negligible VOC emissions under standard indoor conditions.
- Moderate-risk materials, including certain composite boards and surface finishes, that exhibited measurable emissions in the early phase of usage but declined with age.
- High-risk materials, such as adhesives, paints, and some wood-based panels, which demonstrated both high initial emissions and longer emission durations.

This classification is consistent with previous reports (e.g., Mai et al., 2024; Ruiz-Jimenez et al., 2022) emphasizing the role of material composition and finishing products as critical sources of indoor VOCs.

(2) Average Service Life and Emission Patterns

The analysis of average service life indicated that materials with shorter lifespans (e.g., coatings, adhesives) tend to release a higher fraction of their pollutants in the early usage period, while long-lasting materials (e.g., flooring, structural panels) may contribute to prolonged but lower-intensity emissions. Specifically, low-risk materials have an average service life ranging from approximately 50 to 100 years, and in some cases can last for centuries, whereas moderate-risk materials typically have a service life of less than 50 years, and high-risk materials generally last less than 25 years. This aligns with the model proposed by Lee (2005), which considered both emission and re-adsorption processes in porous substrates.

(3) Influence of Environmental Conditions

The results highlighted the significant influence of temperature and relative humidity on VOC emission rates. Materials categorized as low-risk under standard conditions were observed to become active emission sources under elevated temperature and humidity scenarios. This finding confirms the observations of Ruiz-Jimenez et al. (2022), who reported

environmental sensitivity as a key driver of VOC release dynamics.

(4) Pollution Age of Materials

One of the key contributions of this study is the introduction of the Pollution Age concept, defined as the time span during which a material remains an active source of pollutants. The results demonstrated that:

- High-risk materials have a short but intense pollution age.
- Moderate-risk materials exhibit a longer pollution age with gradually declining emissions.
- Low-risk materials only become problematic under extreme environmental conditions.

The study also indicated that materials in Group 1 have a Pollution Age of zero, meaning they are not considered active pollutant sources by themselves, but under various environmental conditions, they can contribute to indoor pollution; the details of these environmental effects are discussed later. This conceptual framework provides a new lens for evaluating indoor air quality management strategies and may inform guidelines for material selection in sustainable building design. The study introduced a classification system for building materials based on their Pollution Age and emission intensity, as summarized in Table 1. Materials in Group 1 were identified as having a Pollution Age of zero, indicating minimal direct risk to indoor air quality at the time of installation. In contrast, materials in Groups 2 and 3 demonstrated delayed emission patterns, with their acute Pollution Age extending over several months. These findings, visualized in Figure 3, reveal how different materials gradually transition into active pollution sources, highlighting the importance of considering long-term emission behaviors rather than focusing solely on initial release levels.

Moreover, certain finishing materials exhibited a distinct emission profile characterized by rapid yet persistent release. Specifically, latex paints and solvent-based adhesives showed significant VOC emissions during the first few days of application, with noticeable levels persisting for weeks afterward, as depicted in Figure 4. This underscores the necessity of proper ventilation strategies during early occupancy and careful scheduling of material application in architectural practice. Overall, by integrating emission intensity with Pollution Age analysis,

this study provides a dual-criteria framework that supports more informed and sustainable material selection. Beyond its scientific contribution, this framework offers architects and designers a practical decision-making tool to reduce occupant exposure, promote healthier indoor environments, and enhance the environmental performance of buildings.

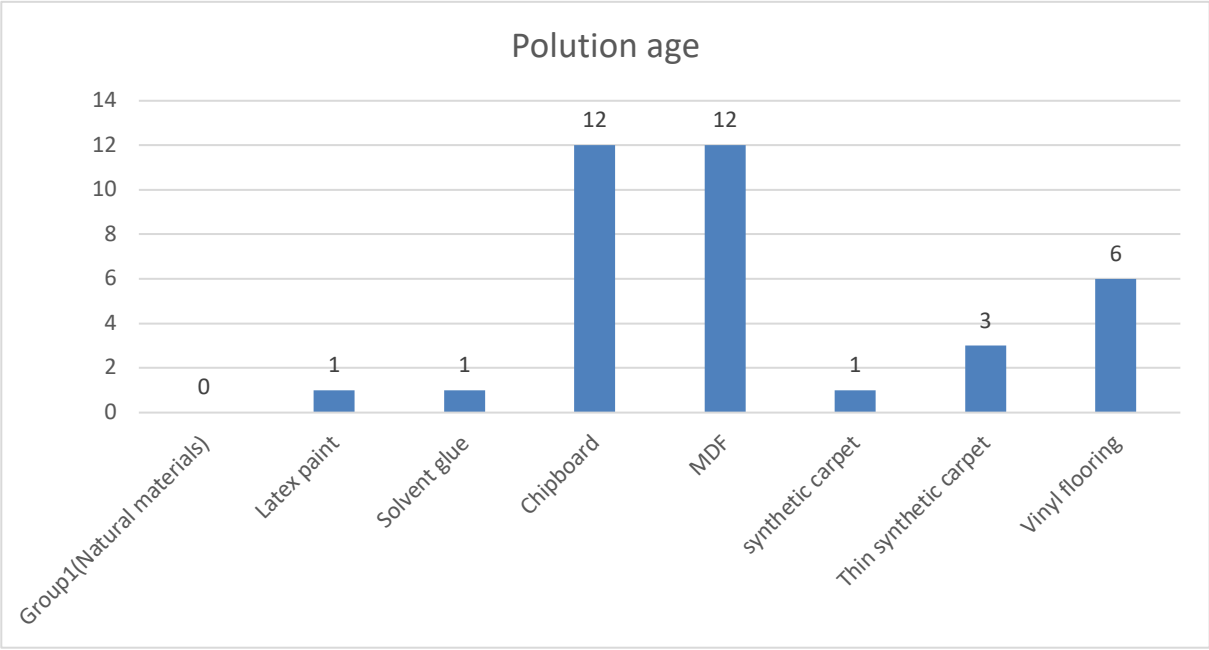

Figure 4. Assessment of the Pollution Age of Interior Building Materials

Notes1. Natural materials are copper, aluminum, steel, glass, ceramic, natural stone, natural wood, clay, natural gypsum, concrete, brick, natural flooring, green MDF

Notes2. Each numerical unit in this table corresponds to a 30-day period

(5) Implications for Indoor Air Quality and Policy

The findings reinforce the idea that VOC emissions in indoor environments are a combined function of material choice, environmental parameters, and building operation practices. From a policy perspective, these results underline the need for:

- Transparent labelling of building materials regarding their VOC emission potential.
- Regulatory limits that consider not only initial emissions but also pollution age under variable environmental conditions.

• Design guidelines encouraging the use of low-emission and durable materials to maintain long-term indoor air quality.

This aligns with the calls from Kotzias (2021) and Baeza-Romero et al. (2022) for more coherent research-policy frameworks to reduce the impact of VOCs in residential and commercial buildings.

(6) Effect of Temperature and Humidity on the Pollution Age of Building Materials

The analysis indicated that both humidity and temperature significantly influence the intensity and duration of pollutant emissions from various building materials. Elevated temperatures generally increase the emission rates of VOCs and other pollutants, particularly for materials with rapid emission phases such as latex paints and solvent-based adhesives, which release the majority of their emissions during the initial days and may continue emitting for several weeks. High humidity can further enhance chemical activity and pollutant release, especially in moisture-absorbing materials such as wood and gypsum. The provided charts illustrate that the combination of high temperature and humidity leads to a substantial increase in indoor pollutant concentrations. Materials that appear to be low-emitting under normal conditions may become long-term pollutant sources under these environmental conditions.

Research Limitations

In the present study, it was found that the Pollution Age of low-risk and natural materials is zero under standard conditions, indicating that these materials do not act as direct pollutant sources. However, the results also showed that under adverse environmental conditions, such as elevated temperature and humidity, even these materials can become indoor pollutant sources. Due to time constraints and limited laboratory capacity, it was not feasible to systematically assess the effects of temperature and humidity for each individual material. Therefore, the Pollution Age was evaluated only for low-risk, non-hazardous, and high-risk material groups. This limitation suggests that future research should systematically investigate the impact of environmental conditions on all material types to develop a more comprehensive and practical framework for Pollution Age assessment.

Conclusion

This study demonstrated that building materials are critical determinants of indoor VOC levels and overall Indoor Air Quality (IAQ), with emissions strongly influenced by material type, service life, and environmental conditions. The introduction of the Pollution Age concept provided a novel framework for understanding both the duration and intensity of emissions across different materials. Findings highlighted that while some materials pose minimal risks under standard indoor conditions, they may become significant pollutant sources when exposed to elevated temperature and humidity. Conversely, high-risk materials require particular attention due to their intense early emissions and long-term impact. A key implication of this research is the role of natural building materials. These materials offer important benefits such as reduced reliance on synthetic compounds, lower embodied energy, and alignment with sustainable construction principles. However, results indicate that even natural materials may contribute to indoor pollution when subjected to unfavorable environmental conditions. This underscores the necessity of managing temperature and humidity control to optimize the performance of natural materials and minimize pollutant emissions. From a design and policy perspective, achieving sustainable and healthy indoor environments requires a more comprehensive approach: careful material selection, transparent emission labeling, and regulatory frameworks that integrate both short-term and long-term pollution dynamics.

For future research, it is recommended to expand on the findings of this study by systematically examining the interaction between environmental parameters (humidity, temperature, ventilation) and natural materials. Adjusting and controlling these conditions may significantly enhance the usability of natural materials, thereby extending the scope of sustainable building practices. Further studies should also refine and validate the Pollution Age framework in real-world contexts, enabling its integration into building design, standardization, and environmental policy.

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INTEGRATING SEISMIC RESILIENCE AND CIRCULAR ECONOMY: THE ROLE OF COLD-FORMED STEEL IN SUSTAINABLE CONSTRUCTION

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Integrating Seismic Resilience and Circular Economy: The Role of Cold-Formed Steel in Sustainable Construction

Abstract: This study positions Cold-Formed Steel (CFS) at the intersection of seismic resilience, sustainability, and durability. The study describes CFS benefits in recyclability, waste reduction through industrialisation, and lower embodied carbon but lightweight fabrication and efficient transport. The paper refers to how Building Information Modeling (BIM) based design supports accurate production and Life Cycle Assessment (LCA) integration, while detailing and Structural Health Monitoring (SHM) strategies enable near-real-time post seismic evaluation. Using case studies (Casa in Acciaio Modena and San Nicolao), the paper proposes practice-oriented suggestions that marries circular-economy principles with digital workflows for sustainable urban regeneration.

Keywords: Cold-Formed Steel (CFS), circular economy, building-on-the-built

Introduction

Cold-Formed Steel (CFS) is increasingly recognized as a material that can reconcile seismic resilience and environmental sustainability through lightweight, industrialised and recyclable construction systems. This study evaluates the performance potential of CFS with a focus on: strength-to-weight advantages for lightweight retrofit and over-roof interventions; connection design and detailing for moment resistance and ductility; BIM-driven fabrication and LCA integration; and hybrid damping and Structural Health Monitoring (SHM) for near-real-time post-quake assessment. Findings are intended to inform design practice, policy and university curricula.

Back in the history of Cold-formed steel

Cold-formed steel (CFS) has played a transformative role in architecture since its emergence in the mid-19th century, combining innovation with sustainability. Pioneers like Jean Prouvé in France advanced industrialised steel systems through inventive assemblies, while Buckminster Fuller in the U.S. envisioned mass-producible structures like the Wichita House, though technological limitations of his era hindered full realization. In Australia, Glenn Murcutt integrated CFS with environmental principles, drawing inspiration from Indigenous and colonial building techniques, whereas Japan utilized its seismic resilience to develop resource-efficient, life-cycle-oriented construction. Today, digital tools like BIM and parametric design further enhance CFS's potential, enabling lightweight, recyclable, and prefabricated solutions that align with modern sustainable architecture. The evolution of CFS demonstrates its enduring role in merging structural efficiency with environmental responsibility (Barucco,2015).

Recyclability, Efficiency and Lifecycle Gains

CFS can be 100% recycled without loss of quality or strength, and thereby reused over and over again infinitely, reducing landfill space and natural resources. Waste on site is minimized by the industrialised procedure, and the lightness of CFS minimizes transport energy and carbon emissions compared to heavier products like concrete. In addition, CFS design and build activities are in line with the most modern working systems: sharing the project among specialists is only part of this issue. The rapid development of construction sites is very important: there is no need to use machinery with a high environmental impact and intelligent, less tiring and rapid use of labour are fundamental qualities of this system. CFS construction is faster than using wood or concrete, reducing project time, labor costs, and resulting energy losses.

Today, buildings must meet numerous requirements and develop highly complex performance: CFS is a frame that allows for the development of every possible technological solution to achieve high standards also using high-performance insulation useful to reduce long-term energy consumption and costs. Beyond its structural benefits, the CFS frame can be detailed for fire resistance in the same layered way as thermal or acoustic insulation: the frame provides a customizable backbone in which tailored assemblies achieve performance targets layer by layer.

Economically, CFS frames have reduced foundation demands because of their light weight, CFS is indeed really fast to install and this saves construction costs. The longevity and the simple maintenance in the life span of the building reduces repair expenditures in the long run.Additionally, steel manufacturing creates zero waste in construction sites and very little waste material during the production (scraps are easily recyclable): the elimination of waste makes CFS a very cost-efficient and environmentally friendly building material .

By combining recyclability, freedom for bespoke design , waste minimization, and long-term economic benefits, CFS is a sustainable, visionary solution for today's building (BuildSteel,2025; Leff,2025; Leffler et al.,2023).

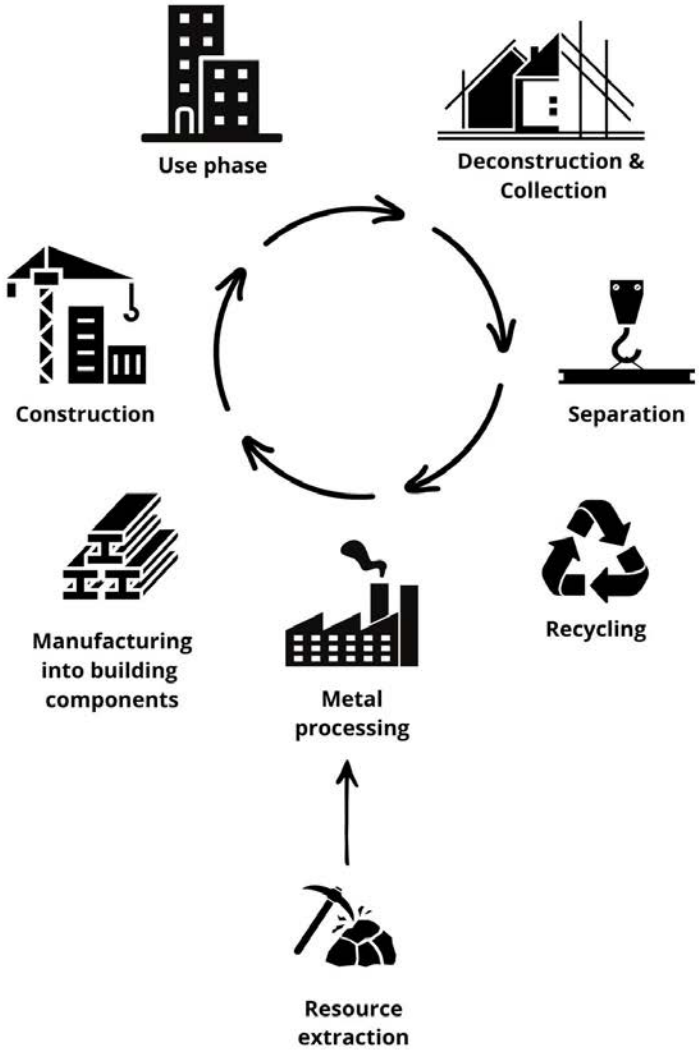

Figure 1. Life-cycle diagram of Cold-formed steel
(Author's elaboration from ArcelorMittal, 2014)

BIM-Driven Fabrication, Quality Control & LCA Integration

Ottagono Design's Casa in Acciaio Moderna (Modern steel house) project exemplifies sustainable construction through its innovative use of CFS finished with natural materials. The design prioritizes environmental sustainability by combining recyclable steel with low-impact, renewable materials like hemp-lime composites, which act as breathable insulators to enhance energy efficiency (achieving A4 energy class; in Italy the APE scale runs from G to A4; A4 denotes the highest energy performance nationally) (Ministero dello Sviluppo Economico, 2015). The system that completes the steel frame has been called the "Eco Bio Air wall system": hemp-lime panels form ventilated, high-performance envelopes and hemp panels production sequesters CO_2 from the atmosphere, making the whole building more sustainable. In addition,

material use has been reduced because calculations were optimised using Building Information Modeling (BIM). This project demonstrates how CFS can deliver habitable, low-carbon buildings without compromising architectural flexibility.

Central to the project's methodology is the integration of BIM, which streamlines design accuracy, waste reduction and real-time project monitoring. BIM enables the meticulous engineering of custom-fabricated steel components, ensuring seamless assembly and minimizing construction errors. Every aspect of the project is verified before the production of the profiles and the start of construction: plant engineering, structures and architectural forms are developed in parallel, to benefit a non-hierarchical, collaborative work organisation. Architects' use of parametric design tools allows for customizable architectural forms while maintaining structural integrity, as seen in the project's suspended volumes and open spaces. Additionally, the Materials Library (Materioteca) at the general contractor's headquarters facilitates dialogue with clients, who can learn about and appreciate the qualities of the proposed materials selected for their natural, low-impact properties. This makes the workflow more effective and informed, truly combining technological innovation with ecological responsibility. These digital and material advancements position this project at the forefront of sustainable, high-precision construction.

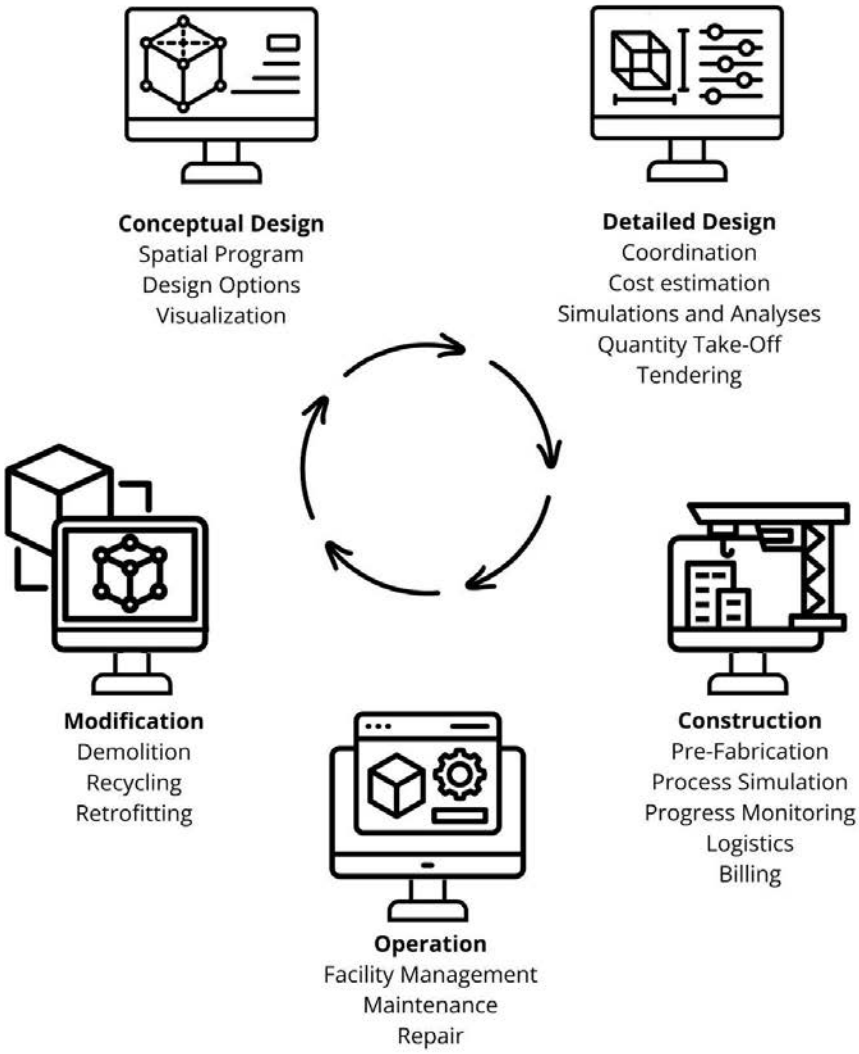

Figure 2. BIM in the life-cycle of a CFS building
(Author's elaboration)

Earthquake resilience and Structural Advantages

CFS uniquely addresses both seismic resilience and sustainability needs. Its lightness reduces inertial forces during earthquakes, while high ductility allows the system to act as a "shock absorber", bending under stress without brittle failure and improving energy dissipation. Precision fabrication ensures consistent performance across profiles, and the strength-to-weight ratio delivers structural integrity without excessive mass. Carefully designed connections (screws, bolts, or welds) reduce the risk of joint failure, and innovations such as self-centering frames and energy-dissipating connectors promise future gains, as evidenced by the 10-story CFS shake-table test (CFS10, University of California San Diego) (BuildSteel,2025; DesignSafe,2025; Leff,2025; Velent,2025; Lubec,2024). Recent studies investigate joint

configurations (through plates, gussets and stiffeners) and hybrid dampers, often coupled with digital Structural Health Monitoring (SHM) for a near-real-time post-earthquake assessment (Barucco et. al.,2025; Bagheri Sabbagh et al.,2019). Challenges remain (thin-walled buckling, demanding assembly), but improved detailing together with ongoing research, parametric design and digital fabrication can steer practice toward lighter, less invasive seismic upgrades that align with circular-economy principles.

Circular-economy thinking positions CFS as a strong candidate for sustainable urban construction in earthquake-prone regions. As research advantages and urban codes adapt, CFS can shift practice toward lighter, less invasive interventions that reconcile structural upgrades with environmental goals (Arkitech,2025; BuildSteel,2025; DesignSafe,2025; Leff,2025; Velent,2025).

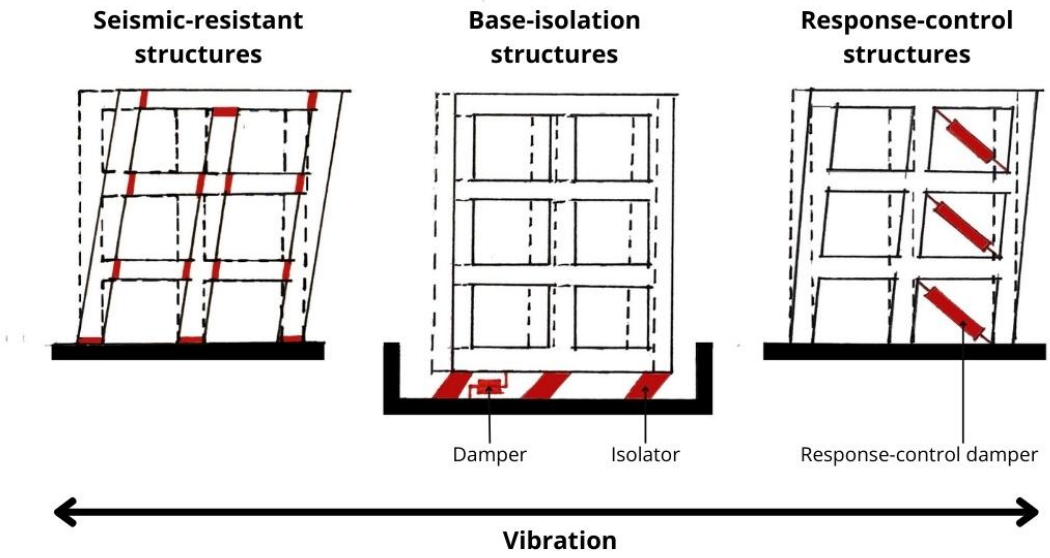

Figure 3. Seismic-resistant CFS structures: base-isolation and response-control systems (Author's elaboration)

Building-on-the-built and land conservation

CFS also supports urban strategies that reduce land consumption and preserve existing fabric by enabling fast, light and low-impact retrofits. The San Nicolao redevelopment in Milan exemplifies this approach: over ~11,000 m² the intervention upgraded a 1960s office complex from energy class G to A (A is close to the top A4 band in the national scheme), achieving an EPH of 5.62 kWh/m³a through envelope, HVAC and insulation measures while integrating Light Steel Frame (LSF/C.I.P.A.®) reinforcements. CFS elements were digitally designed and custom-fabricated to fit the building's geometries, allowing an off-site production approach that

minimized waste, sped assembly (in some phases avoiding crane use) and ensured high dimensional precision. The San Nicolao case shows how parametric modelling, tailored CFS components and industrialized yet bespoke fabrication produce structural reinforcement and recladding in a single, scalable operation, reconciling seismic upgrade with architectural quality.

In dense, historic Italian cities (where demolition is both environmentally costly and often technically constrained) "building-on-the-built" interventions offer a replicable model or route for sustainable urban regeneration. Preliminary insight from ongoing, unpublished interviews with Italian CFS firms (Manni, Ottagono, Sistema CIPA, Scaffsystem, …) indicate that a primary application of CFS is redevelopment via lightweight extensions and vertical elevations.. Interviewed firms report that CFS's combination of lightness, prefabrication and precision fabrication frequently enables simultaneous structural remediation, thermal upgrading and space addition in a single operation, often avoiding demolition.

Conclusion

This study shows that CFS combines high strength-to-weight performance, connection detailing that supports moment resistance and ductility; BIM-driven fabrication improves quality control and LCA outputs; and SHM-enabled damping for targeted post-quake response. Together, these features make CFS particularly suited to lightweight retrofit and "building-on-the-built" strategies that reduce embodied carbon and land take. A footcoming practical guidance will synthesise interviews and case studies to support designers, contractors, students and educators.

Acknowledgments

We gratefully acknowledge the time and expertise of the firms and the industry participants. Interviews are ongoing and reported here only in preliminary form; all participants provided informed consent and interview data will be anonymised in the forthcoming full synthesis and guidance document.

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FROM INTERNAL AREAS TO SUSTAINABLE BUILDINGS: A FRAMEWORK FOR INTEGRATING QGIS AND LCA FOR THEIR PLANNING AND REGENERATION

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From Internal Areas to Sustainable Buildings: A Framework for Integrating QGIS and LCA for their Planning and Regeneration

Abstract: The assessment of inner areas and the application of Life Cycle Assessment (LCA) are crucial elements in spatial planning and sustainability in the construction sector. Spatial analysis, which is fundamental in the context of inner areas, is supported by open source geospatial reference tools such as QGIS. At the same time, specialised platforms such as OneClick LCA are used to quantify the environmental impact of buildings. In this context, the study focuses on the synergistic integration of these tools. The aim is to develop methodologies that combine the detailed spatial analysis of QGIS with the environmental assessments of OneClick LCA. This fusion provides a more in-depth and holistic understanding of the territorial dynamics and life cycles of existing buildings belonging to the heritage of the inner areas, offering advanced decision-making support for the promotion of building and land management practices geared towards a more sustainable and efficient approach.

Keywords: Inner areas; QGIS; LCA, regeneration, sustainability

Introduction

Achieving the ambitious goal of climate neutrality by 2050 (European Union, 2020) requires decisive and multidimensional action. The crucial element of this transition is the redevelopment of existing buildings, which are characterised by their high energy intensity, into a high-performance system. In this sense, the regeneration of existing buildings in inner areas, characterised by a significant distance from the main service centres, as defined by the National Strategy for Inner Areas (SNAI), represents a territorial policy aimed at raising the quality of civic services and enhancing economic opportunities in these ambits, which are frequently subject to marginalisation. Through a series of interventions focused on mitigating carbon production by adopting energy efficiency measures and using advanced technologies, which would facilitate the transition to a low greenhouse gas emission economy, long-term restructuring strategies would be implemented. These would not be limited to optimising operational energy, but will also aim to reduce embodied energy and carbon (Cannaviello et al, 2024). In this context, it is essential to use information systems, platforms and models for the management, planning and modelling of the territory and built environment, which require greater attention to interoperability and data quality during the entire process (Chen et al, 2024).

In line with the growing need to integrate data obtained through territorial analysis with environmental impact assessment, this study and its innovative approach are based on the methodological synergy of tools that analyse two distinct parameters, namely spatial analysis and life cycle assessment.

Specifically, the Geographic Information System (GIS) is used, which is indispensable in land planning and management, allowing the visualisation and analysis of georeferenced data, which can be implemented and characterised by a series of useful information for the implementation of complex decision-making processes. The open source application of the Quantum Geographic Information System (QGIS) is a valid solution, recognised in both academic and professional circles. Thanks to its versatility and wide range of functionalities, through the use of a series of plugins, it is possible to implement and obtain a quantity of information associated with the built heritage and the evolution of the urban settlement (Becker et al, 2021).

In addition to spatial analysis, the impact of buildings is quantified using the Life Cycle Assessment (LCA) methodology, which is applied in accordance with international standards, following technical standards such as the ISO 14040 series and UNI EN 15978:2011, which defines the calculation method for assessing the environmental performance of buildings. To carry out this evaluation, the study uses the OneClick LCA platform, which facilitates the calculation of environmental impact and the generation of Environmental Product Declarations (EPD) (GBC Italia, 2021). This tool, integrated with the main design software, allows the assessment of carbon emissions and other relevant indicators throughout the entire building cycle, from the preliminary phase, i.e. the extraction of raw materials, to decommissioning and disposal.

The use of this platform allows for rigorous quantitative analysis, which is essential for sustainability management in construction and for promoting building practices with reduced environmental impact (Moshood et al, 2024). The prospects are promising, but further developments are needed to overcome technical and organisational barriers and maximise the impact of these methodologies, whose combined approach offers advanced decision support.

Literature Review

The literature review explored the conceptual evolution of sustainability in construction, focusing on its theoretical foundations and the evaluation criteria adopted in projects, highlighting how theoretical principles translate into practical applications and identifying the essential components of environmentally responsible construction. The bibliographic review showed the need for an integrated methodological approach that can overcome the limitations of sectoral analysis, confirming that tools that combine spatial assessment and analysis of the building's life cycle and environmental impact are more relevant in urban contexts such as inner

areas, which are often marginalised. The process of integrating spatial analysis and life cycle assessment (LCA) has several significant advantages. In particular, the integration of geospatial technologies (GIS) with the LCA methodology allows for detailed spatial analysis, enabling the mapping and visualisation of emissions distribution and the identification of areas with high concentrations of environmental impact. This approach facilitates the development of targeted and territory-specific mitigation strategies (Mao et al, 2024) (Li et al, 2021) (Patouillard et al, 2018) (Shi et al, 2024). Furthermore, the combined use of spatial data, Material and Energy Flow Analysis (MEFA) and LCA promotes a systemic and dynamic approach to sustainability assessment, which considers both operational and embodied emissions, taking into account temporal evolution and territorial characteristics (Pei et al, 2024) (Mao et al, 2024) (Papageorgiou et al, 2024) (Seyedabadi et al, 2024). This methodology supports the implementation of circular economy strategies, in line with the concept of urban metabolism, allowing for the design and monitoring of high-impact flows and the allocation of resources in a more efficient manner (Papageorgiou et al, 2024). However, the implementation of this approach still presents some methodological challenges. Significant difficulties remain in data collection and harmonisation, regionalisation of LCA inventories and standardisation of processes (Fnais et al, 2022) (Patouillard et al, 2018) (Shi et al, 2024). To overcome these limitations and increase the reliability and relevance of assessments, the scientific literature suggests the adoption of dynamic models, the integration of technologies based on artificial intelligence, and the creation of specialised, regionalised databases (Pei et al, 2024) (Fnais et al, 2022) (Shi et al, 2024).

Methods

In line with an interconnected methodological approach, this study is based on a theoretical and developing integration model that connects spatial analysis with environmental assessment. This paradigm is based on the synergy between GIS, represented by QGIS software, and LCA methodology, implemented through the use of the OneClick LCA platform.

The integration process is divided into sequential phases that guarantee the consistency of the process. First, QGIS's ability to analyse and map the characteristics of the intervention area from a spatial point of view is used, acquiring georeferenced data relating to the presence of territorial constraints, destination of use and environmental risks. This information requires the use of Building Information Modelling (BIM), which is useful for representing building design models within their context. It is essential that the classification and naming of materials

within the BIM model are standardised in order to provide correct interoperability with OneClick LCA (Lima et al, 2024), which platform will then process the data by calculating the environmental impact of the work carried out on the building in question, analysing the type of materials, their quantity and location. In this way, it is possible to rapidly and accurately evaluate different design and redevelopment scenarios (Rabani et al, 2021), considering emissions embodied in materials and operating emissions.

The objective of achieving sustainability through the regeneration of existing built heritage and optimised spatial planning requires the process to be divided into a series of interconnected phases, which begin by selecting and delimiting an inner area. The phases are divided into:

- Phase 1: Analysis and territorial planning. The import of geographical, demographic and socio-economic information relating to the state of the existing built heritage is conducted. Subsequently, the mapping, study of the distribution and density of buildings is done, identifying the most degraded areas or those with high regeneration potential, evaluating critical factors such as connectivity, accessibility to services and other data useful for better understanding the territory. The processing of the data obtained generates alternative scenarios, visualised through thematic maps and models that outline potential areas for redevelopment, green spaces and new infrastructure.

- Phase 2: Environmental assessment. This focuses on specific buildings or groups of buildings selected based on the results of the previous phase. The project data for building regeneration, which includes details on materials, construction techniques and estimated energy consumption, is included in the OneClick LCA platform, performing an LCA calculation, which measures the environmental impact based on multiple indicators throughout the entire life cycle of the building, from construction to decommissioning. This phase permits the evaluation of different scenarios, such as renovation compared to demolition and reconstruction, in order to understand the best intervention option with the lowest environmental impact.

- Phase 3: Synergistic integration and decision-making. The synergistic integration of the two previous phases allows the environmental impact data generated by OneClick LCA to be re-imported into QGIS, enabling the results to be superimposed on the initial spatial maps, contextualising the impact of each intervention within the geographical framework of the inner area and offering a multi-level view. Based on this combined

analysis, it formulates an informed decision on the type of intervention to be chosen, that will be constantly implemented and monitored, utilising both tools, to measure progress towards improving the territorial asset and reducing environmental impact.

In this way, it will be possible to obtain a sustainability plan for inner areas, which integrates informed territorial planning with rigorous environmental analysis. The result will be a strategy that stands out for its ecological and economic efficiency, whose process is conceived as an iterative cycle, continuously optimising intervention actions oriented to maximising benefits.

Findings and Discussion

The process of automating environmental assessment through the integration of GIS and LCA tools in the construction sector, although promising, is still hampered by significant technical, informational and organisational challenges. One of the main barriers is data interoperability, given the difficulty of harmonising formats, structures and classifications between GIS software, BIM and LCA platforms. The absence of shared standards for material nomenclature not only complicates the automatic transfer of information, but can also compromise the reliability of calculations, due to potential data loss or mapping errors. In terms of information, data quality and granularity are critical issues, especially in the beginning stages of design, when information on materials and construction processes is often incomplete, affecting the accuracy of automated assessments. Added to this is the limited availability and updating of reliable LCA databases that are compatible with digital models. From an organisational point of view, the effective adoption of these workflows requires specific technical skills and strict interdisciplinary collaboration. Managing uncertainties related to incomplete data or project assumptions emerges as an additional challenge which, if not addressed correctly, can amplify errors in the results. Despite these difficulties, the integration of QGIS and OneClick LCA represents an advanced practice for sustainable construction management, particularly for the regeneration of building stock in inner areas. This synergy promotes the selection of recyclable materials and reuse-oriented design, supporting the principles of the circular economy and carbon emission reduction. Resource management on site and consumption monitoring are optimised, promoting an ecologically and economically efficient approach. Overcoming barriers related to training, managerial skills and initial costs is crucial for the dissemination of these innovative methodologies. The adoption of such practices in inner areas is a strategic tool for enhancing the value of the territory and promoting sustainable development (Dalla Mora et al, 2020).

Conclusion

This study explored an advanced and integrated methodological approach for sustainability assessment and urban regeneration planning in inner areas. The integration of these tools not only allows for the identification and prioritisation of regeneration interventions based on objective data, but also offers a holistic understanding of environmental impacts in the specific territorial context. This is an important contribution to the discipline of sustainable construction management, providing an operational framework for promoting the circular economy and the reuse of existing building stock. The proposed systemic approach has made it possible to assess the impact of different intervention options, providing scientifically based decision support. However, the research has also highlighted persistent challenges related to interoperability between different software, data standardisation and the need for specific technical skills. With a view to the future, it is desirable that research focus on developing more robust interoperability protocols and creating regionalised and dynamic LCA databases that can more accurately reflect local specificities. The further integration of systems based on artificial intelligence and machine learning could also further automate analysis processes, making these methodologies accessible and applicable on a large scale. In conclusion, the adoption of an integrated and interdisciplinary approach appears to be the most promising way to guide a transition towards truly sustainable construction, especially in complex territorial contexts at risk of marginalisation, such as inner areas.

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A NATURE-BASED APPROACH FOR REGENERATIVE BUILT ENVIRONMENTS

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A Nature-Based Approach for Regenerative Built Environments

Abstract: The use of nature to increase the climate resilience of built environment is growing. Many international agreements and initiatives support the need to promote nature-based approaches. Through the analysis of a virtuous case study, the paper investigates the main actions that can be taken to renaturalise cities through the local implementation of NBS, in order to increase their environmental resilience and their ability to address climatic, social and economic challenges, in line with European strategies. These actions are evaluated in relation to their effectiveness as an integrated strategy for urban regeneration, in order to identify the results achieved and the strengths for outlining strategies for the renaturalisation of cities through NBS, which can also be exported to other contexts. The virtuous example of Vitoria Gaistez demonstrates that nature itself can be called upon to offer multifunctional solutions contemporary challenges.

Keywords: Nature Based Solutions (NBS); renaturing cities; green infrastructure.

Introduction: Searching Nature in Town

Open space public areas have always been considered as primary indicators of urban recognizability. In particular, public gardens from the early era of urbanization constituted an essential reference like a common heritage in view of strategies for dispersing urban pressure. If we still lived in conditions similar to those of the early stages of urbanisation, we would first support traditional urban projects, opening channels and lines of connection between green areas and the built environment in order to improve well-being, while emphasising the recognisability of collective identity. In this way, we could still achieve good results, strengthening people's involvement in community life through the design of typical elements of open spaces.

However, urban life is changing today, and traditional structures are at least altered, or destroyed in some cases, in a new scenario shaped by different climates, natural hazards, and economic situations, while the lives of more than half of the world's population are concentrated in urban areas. The future outlook is even more complex in the coming years, as the process of urbanisation is set to expand. Consequently, a new vision of urban life is essential, and we must be prepared for new design experimentation.

Urban life must be now coordinated with open space design, even with the smallest detail of the constructive elements: “built landscapes are made for human use and contact. They include all the outdoor surfaces and places that people touch, use and benefit from in their everyday lives” (Ferguson, 2021).

As in the case of Vitoria-Gasteiz, illustrated below, an emblema of well balanced design of nature into town, a new grade of complexity must be added when designing a contemporary

open space in a city, as a strategic tool for initiating a progressive process of reconnection between urban built environment and nature in an osmotic regeneration process (Glatron and Granchamp, 2018). In that way, with a coordination with public community art experiments, in open space projects "works of art have aesthetic functions that are essential to them, but also allows that they have other, non-aesthetic functions, for example practical or ecological ones" (Van Etteger et al., 2016).

Generally speaking, in every open space, the point to be considered is always just the relationship between practical and aesthetic urgencies in the systems of vegetation, water, settlement structures, and infrastructural elements, creating an unpredictable series of perceptions. But when we are in the center of a town, the surprise is bigger, especially "when you enter through a building and you are sure of entering inside an interior space, while you suddenly are in an exterior one" (Aben, R. De Vit 2001).

Searching for key concepts of interior and exterior relation between constructions and vegetation in Open Space Design, one image stands out in mind as foundational source: the antique pompeian court. The reference to Pompeii becomes crucial. Here, built environments' intrinsic patterns find a complex substance in the interrelation of nature and architecture into the urban structure, which includes open fields, gardens, cultivated lands, water distribution and supply, areas for social gatherings, and private spaces within the urban typology (Maiuri, 1998). The voids seem to be perceptively connected with other adjacent voids through a series of openings in sequence, and the correlated system of connected open points is clearly evident in Le Corbusier's Pompeian sketches, with open spaces appearing at the same time as enclosed and opened, with a succession of multiple views which are ever-changing, in a way that creates interchangeable associations. The connectedness of layout was, anyway, corresponding to the connectedness of human relationships, involving at the same time the appearance of places and the lives of Pompeian people. Keeping in mind this overall balance of nature and constructions in the old fundamentals of Pompeian archetips, a new concept of interrelation and conjunction of open spaces seem emerging and we can aspire to establish environments that reflect a new social and ecological balance.

Communities express the desire to find better places for enjoying everyday moments of profound wellness, so urban open spaces, considered as places capable of representing the desire for a new rurality, could constitute a strategic key to truly positive environmental effects on general urban quality. There could be a social strategy, as Kate Orff suggests even the loss

of social cohesion could be afforded with the instrument of "an urban landscape design as a form of activism" (Orff, 2016).

Making public spaces at the same time more inviting and more complex let them become, automatically, also more inclusive in a synergic way, connecting them with other urban sites, even not close ones, as an osmotic regeneration process can influence even elongated areas (Langdon, 2017).

Literature Review

The use of nature to enhance the climate resilience of urban areas is becoming increasingly common (European Commission, 2015). Many international agreements and initiatives, such as the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals (SDGs), and the Paris Agreement on climate change, support the need to promote nature-based approaches (World Bank 2021).

The renaturalisation of urban environments can be considered an effective solution for promoting climate change mitigation and adaptation, combating ecosystem degradation, and restoring connections between humans and nature (Sarabi et al 2023). It is also in line with the key global objectives of the Kunming-Montreal Global Biodiversity Framework (2022), which aim to halt biodiversity loss by 2030 and reverse the trend by 2050. Greater integration of nature into the built environment is therefore an important step in the transition to Nature-positive cities (Frantzeskaki et al 2022).

Nature-based solutions (NbS) have been defined, by the International Union for Conservation of Nature (IUCN), as actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges in an effective and adaptive manner, while delivering benefits for human wellbeing and biodiversity. They have been recognised as one of the most comprehensive approaches to developing resilient landscapes and cities, as they offer multi-purpose solutions that often have greater collateral benefits than traditional technical measures. However, the challenge facing governments and scientific communities in moving from general declarations to practical applications remains (Lafortezza et al 2018). Despite significant investments at European level to promote the spread of NBS, large-scale implementation is still lacking, partly due to concerns about post-implementation issues, such as management and maintenance, which can affect social acceptance (Castellar 2024).

Methods

The paper investigates, through the analysis of a virtuous case study, the main actions that can be taken to renaturalise cities through the local implementation of NBS, in order to increase their environmental resilience and their ability to address climatic, social and economic challenges, in line with European strategies.

In Vitoria Gasteiz, a medium-sized Spanish city and capital of the Basque Country, a well-designed urban regeneration programme was launched in the 1980s, aiming to place nature at the heart of renovation policies and strategies, emphasizing the transformative power of urban greenery. The 'Anillo Verde' (Green Belt), was designed to connect urban areas with green infrastructure while redeveloping degraded urban suburbs. It marks the beginning of a series of urban renaturalization projects that are organized coherently in terms of both time and space.

The actions taken were analyzed concerning both the objectives set and the benefits achieved, to verify their alignment with those identified by the EU for NBS (European Commission 2015). The strengths of these interventions were examined to develop strategies for urban redevelopment and renaturalisation through nature-based solutions, applicable in other contexts as well.

The publications of the Centre for Environmental Studies in Vitoria Gasteiz (CEA 2014, CEA 2018, CEA 2021) have helped analyse how the many actions tested have helped to increase the city's resilience to the risks posed by climate change and biodiversity loss, while also making it more livable.

Findings and Discussion

New approaches to urban regeneration have led to a paradigm shift in the relationship between cities and nature, focusing on the introduction of measures aimed at incorporating natural functions into the urban environment. In this context, the *City-nature living network* of Vitoria Gasteiz (CEA 2018) stands out as a successful example: peri-urban green belts and a network of multifunctional green spaces testify to the achievement of a balanced and sustainable relationship between the city and its environmental context (Hernandez et al 2015).

The *Anillo Verde,* a complex project focused on environmental and social regeneration in the city's distressed outskirts*,* can be considered one of the most emblematic projects, as well as one of the the main signs of identity of Vitoria-Gasteiz (CEA 2018). This approach to renaturalising the city, which has been maintained over time and systematically expanded with

new projects, earned Vitoria Gasteiz the title of European Green Capital in 2012 and the United Nations Global Green City Award in 2019.

The interventions carried out since the 1990s, which represent environmental design strategies aimed at addressing multiple critical issues, can be considered a precursor to the application of the NBS concept on an urban scale.

The European Union (2015), identifying NBS as an essential component for greening the economy and achieving sustainable development. Four objectives have been identified that can be addressed using NBS, along with seven types of nature-based Research & Innovation Actions that can be implemented to achieve these objectives (Table 1).

Table 1. EU Research & Innovation agenda on NBS and Re-Naturing Cities (EC 2015).

Goals	Nature Based R&I Actions
Enhancing sustainable urbanisation Restoring degraded ecosystems Developing climate change adaptation and mitigation Improving risk management and resilience	• Urban regeneration • Improving well-being in urban areas • Coastal resilience • Multi-functional watershed management and ecosystem restoration • Increasing the sustainability of the use of matter and energy • Enhancing the insurance value of ecosystems • Increasing carbon sequestration

Initiatives implemented in Vitoria Gasteiz can be classified according to the scale of intervention (district, city, region), key issues (i.e. objectives to be achieved) and benefits obtained. Based on the key issues identified (biodiversity, water, energy, mobility, socio-economic factors, public space, food), six types of NBS have been defined (CEA 2021):

- increasing biodiversity
- increasing ecological connectivity
- improving water management
- urban agroecology and improving soils
- improving public use and accessibility
- urban rehabilitation and creation of micro-landscapes

The “Initial proposal for an Urban Green Infrastructure System in Vitoria-Gasteiz” is based on *core elements, nodes and connectors* (CEA 2014). The core elements are represented

by peri-urban parks (Armentia, Salburua, Olarizu and Zabalgana), with a high level of naturalness, located in areas adjacent to the city. Some of them are part of the Natura 2000 network, the European Union's main policy instrument for biodiversity conservation. Nodes are mainly represented by urban parks, which, due to their size and/or location, are strategic structural elements of the urban green system. Finally, the connectors are linear elements, whose main function is to facilitate the connection between the central elements and the nodes.

The concept of the Anillo Verde, linked to the initial need to organise peri-urban natural areas and stem urban pressure on agricultural areas outside the city, has evolved over time into a genuine strategy that has also guided urban planning tools (Todaro 20219). This strategy goes beyond the concept of an ecological corridor, with its exclusive environmental protection value, and is characterised by its multi-functionality, capable of generating significant environmental and social benefits, making it perfectly consistent with the concept of NBS and the objectives of the EU.

In various urban and peri-urban parks, there are multiple objectives to be achieved, among which the main ones are the restoration of degraded ecosystems, the improvement of public use, and the promotion of biodiversity through the creation of new ecological niches. They are able to provide various ecosystem services, which vary depending also on the type and quantity of vegetation present (Mexia et al 2018).

The multiple benefits derived from the implemented actions are detailed in Table 2.

Table 2. Main benefits associated with the implemented actions (CEA 2018).

Environmental	Social	Economic
Landscape enhancement Increased biodiversity Improved Ecological connectivity Flood prevention Improve water quality Improved soil fertility Improved sewage treatment Mitigation of CO_2 emissions Reduction in the heat island effect Improved air quality	Increased social interaction Encouraging public usage Encourage awareness and public participation Improved health Improved public use	Development of socioeconomic activities Promote tourism Food production Energy production Research and development

Of particular interest is the restoration and environmental redevelopment of the Salburua wetland (fig. 1), which had been drained and transformed into agricultural land, but since the 1990s has been returned to its former state as a floodplain marsh, becoming an

important oasis of biodiversity and a refuge for migratory birds, as well as an area of study involving local residents. This is a regional-scale intervention, whose key objectives have been biodiversity, water and public space, which has brought considerable benefits, as wetlands are not only a reservoir of biodiversity but also perform many other ecological functions and play an important role from a hydrological point of view. In 2002, the Ramsar Convention declared it a Wetland of International Importance (Hernandez et al 2015).

Figure 1. Anillo Verde and Salburua Park (Cannaviello, 2025).

Although NBS are closely linked to the context in which they are implemented, several key aspects have contributed to the success of the Vitoria case. These factors could inform future strategies that can be implemented in other contexts, not only promoting climate change adaptation and mitigation, but also as an integrated strategy for urban regeneration:

Redefining urban boundaries: the Anillo Verde represents a new way of delimiting the built environment, using green and permeable margins as resilient urban boundaries that ensure a gradual transition between the urban and rural spheres, containing urban expansion while improving the native natural environment (Bajo Martinez de Murguia 2021).

Recovery of peripheral, marginal and degraded areas: ecological and environmental recovery interventions, such as the creation of peri-urban parks, can create new and important value for public space, especially through citizen participation (Hernandez et al 2015).

Strong relationship between the implementation of green infrastructure measures and urban planning (Hernandez et al 2015).

Self-sufficiency of parks: park design must address issues related to the management of large green areas, minimising maintenance requirements through different combinations and sizes of native grasses and shrubs, enabling nature to manage itself.

Participation of citizens in the process: Educational programmes in schools and civic centres help raise awareness of the value of biodiversity and the importance of preserving the natural environment, while dedicated information panels enable the population to actively participate and understand the improvements resulting from the various interventions.

Living laboratory: the green belt serve as a space for study, work and experimentation, within which various social participation initiatives have been launched, involving citizens actively collaborating to ensure the proper management of the Green Belt (CEA 2018).

Interaction of multi-scale actions: the interventions range from large peri-urban parks to urban parks, to interventions in squares and on buildings, and are applicable at different scales: district, city and regional. Their effectiveness is due not only to the inclusion of green spaces of different sizes, but above all to the way in which these green spaces are connected to in order to ensure their proper functioning in various ecological and social roles.

Conclusion

We need to rethink the relationship between nature and the built environment. The virtuous example of Vitoria Gaistez demonstrates that nature itself can be called upon to offer multifunctional solutions to contemporary challenges. Today, the city presents itself as a dense and complex mosaic of urban green spaces, of different scales and with different functions, capable of generating extensive benefits for inhabitants and biodiversity. An analysis of the strategies implemented shows that, even though the 'green belt' as a tool for reconnecting the city with the natural environment has certainly been one of the cornerstones of the institutional strategy, and can be considered the driving force behind the conception and implementation of other interventions, it is precisely this continuous implementation of NBS over time that has contributed to making the Basque city a particularly virtuous example of urban regeneration *with nature and for nature*.

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BUILDING TECHNOLOGICAL DISAGGREGATION METHODOLOGY TO IMPROVE KNOWLEDGE ABOUT THE EXISTING BUILDING STOCK FOR CIRCULARITY

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Building Technological Disaggregation Methodology to Improve Knowledge About the Existing Building Stock for Circularity

Abstract: To achieve the ambitious goal of climate neutrality by 2050, the European Union should implement actions that go beyond mere emissions reduction. It is imperative to integrate circular models to optimise resource use, minimise waste and promote the restoration of natural ecosystems. In the construction sector, the adoption of such models is hampered by a lack of accurate data on the existing building stock. To fill this gap, the research project has focused on developing a user-friendly operational tool called "Technological Component Passport (TCP)". The results presented are about a hierarchical multilayer analysis methodology of the building system into technological components, classified according to function and lifespan (time). This approach makes it possible to assess the energy and environmental (CO_{2eq}) performance and the remaining service life of each component. These data are essential for conducting the life cycle assessment (LCA) of existing buildings, facilitating the implementation of circular strategies.

Keywords: building stock analysis; technological components analysis; knowledge for circularity; classification methodology.

Introduction

With the Green Deal, the European Union has undertaken a path of change aimed at achieving climate neutrality by 2050, a goal that has been made binding by the European Climate Law. The building sector is one of the most critical areas for this transition as the existing building stock is heterogeneous and obsolete, making it responsible for 40% of final energy consumption and 36% of greenhouse gas emissions (Violano & Cannaviello, 2023). Considering that approximately 50% was built before 1980, i.e. before the modern energy requirements (European Commission, Building Stock Observatory, 2020), it is estimated that around 80-95% will still be in use in 2050 (European Commission, COM 662, 2020). The strategies initially implemented were aimed at reducing energy consumption and operational carbon through redevelopment, renovation and retrofitting, and the introduction of renewable energy sources (Merola, 2023); but these are not enough. The European Commission's COM 98 (2020) - A new Circular Economy Action Plan for a cleaner and more competitive Europe – indicates that the implementation of circular practices throughout the entire life cycle of a building is one of the prerequisites for achieving climate neutrality, not only at the end of its life, through the management of construction and demolition waste, through an effort to reintroduce materials, systems or components into a new production cycle, in accordance with the value chain. Furthermore, considering that this sector accounts for approximately 50% of extracted raw materials, it is clear that the real transition must no longer be just energy-based,

but circular, abandoning the linear "take, make, dispose" model. Practices such as maintenance to extend useful life, the recovery of materials and products to be redirected to circular supply chains, and replacement with elements with low embodied CO_{2eq} content are among the main guidelines for circularity (Leoni, 2021), so that the image of existing buildings can be redefined from "waste in waiting" to material banks (Rose & Stegemann, 2018). Through circular practices, the concept of 'end of life' disappears and becomes 'end of useful life', which turns "waste" into a 'secondary resource' to be reintroduced into a new cycle (Giorgi, 2024). To do this, companies should collect and recover building materials and components and reintroduce them into the value chain, also from an economic point of view (Güngör, 2024).

However, this is extremely difficult, as there is insufficient knowledge of the composition of existing buildings in terms of materials and components, their location, quantity, quality and value (Mohammadiziazi & Bilec, 2022).

From this perspective, the research currently underway is aimed at developing an operational user-friendly tool called Technological Component Passport (TCP) to implement the knowledge of the existing building stock from a component-technological point of view in order to manage it in a circular way. This article will present some of the results of the research titled "TCP to circular manage the existing building stock", aimed at developing a method to divide the building system into technological components to be analysed from a material, energy and environmental performance point of view.

Theoretical Framework

The development of a disaggregation methodology aimed at understanding and analysing the building from a technological point of view required a preliminary investigation of existing theories and systems in order to guide the design choices. For reasons of efficiency, this section will only present case studies that have actually influenced the design of the system. The first theory analysed is the concept of "building in layers", which divides the building into different levels, each characterised by a set of component systems organised according to two criteria: lifespan and function (Marchesi & Travares, 2025). The first to propose this theory was Frank Duffy in 1990, stating that "A building properly conceived is sever layers of longevity of built components" (Duffy, 1990). The system he proposed is divided into four levels, using as the unit of analysis not the building itself, but the use made of it over time:

- Shell: the structure of the building, which has a lifespan equal to that of the building itself.

- Services: all systems such as pipes, wiring, air conditioning and lifts, which should be replaced approximately every 15 years.
- Scenery: internal partitions and decorative building elements; replaced every 5 to 7 years.
- Set: furnishings; changed at intervals of a few weeks or months.

Subsequently, Steward Brand, in his book (Brand, 1995) expands Duffy's theory, which was considered limited as it was designed basing on commercial buildings, proposing a classification of 6 dynamic layers that group components with similar functions and lifespans and generate a dynamic system capable of responding to changes in users over time (Marchesi & Travares, 2025):

- SITE – the geographical location of the building – LIFESPAN: infinite.
- STRUCTURE – foundations and load-bearing elements – LIFESPAN: 30 to 300 years.
- SKIN – the building envelope – LIFESPAN: approximately 20 years, for reasons of fashion and technology.
- SERVICES – all systems and moving parts (escalators or lifts) – DURATION: become obsolete approximately every 7 to 15 years.
- SPACE PLAN – the internal layout (walls, ceilings, floors and doors) – DURATION – from 3 (commercial premises) to 30 years (residential buildings).
- STUFF – furniture and everyday items – LIFESPAN: days – months – years. In Durmisevic & Brouwer (2002), the idea of a dynamic and flexible building system is revisited, addressing the topic of decomposable buildings as the best solution for implementing sustainability. In order to implement the three dimensions of transformation (structural, spatial and material), a building is proposed as a hierarchical pyramid of elements and relationships, on four interconnected levels: at the top, the *building level* as a set of systems; the *system level* as a set of components; the *component level* as an assembly of elements and materials; the *element/material level*, i.e. the basic parts that compose the component level. Although this classification was proposed with reference to the design of modular buildings, it was considered applicable at a theoretical level also to existing buildings, albeit with greater difficulty due to the nature of the techniques used in their construction, which do not foresee the implementation of end-of-life practices related to circularity.

With regard to the regulatory frameworks, the Italian standard UNI8290-1 of 1981 was analysed, as it provides an orderly and organic disaggregation of the building system into three levels, to unify the terminology to be used in reference to the building's technological system in all activities carried out in the construction sector.

- Technological unit classes: the first level of disaggregation of the technological system based on the general and common function performed by the sub-levels – *load-bearing structure, closure, internal partition, external partition, service supply system, security system, internal equipment, external equipment*.
- Technological units: "grouping of technologically compatible functions necessary for obtaining environmental performance", i.e. performance relating to "the translation of a need into physical-environmental factors and requests for technological services, designed to identify the conditions for its satisfaction by an environmental unit" (Italian Standards Body (UNI), 1999) – example: *foundation structures, elevation structures, containment structures*.
- Classes of technical elements: levels of grouping of technical elements, i.e. "more or less complex building products capable of performing, in whole or in part, the functions of one or more technological units and which constitute a characteristic component of a technological subsystem", i.e. "a structured subset of the technological system of the building organism characterised by the functional homogeneity of the technical elements that compose it" (Italian Standards Body (UNI), 1999) – example: *direct foundation structures, indirect foundation structures*.

This system is therefore based on functional classification, which allows all technical elements to be placed in at least one main class, one technological unit and one class of technical elements. Furthermore, there is also the possibility of expansion in order to keep pace with technological developments.

Methods and Results

In order to develop a building disaggregation methodology, it is important to consider that, like any other classification system, it must be applicable in all cases and contexts and must allow for the addition of new elements where necessary (Danotti, et al., 2017). In order to adequately meet these requirements, it is important to remember that the application of this methodology will take place within the framework of a user-friendly operational tool, therefore, it must not be overly complex, and it will be applied to existing building stock, which is

characterised by a high degree of heterogeneity and, in most cases, built using traditional construction techniques.

According to Campioli & Lavagna (2013), a building "can be considered a system consisting of different parts and constituent elements which, taken together, each with a specific role and contribution, respond to the requirements underlying the project". Existing buildings can be considered as "traditional building structures" in which the elements are organised hierarchically (Durmisevic & Brouwer, 2002), so it was deemed appropriate to divide the building into hierarchical grouping levels, with each layer becoming a set of building systems or components according to function and estimated useful life. It is clear that the lifespan varies between components and is influenced by countless variables. First of all, the lifespan of a component (or service life) is determined by the material with the shortest lifespan. When one of the materials/elements that compose the component deteriorates, even if the others are still functional, unless it is replaceable, the entire component reaches the end of its life (Tleuken, et al., 2025). Other factors that influence the useful life of a component are: the quality of the internal and external environment, maintenance, basic design, etc. (Potrč Obrecht, et al., 2019). In order to organise this diversity, it is necessary to identify components in different time (Askar, et al., 2024) and functional levels according to an access hierarchy related to their respective life expectancies (Ungureanu, et al., 2025). In Table 2 is presented the provided LAYER division, described as follows:

- LAYER1(*macrosuystems*): the building classification system based on function and useful life proposed by Brand (1995) was reviewed and overlapped to the disaggregation of the technological system into classes of technological units, provided by the Italian standard UNI8290-1:1981, as shown in Table 1. The following levels were excluded from Brand's classification: *Site*, as it is context-related and no correspondence with UNI8290 was found; *Structure*, negligible from an energy point of view unless it coincides with the Skin (e.g. load-bearing masonry); *Stuff*, as it is not part of the building's rigid entity (Tleuken, et al., 2025). A final layer was dedicated to *Connections*, knowledge of which, layer by layer, is essential to facilitate the possible separation of systems, components and materials, depending on the sub-level at which one is operating.

Table 1. Development of LAYER1 according to Brand and UNI8290-1:1981.

(Brand, 1995) Building layers	New classification for TCP LAYER 1	UNI 8290-1:1981 classes of technological units
Site	-	-
Structure →	-	← Load-bearing structure
Skin →	SKIN	← Closures
Services →	SERVICES	← Service supply system & security system
Space Plan →	SPACE	← Internal partition & external partition
Stuff	-	Internal equipment & external equipment
-	CONNECTIONS	-

- LAYER2 (*systems*): a system is defined as a set of components designed to perform a specific function (Tleuken, et al., 2025). The systems have been grouped according to different variables. For the *Skin* macrosystem, the classification includes: *opaque envelope*, which includes all components such as: vertical perimeter walls, ground floor, roof, floor over open spaces, etc; *transparent envelope*, which includes windows and doors; *shading elements*, which include screening components integrated into closures. For the *Services* macrosystem, the classification is based on the type of system analysed (water, electrical, etc.). For the *Space* macrosystem, there are two types of systems: *opaque*, internal and external partitions as per UNI8290, excluding doors and windows; *transparent*, internal vertical and horizontal doors and windows of internal partitions (UNI8290).
- LAYER3 (*components*): these are individual building components consisting of a set of materials assembled to meet specific needs and requirements related to the system in which they must contribute with their performance (Tleuken, et al., 2025) (e.g. windows, doors, floor slabs, walls, etc). The useful life of components is strongly

influenced by the durability of the materials they are made of and also by their maintainability and replaceability.

- LAYER4 (*materials*): contains the list of individual materials that make up the components of LAYER3. As reported in building maintenance manuals, materials have different lifespans depending on the position of the layer within the component, which determines how easily it can be accessed. This establishes the timing and methods of intervention.

Table 2. Layering proposed for the classification system for the TCP.

LAYER 1 *macrosystems*	LAYER 2 *systems*	LAYER 3 *components*	LAYER 4 *materials*
SKIN	OPAQUE		
	TRANSPARENT		
	SHADING SYSTEM		
SERVICES	WATER SYSTEM		
	ELECTRICAL SYSTEM		
	VENTILATION SYSTEM		
	HEATING/COOLING SYSTEM		
	HOME AUTOMATION		
	ENERGY PRODUCTION SYS.		
SPACE	OPAQUE		
	TRANSPARENT		
CONNECTIONS	between LAYER 2 systems	between layer 3 components	between layer 4 elements

Conclusion

This research proposes a hierarchical classification system for buildings into macrosystems, systems, components and materials, which forms the basis for the development of the TCP. The method, based on functional and temporal variables, allows for a structured

assessment of the energy performance, environmental impact (CO_{2eq}) and remaining useful life of building elements, thus facilitating the life cycle assessment (LCA) of existing buildings. The main principle that emerges is that systematic knowledge of the material and technological composition of buildings is an indispensable condition for implementing circular strategies in the built environment.

The generalisation of the method indicates its potential applicability to a heterogeneous and obsolete building stock, although exceptions remain due to uncertainties in estimating useful life, variations in construction practices and maintenance conditions. From a theoretical point of view, the system integrates different frameworks (cf. Durmisevic & Brouwer, Brand, UNI 8290-1:1981 standard), contributing to a consolidated conceptual basis for viewing buildings as dynamic and decomposable entities.

In practice, the TCP provides an operational and easy-to-use tool, aligned with EU policies such as the European Digital Building Logbook, Renovation Passports and the Global Warming Potential indicator. Future developments will define performance indicators for each level, validate the system on case studies and test interoperability with BIM platforms. Ultimately, the study demonstrates that knowledge is the cornerstone of the circular transition, transforming existing buildings into material banks for a climate-neutral future.

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RE-DESIGNING FASHION SUSTAINABILITY: BRIDGING ACADEMIA AND INDUSTRY IN THE TRANSITION TO CONSCIOUSNESS

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Re-Designing Fashion Sustainability: Bridging Academia and Industry in the Transition to Consciousness

Abstract: The contribution presents an educational-experimental experience developed as part of the "Yamamay Reloaded" project, which addresses the transition from fast fashion to fashion consciousness by integrating creative reuse, responsible consumption and eco-design, and experimenting with the use of the Digital Product Passport (DPP) tool. As part of European strategies for sustainable textiles, the project transformed unsold stock into new collections through slow production processes, digital traceability and rigorous design documentation, according to the Research-Action approach.
The results highlight not only the environmental and economic relevance of the experiment, but also its socio-cultural dimension, as the PDP is a tool for transparency literacy and consumer empowerment across all consumer types, promoting critical awareness and new forms of accountability. The methodology adopted, based on a combination of scientific research and educational experimentation, proves to be replicable and transferable to other areas of design beyond the fashion sector, providing a model of innovation capable of integrating scientific rigour, design creativity and sustainability.

Keywords: ecodesign; fashion conscious; slow fashion; digital product passport; project geometry

Introduction: from fast fashion to conscious fashion

Fashion has always been a central element in human life, contributing to a sense of belonging within society across various historical periods. However, our contemporary society is highlighting some profound critical issues related to this sector, such as the problems associated with fast fashion and production processes that are unsustainable from an environmental impact perspective. Fast fashion generates enormous quantities of textile waste, forming veritable "waste deserts" in poor areas of the world, such as the Atacama Desert in Chile or the Accra Desert in Ghana. This production model, characterised by low-priced clothing, leads to excessive consumption and rapid disposal of garments, especially non-biodegradable synthetic ones, without any control over the analysis of the material in relation to its life cycle. Such textile waste contaminates soil and water, releasing toxic substances, and in most cases is burned, worsening air pollution and damaging the health of local communities, which unfortunately, in many cases coexist and survive thanks to these "new businesses for poor countries". Transforming waste into a new product through the methodological practice of the design project is the focus of the 'Yamamay Reloaded' project, which aims to raise awareness among young students of Fashion Design courses about innovative design practices in post-production and slow fashion manufacturing, with a view to raising consumer awareness of fashion that does not die but transforms and is reborn. This perspective becomes the focus of the collections created, offering an innovative and sustainable vision of garments, designed to last longer in order to educate consumers towards more conscious and respectful consumption. The Yamamay Reloaded project was born from the recovery of unsold stock from

the Yamamay company to give it new life, with a commitment to reducing the environmental impact caused by the production of new garments. The project seeks to embrace the new direction of “conscious” fashion by giving new life to something that would normally create a disposal problem. For this reason, Yamamay donated approximately 600 garments to around 70 student teams (420 students) who, under the supervision of various course lecturers, carried out a pilot educational project as part of Vanvitelli's Bachelor's and Master's degree courses in Fashion, helping to create around 150 fashion collections, each designed according to the principles of Ecodesign (Faraca et al, 2024) and slow manufacturing. The project is also analysing the possibility of putting the garments awarded by the Ethical Fashion Brand PRISM into production, working closely with social tailors to continue the project towards ethical production.

The project concluded on 16 July 2025 with a fashion show featuring 60 items from the collection, selected from among all the garments created by the students. Fifty-five students actively collaborated in the fashion show, participating in an internal internship for the organisation of the event, some images of which are shown here (Fig. 1).

Figure 1. Textile Soul (by: M. D’Antuono, L. De Monte, B. Gentile, T. Iandolo (Stylist), S. Polverino, PhD students L. Chierchia, S. Di Sarno, prof. Roberto Liberti, Corso di Fashion Eco design 1, Laurea Magistrale in Design per l’Innovazione curriculum in Fashion Eco Design)

Tracking sustainability: literature insights on responsible consumption and sustainable thinking

The Yamamay Reloaded project is part of a broader scientific framework, in which the relationship between research and education becomes a tool for critically investigating the transformations of the fashion system and placing experimentation within the theoretical and international debate on sustainability. The studies conducted have highlighted that the transition from fast fashion to fashion conscious (Iannilli&Spagnoli, 2024) requires a twofold change: cultural, through responsible consumption and sustainable thinking, and technological, with the adoption of traceability and conscious management tools. Fast fashion has been widely analysed as one of the main unsustainable production models, characterised by rapid obsolescence of garments, high volumes of textile waste and significant environmental and social impacts (Niinimäki et al., 2020). In light of these critical issues, research on responsible consumption has highlighted how consumer awareness and the adoption of purchasing behaviours oriented towards durability and product reuse are key factors in the transformation of the fashion industry (Kulakova et al., 2021; AA.VV., 2023; Gramberger, 2014). Parallelamente, il sustainable thinking si configura come un approccio sistemico che integra dimensioni ambientali, sociali e tecnologiche per guidare processi di eco-innovazione e di economia circolare (Bistagnino, 2017; Chesbrough, 2003). Within this framework, circular fashion is based not only on the design of more durable and recyclable products, but also on educational and cultural strategies capable of spreading an ethic of conscious consumption, aimed at reducing pressure on natural and social capital (Tiffany et al, 2025). Alongside this cultural dimension, there is an essential technological component: the Digital Product Passport (DPP), introduced by recent European policies as a key tool for the ecological and digital transition of the textile sector (COM(2022); Eionet Report, 2022; EC, 2020, European Parliament, 2024). The DPP ensures the traceability of materials, the transparency of production processes and access to information on the reparability, recyclability and environmental impact of products, enabling new business models based on extended producer responsibility and the activation of circular supply chains (Legardeur&Ospital, 2024). The combination of the cultural drive towards responsible consumption and the technological adoption of the DPP has therefore shaped a path of research and innovation that has made it possible to transform the fashion system, also providing the theoretical and methodological basis for educational experiments developed in collaboration with the company Yamamay, aimed at testing the effectiveness of these tools in training future professionals and raising consumer awareness.

Methodology: from project geometry to Digital Product Passports. Raising awareness of the link between sustainability, technological innovation and social responsibility

The didactical experimentation on the DPP, carried out within the Fashion Design degree programme in the Technologies and Materials for Fashion Design course for the academic year 2024-2025, was aimed at providing students with a critical understanding of the DPP as a tool for transparency, traceability and sustainability in the fashion industry.

The methodology was divided into four phases. The first phase of research and benchmarking involved the analysis of international case studies (e.g. Stella McCartney, Patagonia, Eileen Fisher, Adidas, The Fabricant) that adopt advanced practices of transparency and process digitalisation, to identify the relevant categories of information to be reported in the DPP. The second phase of technical description involved the collection and systematisation of information relating to the reinterpreted garment: origin and composition of materials, manufacturing processes used, any applicable certifications, ecological footprint, care instructions, recycling strategies and end-of-life disposal methods. The third phase of the DPP design required students to develop a digital file in which this information was codified in a standard format, integrable with unique identification solutions (QR codes) and usable by the end consumer. The fourth phase of critical analysis and feedback involved assessing the completeness and readability of the DPPs produced, with a comparison between groups on strengths and areas for improvement, as well as the formulation of innovative proposals to expand the functionality of the DPP (e.g. inclusion of data on creative reuse or the possibility of returning the garment to the company). The tools used included the analysis of web sources and company documents for the case studies, graphic design software and digital presentations for the drafting of the DPPs, and digital coding systems (e.g. QR code generator) for the simulation of technological implementation. Each group finally produced a summary document consisting of a maximum of ten slides, including a description of the transformed garment, a map of the data collected, the PDP developed, and a critical reflection on areas for improvement.

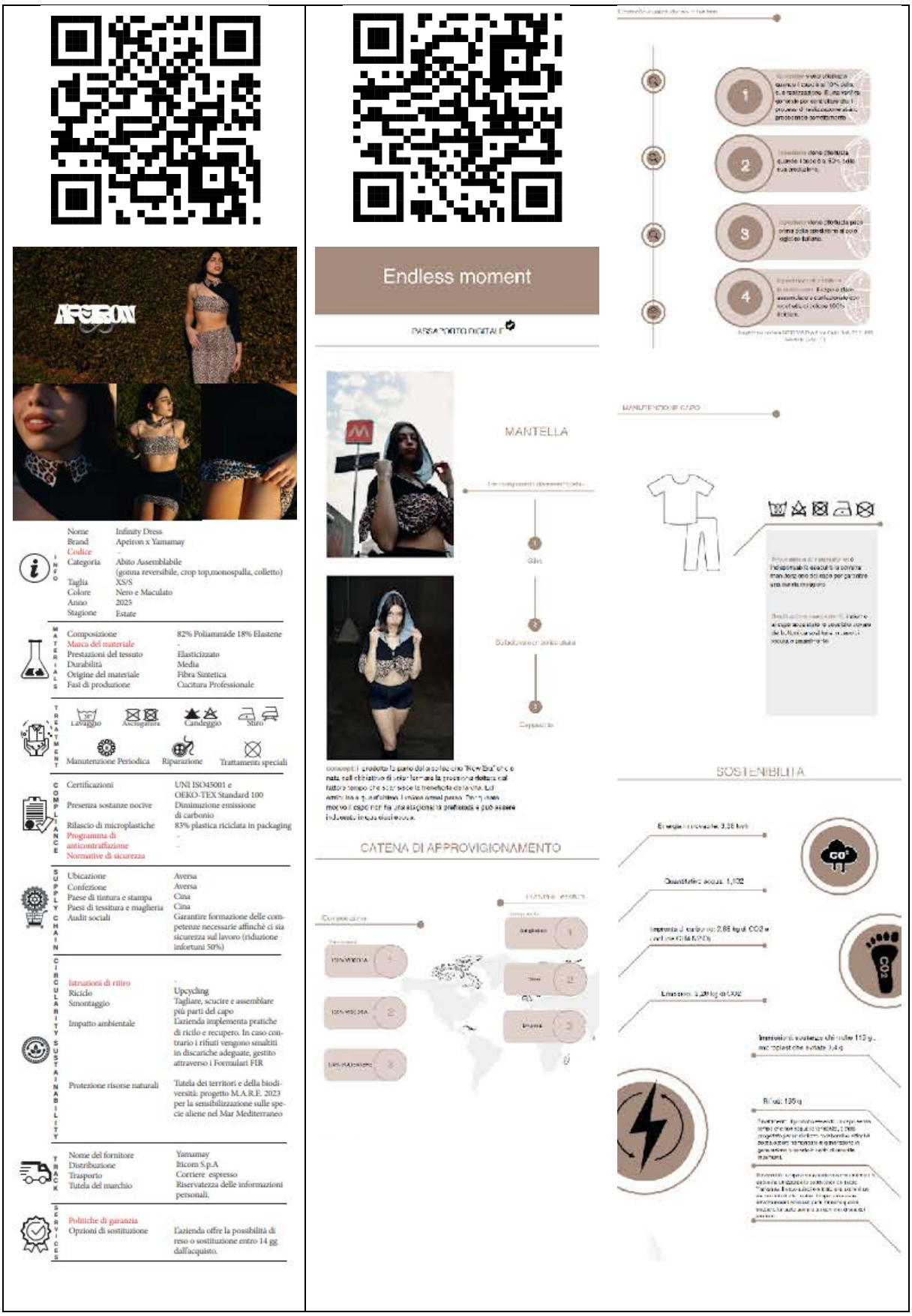

Figure. 2 Two examples of DPPs developed by the working groups

This methodology has allowed to combine the design dimension of fashion design with the operational application of the DPP, strengthening participants' awareness of the link between sustainability, technological innovation and social responsibility in the fashion system.

In line with the objective of the 'Yamamay Reloaded' project to transform unsold stock into collections by activating traceability processes, the geometric analysis and graphic documentation of the models provided by the Italian company are preparatory and integrative activities for the redesign of unsold garments and the development of the related DPPs. The aim is to use the scientific rigour of technical drawing to build an archive of models destined to be transformed to create micro-collections designed by students enrolled in the Drawing and Fashion Design 2 Laboratory courses of the three-year degree programme in Fashion Design involved in the project. With a methodological approach that is the reverse of the usual methods of designing and manufacturing clothing, the technical representation of the garments analysed confronted the students with a geometric process that leads from the three-dimensional spatiality of the physical object - the clothing product - to the flat entity through dimensional measurement, proportioning and geometric development of the paper patterns. This made it possible to investigate the forms to be reinterpreted, revealing their conceptual design through the measurement of their outlines constructed on the bodies that "inhabit" them, adapting to or denying their anatomical topography.

The methodological approach adopted confirms the continuing relevance of drawing as a medium for critical interpretation, not only of complex surfaces and their three-dimensional organisation, but also of the creative process that generated them. The technical drawings that constitute the executive matrix of the fashion product make use of graphic codes, systems, methods and techniques of geometric representation that refer to those of the discipline of drawing.

The teaching experience, divided into consecutive stages, is consistent with the contents of the Fashion Design Courses as it applies the theoretical principles of the Science of Representation, such as symmetry, proportionality and scalability, already used in the design of the human figure and fashion sketches, to the Yamamay case study.

In the first phase, students, divided into work teams, analysed the selected garments by photographing them and processing the relevant eidotypes of the models. The photos were taken with the camera positioned vertically in relation to the surface on which the garments were laid out in order to obtain nadir images to support the correct proportioning of the models. The relief eidotypes recorded the dimensional characteristics of the models, taken using

traditional pattern-making methods and tools and referring to the Yamamay size chart, which were useful for the development of the geometric tracings (plat) in planimetry.

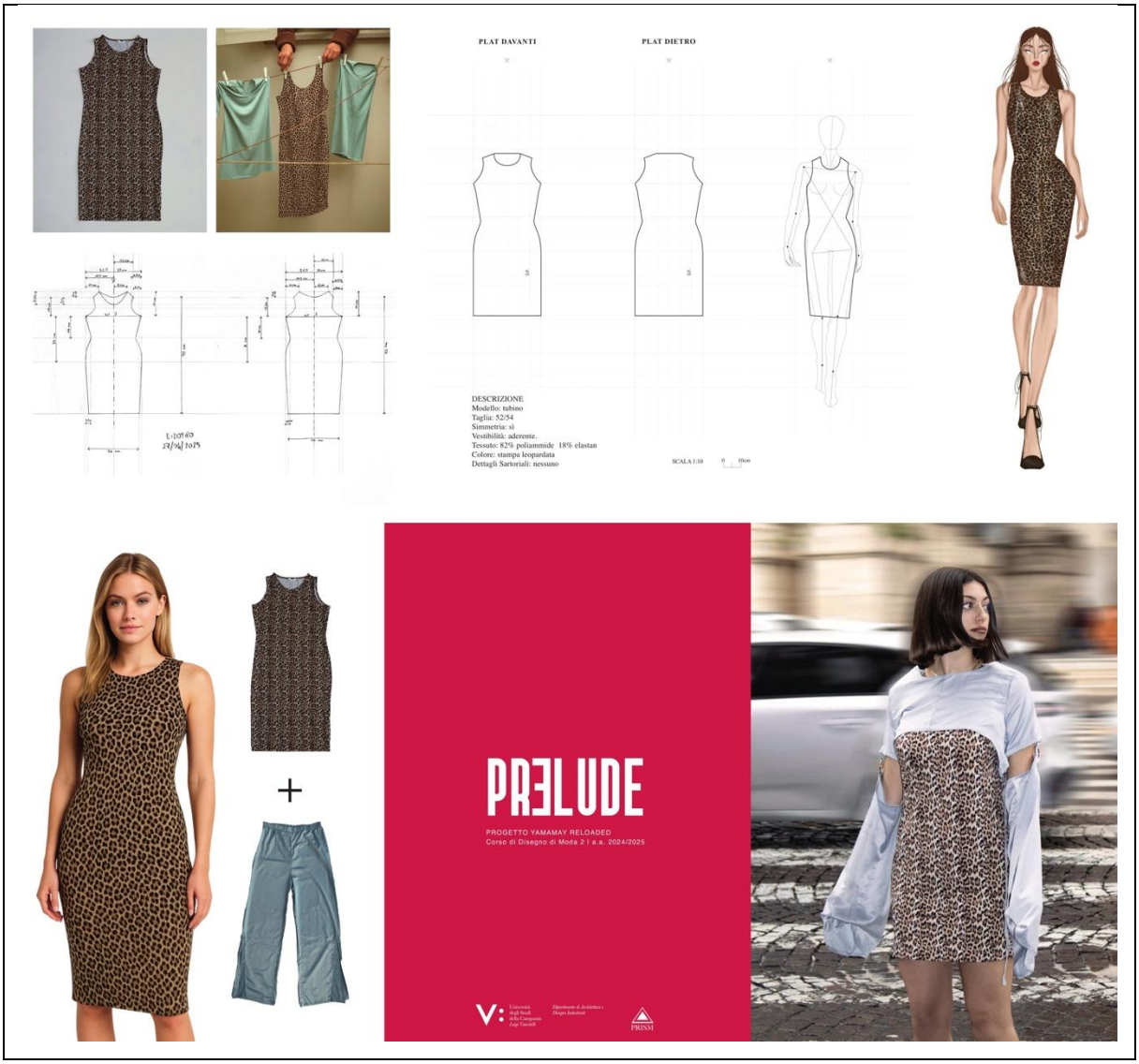

Figure. 3 “PreLude” project documenting unsold Yamamay models. Brochure created by students of the Fashion Design 2 course, academic year 2024/2025.

In the next phase, the relief eidotypes were reproduced in technical drawings on an appropriate scale, to which the main sartorial data of the model were associated (name, size, symmetry/asymmetry, fit, fabric composition, colour/print, sartorial details). To verify the fit of the model, the geometric outline was laid on the body represented by its silhouette, ensuring mutual geometric and dimensional proportionality between the garment and the body through the proportioning scheme according to the classic canon in eight modules of the female figure, still in use in professional fashion design. The graphic documentation of the models destined to be transformed and hybridised with other models in the project was completed with the

creation of stylised sketches, to graphically represent, through the use of appropriate graphic techniques, the characteristics of the fabrics used to make the models.

The graphic material produced by the students at the end of the analysis activity was incorporated into the "PreLude" project, presented in summary brochures representing the photographic, technical and illustrative documentation process carried out for each garment destined to lose its original configuration and merge into that of the project.

Findings and Discussion

The experimentation demonstrated that combining the creative reuse of unsold stocks with the application of the DPP constitutes an effective didactic model that integrates sustainability, transparency, and accountability in the fashion system. Each group elaborated a DPP for the redesigned garment, translating complex production and transformation processes into structured and communicable datasets, including materials, processes, certifications, and end-of-life strategies. Alongside this technological dimension, fashion drawing and project geometry played a strategic role: surveys, eidotypes, and technical drawings allowed students to document the original Yamamay models scientifically and to guide their reinterpretation. The use of graphic codes, systems, and geometric representation techniques was not only descriptive but also an analytical and critical tool, supporting both the creative process and the construction of the DPP. Findings highlight three key aspects: the value of transparency for consumers, the need to standardize datasets in line with EU directives, and the importance of drawing and geometry as mediators between design and traceability. Despite these results, the absence of quantitative metrics and the limited sample size indicate the need for further validation.

Conclusion: operational model for sustainable and traceable fashion design

The experimentation has outlined a didactic-operational model that integrates the reuse of unsold stocks, sustainable design practices, and the implementation of advanced monitoring tools such as the DPP. Each garment was associated with a complete, transparent, and communicable dataset, thus transforming the act of design into a process of accountability and knowledge production. The project can be interpreted as a form of Action Research, in which the integration between scientific research and teaching experimentation generates results that are both academically rigorous and practically impactful. Within this framework, sustainability emerges not only in its environmental and economic dimensions but also in its socio-cultural

significance, as it stimulates critical awareness, strengthens collective responsibility, and promotes literacy in transparency and traceability across the entire products supply chain. The DPP has proven to be an effective operational device: by requiring the codification of information on materials, processes, certifications, and end-of-life strategies, it fosters in students the acquisition of specific knowledge on sustainable design while also serving as a tool of consumer empowerment. Its communicability makes it accessible to all types of consumers, from experts to non-specialists, thereby contributing to a more informed and responsible approach to fashion consumption. This aspect underscores the educational value of the DPP, as it not only structures knowledge but also democratizes access to information, bridging the gap between production and use.

Moreover, the methodology developed demonstrates a replicability potential that extends beyond the boundaries of fashion design. The rigorous combination of project geometry, graphical representation, and digital traceability tools establishes a methodological framework that can be transferred to other areas of design where sustainability, transparency, and accountability are equally pressing issues. By positioning design as both a scientific and cultural practice, the proposed approach provides a reference model for future initiatives aiming to merge creativity with research-driven strategies, offering a pathway for academia and industry to collaborate in building more sustainable, transparent, and socially engaged design systems.

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LEARNING FROM PERIURBAN. LABORATORIES IN THE OPERATIONAL LANDSCAPE BETWEEN NAPOLI AND CASERTA

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Learning from Periurban. Laboratories in the Operational Landscape Between Napoli and Caserta

Abstract: In the peri-urban area between Naples and Caserta, the territory traversed by the Regi Lagni is taken as a case study for sustainability education grounded in connections and stitching across fragments. The contribution reconstructs the set-up and delivery of the Urban Design Laboratory of the Department of Architecture and Industrial Design at the University of Campania "Luigi Vanvitelli," which worked in the area between the municipalities of Marcianise and Caivano, using the Caserta PTCP and the Masterplan documentation as shared bases for reading and design. Attention is directed to thresholds and edges between productive areas, ERP housing estates and agricultural fabrics, reframing dross-scapes and interstices as operational resources. The actions explored—targeted renaturalisation, de-impermeabilisation, riparian vegetation, linear afforestation and new connections—are considered replicable interventions that hold together territorial ecology and public space. Along the identified margins, the stitching devised by the student groups recalibrates compatibilities between functions and uses.

Keywords: peri-urban, operational landscape, sustainable urban design laboratories

Peri-urban hydraulic networks. Regenerative strategies and visions for the Terra di Lavoro

In the Campanian plain between Naples and Caserta, historically known as the Terra di Lavoro, the hydraulic system of the Regi Lagni constitutes a historical structure that enabled land reclamation and guided settlement patterns, and today can provide the trace for a major operation of territorial regeneration. This overarching trace within the "palimpsest territory" crosses urban and rural portions where intensive uses, discontinuous transformations and abandonment have produced inert margins, fragments and leftovers. The Provincial Territorial Coordination Plan (PTCP) of Caserta designates these fragments as "aree negate": places where functional abandonment and degradation coexist with environmental potential never activated, offering an institutional taxonomy useful for orienting readings and priorities (De Lucia, 2012). In the face of the limited effectiveness of ordinary urban plans on such issues, strategic devices are needed to guide decision-making and public policies. The Masterplan of the Regi Lagni, developed by LAND for the Consorzio Generale di Bonifica del Bacino Inferiore del Volturno, moves within this frame and proposes an interpretation of the hydraulic system not as a mere drainage infrastructure, but as an ecological and symbolic backbone. The renaturalisation of canals with riparian vegetation, the use of constructed-wetland treatment, the construction of a continuous forest corridor and the focus on interfaces between productive areas, public housing estates (ERP) and infrastructural margins outline a project field in which water reconnects soils, practices and communities. Against this background, a number of teaching experiences carried

out at the Department of Architecture and Industrial Design of the University of Campania "Luigi Vanvitelli" have addressed the dimension of urban design and the principle that sustainability in design disciplines cannot be detached from place; it requires matrices that allow for reading stratifications, composing scales and negotiating choices with those who inhabit and govern the territory. The weave of the Regi Lagni offers this opportunity: not a repertoire of systems to replicate, but a grammar of relations to be reconstructed. The scope of work is circumscribed and situated; no impact measurements or experimental hydraulic assessments are introduced. The reflection concerns the alignment between the planning framework, ongoing projects and available analytical frames, with the aim of defining a training pathway capable of intertwining applied ecology, public space, landscape cultures and the trans-scalar dimension of urban design.

Operational landscape, urban metabolism and sustainable urban laboratories

Studies on urban metabolism show how settlement systems are fed by flows of matter and energy, and how economic and demographic transformations modify their intensity, directions and residuals, with evident effects on water cycles and ecosystem conditions (Kennedy, Cuddihy & Engel-Yan, 2007). In the Paris metropolitan area, the historical reconstruction of material and energy flows has provided examples of how a systemic analysis can inform policies for input reduction, closure of cycles and recalibration of city–territory relations (Barles, 2009). Operatively, these studies have found an interlocutor in landscape design and ecological planning, where attention shifts from isolated objects to relational structures capable of linking functions and processes (Ferrão & Fernández, 2013). It follows that form is not an end in itself but a support to ecological connectivity and the quality of dwelling, especially where fragmentation and discontinuity compromise environmental and social functions (Forman, 1995). In dialogue with urban transformations, landscape urbanism has interpreted landscape as an operational medium: a device able to absorb complexity over time, organising processes rather than crystallising definitive images (Corner, 1999; Waldheim, 2006). In the case of the Regi Lagni, the territory traversed by the water system can become a design palimpsest in which riparian vegetation, bank profiles, passages, stops and crossings compose a functional and cultural order together. A consolidated part of the literature recognises that blue-green networks, de-impermeabilisation and targeted interventions on sections and edges of the public realm operate in an integrated way, allowing urban hydraulic systems to be treated as devices for territorial recomposition (Benedict & McMahon, 2002;

Wong & Brown, 2009; Gasparrini, 2018). On the educational side, studies on competencies for sustainable regeneration have outlined frames useful for orienting university curricula and professional development, insisting on systems thinking, anticipatory capacity, strategic orientation, the normative dimension, collaboration and reflexivity (Wiek, Withycombe & Redman, 2011). The development of urban design laboratories on these themes' sequences experience, reflection, conceptualisation and new experience, valuing real contexts as places where knowledge is built through progressive approximations (Kolb, 1984). Situated education reminds us that the link with contexts and communities is not accessory: it helps avoid responsibility-free abstractions, tying the care of spaces to the cultures that traverse them (Gruenewald, 2003). These concepts find confirmation and evolution in various European examples of cooperation among universities, administrations and civil society that make the territory a shared laboratory, where teaching and third mission intertwine (Evans, Karvonen & Raven, 2016; Voytenko et al., 2016), in a framework consistent with the goals of the 2030 Agenda (Nazioni Unite, 2015). Within this frame, the territory crossed by the Regi Lagni offers an application context in which to verify—both in project and teaching terms—the integration between ecological connections, stitching operations and the management of public space.

Set-up and working materials. Documentary readings and sustainable urban design laboratories

The teaching experience of the Urban Design Laboratory at the Department of Architecture and Industrial Design of the University of Campania "Luigi Vanvitelli" involved a reconnaissance of places through readings of planning and design materials, including the Caserta PTCP and the documentation relating to the Regi Lagni Masterplan produced by LAND for the Consorzio Generale di Bonifica del Bacino Inferiore del Volturno (LAND, s.d.). The laboratory therefore adopted the Masterplan as an active backdrop. The documentary reading addressed interpretive frames and stated strategies, with attention to recurring elements: renaturalisation of canalised stretches through reintroduction of riparian vegetation, light morphological adjustments, constructed-wetland devices; forest continuity at corridor scale; articulation of cycle-pedestrian routes grafted onto urban thresholds; treatment of interfaces with productive districts; stitching in residential areas, with particular regard to ERP estates; construction of a network of small public spaces as the outcome of a landscape project operating through insertions and overlays (Kadlec & Wallace, 2009). The reading of the PTCP provided a territorial and conceptual repertoire useful for locating areas and understanding the meaning

of the “aree negate” designation as a signal of potential not yet activated rather than of irremediable deficit. The lab activities therefore concerned the “middle territory” between Caivano and Marcianise; each working group was assigned areas to analyse and reinterpret, identified on the basis of accessibility, proximity to incompatible uses, the presence of open margins, and potential for ecological continuity and public space. Teaching intertwined field reconnaissance, the construction of descriptive atlases and design exercises, avoiding prescriptive formulas (cfr. Lang et al., 2012). The materials produced by the students include interpretive maps, sections and profile details, catalogues of replicable devices at different scales, visual narratives and short dossiers intended for public discussion. The set-up privileged convergence between readings and proposals, as an opportunity to verify in the field insights derived from texts and cartographies, and to recalibrate design choices in the light of constraints, use practices and local memories.

Figura 1. Regi Lagni masterplan. Consorzio di Bonifica del Bacino Inferiore del Volturno. (LAND 2010)

Operational weaves along the Regi Lagni. Learning by designing across water, soils and communities

Each student group developed its own operational masterplan in which all the issues addressed theoretically were applied at a planning level. It emerged that, in the area under consideration, the peri-urban condition takes shape as a relational system rather than a field with recognisable borders: an interlacing of industrial, agricultural, infrastructural and residential fabrics that does not converge into a unitary design but remains in a state of tension. Proximity to the Industrial Development Areas (ASI) and to mobility corridors produces a

landscape of heterogeneous adjacencies, in which productive anchors, recent subdivisions, public housing and agricultural soils compose discontinuous sequences. Under these conditions, the network of the Regi Lagni operates as a potential support for new connections and stitching, capable of inscribing coherence within an otherwise fragmented field. The project perimeter does not coincide with an administrative boundary, but with the breadth of a territorial ecology that includes different flows, times and use regimes, recognising peri-urban dross-scapes as operational resources rather than mere outcomes of degradation. The hypotheses expressed in the masterplans are rooted in the tradition of the operational landscape: the project does not pursue formal unity, but constructs enabling conditions that allow the territory's different elements to form a new system of relations. The principal matter of intervention is the threshold—between productive plot and canal, infrastructural edge and residence, intensive farmland and urban rim—where the peri-urban simultaneously manifests conflict and possibility. At these points of friction, stitching does not act as cosmetic correction but as a translation of compatibilities: it realigns contacts, makes short-range routes legible, and reorganises access to water in controlled and repeatable forms, leveraging targeted interventions rather than comprehensive redesigns. The sequence of productive stretches along the Lagni, far from being an obstacle, becomes a testing ground for a grammar that works on degrees of belonging: it relaxes absolute fences by turning them into filters, reconnects pedestrian and cycling meshes without denying logistics cycles, and reconfigures the canal-side fronts as territorial hinges rather than the backs of plots. Urbanised margins and mixed settlement fringes are not treated as negative realities to be isolated—deficient with respect to the compact city—but as generative conditions. Discontinuity is not removed: it is taken as a compositional principle within which to orchestrate connections between portions now isolated. From this perspective, the PTCP's "aree negate" are not residues to be filled but reserves of adaptability in which minimal action produces effects at scale. The system's malleability is recognised in its capacity to reorder sequences without imposing artificial continuities: work proceeds through open geometries, insertions that respect the temporalities of places, thresholds that accommodate compatible uses and modulate conflicting ones. The resulting urbanism—recalling the lesson of the interstice (Allen, 1999)—is exercised in the interval: it intervenes where voids interrupt the legibility of the network, where the industrial edge can become a hinge, where the proximity between ERP and canal makes possible a new pact of cohabitation with water. Within this frame, the Masterplan offers a shared lexicon more than a repertoire of forms: selective renaturalisation not as a naturalistic paradigm but as a device of connection;

linear afforestation not as screen but as a marker of orientation and continuity; slow routes not as promenades but as proximity infrastructures that support daily movements between work, services and residence.

Figure 2. One of final review boards. Laboratorio di Urbanistica, Università della Campania Luigi Vanvitelli (students: Martina Iavarone, Md Mehzabin Islam)

Along the hydraulic backbone, these elements operate as micro-infrastructures of ordering capable of traversing the ASI–neighbourhoods–farmlands mosaic without forcing a totalising order. In this sense, the project does not “fill” voids but translates them into mediation devices; it does not “close” fractures but governs them by making them traversable; it does not “uniformise” the peri-urban but articulates its components into a recognisable weave. The outcome is a reading that restores to the Regi Lagni the role of a discreet matrix of

transformation: an infrastructure which, by operating through connections and stitching, makes it possible to bring forth a territorial ecology capable of including production, dwelling and mobility within a shared processual frame.

Conclusions

The laboratory-based work on the territory under consideration has shown that place-rooted teaching can translate planning frameworks and theoretical references into operational criteria consistent with the peri-urban condition. The integration of documentary readings (PTCP and Masterplan), in situ reconnaissance and design exercises enabled students to recognise thresholds and edges as privileged sites of intervention, to read dross-scapes and interstices as resources, and to organise replicable micro-actions that hold together territorial ecology and public space. Within this set-up, connections and stitching take a concrete form: targeted de-impermeabilisation, selective renaturalisation, riparian vegetation and slow routes are treated not as occasional add-ons but as components of a shared vocabulary, verifiable and maintainable over time. The laboratory experience further clarified that overall coherence does not derive from a unitary design, but from sequences of compatible interventions that make legible the arrangement among productive fabrics, ERP estates and agricultural soils. Stated limitations remain—absence of dedicated hydraulic measurements and ex post evaluations—that orient the next steps: defining essential metrics, consolidating procedures of ordinary maintenance, and structuring moments of dialogue with managing bodies and administrations. From this perspective, the experience provides a transferable basis for other peri-urban corridors, keeping the focus on situated learning, incremental care and design responsibility.

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A SUSTAINABLE EDUCATION MODEL IN TEACHING DETAIL DESIGN IN INTERIOR ARCHITECTURE

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A Sustainable Education Model in Teaching Detail Design in Interior Architecture

Abstract: The sustainable education approach has been accepted as the mainstream of a curriculum by the educators since the technological and sociological developments of the 21st century are taken into consideration. This paper introduces a course model, which collapses two sets of global priorities—UNESCO's Education for Sustainable Development (ESD) and OECD's Trends Shaping Education 2025—into the teaching of interiors detailing and materials. The model integrates technical detailing with critical and creative design thinking across a 14-week framework. The reconstructed course, Design Details and Finishing Materials, uses the "See, Decode, Synthesize" method, proposed and created by the authors, based on learning theories of constructivism and connectivism. With the learning method of the generation suggested by the ESD, students analyze the visual given to them and dissect it by sketch-based synthesis to work out material behavior, develop sustainable responses, and assess the long-term effects of design choices. Alignment analysis indicates high potential with competencies such as problem solving, digital literacy, and environmental consciousness, as well as highlighting areas for improvement in equity and cultural sensitivity. The study demonstrates how sustainable design education can be integrated into detailing courses and offers a powerful model for cultivating future interior architects equipped with problem-solving skills, ethical responsibilities, and adaptive thinking.

Keywords: interior architecture education; construction detail design; sustainability; trend shaping education, ESD.

Introduction

In the twenty-first century, technologic breakthroughs, particularly in virtual reality, the Internet of Things, and artificial intelligence, have transformed economic systems as well as social life and learning (OECD, 2025; UNESCO, 2020). Specifically, it is necessary for the education of individuals who have completed their cognitive development within this framework to undergo a parallel transformation (Prensky, 2001; Siemens, 2005). These individuals generate and assimilate knowledge in disjointed formats and generally engage with information via brief visual and auditory content (Downes, 2007).

As social media and digital platforms continue to expand, more voices and perspectives are becoming visible in public life. However, the expansion of social media and digital platforms also allows inaccurate or deceptive information to spread without any filtering mechanisms (Wals, 2011). As a result, educational resources should be created with the scope of students' media and learning preferences in mind, emphasizing critical thinking and responsible communication (Sterling, 2001).

Upcoming educational approaches must be designed to improve digital literacy, offer personalized learning environments, and encourage lifelong learning (UNESCO, 2017). These goals are important in every field, but they are especially important for creating the foundation for an international sustainable education approach, which is based on interdisciplinary

understanding and critical thinking, both of which are vital for preparing individuals to solve encountered problems (Barth et al., 2007).

Literature Review: Education for Sustainable Development and 21st-Century Pedagogy in Interior Architecture

The doctrine of sustainable development adheres to maintain the balance between humans and nature, exploiting the natural resources without squandering it, and leaving to future generations a world in which it is possible to live (Kates et al., 2001). The 1987 Brundtland Report defined sustainable development, by stating that "humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs". Education for sustainable development is to ensure that individuals have the understanding, knowledge, and skills required to contribute to a more sustainable future (UNESCO, 2017). These competencies are such as leading to critical, problem-solving and responsibles actions.

According to UNESCO's 2017 definition, "Education for Sustainable Development" (ESD) is an educational strategy meant to assist people in gaining the values, attitudes, abilities, and knowledge required to accomplish sustainable development objectives. Comprehensive guidelines for education systems to develop solutions for global challenges are outlined in UNESCO's ESD for 2030 framework. Beyond environmental education, the idea of sustainable development entails a multidimensional approach to education. Increasing people's ability to change themselves and their societies in sustainable ways is its main objective.

ESD involves building competencies in critical thinking and problem-solving, encouraging sustainable lifestyles, and promoting personal responsibility (Sterling, 2001). It also aims to raise awareness of globalisation and social responsibility (Wals, 2011), to support value-based decision-making (justice, equity, peace, rights), and to foster interdisciplinary and systems thinking (Barth et al., 2007). Moreover, UNESCO (n.d.) prioritises the development of lifelong learning habits and the formation of learning communities.

Table 1 Core Competencies of Education for Sustainable Development (ESD)

Competency Area	*Description*	*Key References*
Critical Thinking and Problem Solving	Ability to analyse complex systems, identify sustainability challenges, and generate responsible solutions.	UNESCO, 2017; Sterling, 2001
Interdisciplinary and Systems Thinking	Capacity to understand interconnections among ecological, social, and economic systems.	Barth et al., 2007
Value-Based Decision Making	Engagement in ethical reasoning and decisions grounded in principles such as justice, equity, peace, and human rights.	Wals, 2011; UNESCO, 2017
Sustainable Lifestyles and Responsibility	Adoption of behaviours aligned with environmental and social sustainability.	UNESCO, 2017; Sterling, 2001
Lifelong Learning and Self-Regulation	Motivation and ability to continue learning across the lifespan with autonomy and selfreflection.	UNESCO, n.d.
Participation and Collaboration	Competence to work with others across cultural and disciplinary boundaries.	Wals, 2011
Transformation and Agency	Empowerment to initiate change for sustainability at local and global levels.	UNESCO, 2017

In addition to UNESCO’s ESD, the OECD's Education Shaping Trends 2025 report, which focuses on global education trends and future studies and is shared with stakeholders periodically, summarizes key education priorities aimed at preparing individuals for the transformations of the digital age and covering a multidimensional framework.

These priorities extend beyond academic achievements to encompass broader competencies such as contributions to lifelong learning and sustainable development (OECD, 2025). At the heart of this framework lie student-centered and flexible learning approaches that are based on individual differences and enhance learners' metacognitive awareness (OECD, 2025, pp. 35–38). It is emphasized that to address the increasing complexity and uncertainty in global environments, the development of 21st-century skills such as critical thinking, collaboration, creativity, flexibility, and digital literacy is vital (OECD, 2025, pp. 46–49).

The report indicates that sustainability is a primary goal, and the curriculum and pedagogy of the proposed educational programs must integrate environmental awareness, climate resilience, and global citizenship (OECD, 2025, pp. 67–72). Schools that ensure that students' opportunities are not restricted by their economic status, gender, or ethnicity are crucial, according to trends pertaining to equality and inclusion in sustainable education (OECD, 2025, pp. 24–25). According to the OECD (2025, pp. 54–56), sustainable education is a lifelong process that requires accessibility and occurs in a social context. The study demonstrates the significance of appropriately integrating technology, particularly in the context of ethical use of data systems, digital spaces, and artificial intelligence (OECD, 2025, pp. 59–66).

Graduates are expected to be not only knowledgeable but also morally upright, politically aware, and socioculturally conscious global citizens since education is described as a culturally embedded institution that must adapt to local identities, values, and democratic responsibilities (OECD, 2025, pp. 73–75).

Table 2 – OECD Educational Priorities According to Trends Shaping Education 2025

Priority Area	*Description*	*Key Reference*
Student-Centred and Flexible Learning	Education systems must accommodate learners' individual needs, foster agency, and support diverse learning pathways.	OECD, 2025, p. 35–38
Competencies	Emphasize critical thinking, adaptability, collaboration, creativity, and data literacy to address complex societal and technological changes.	40–49
Lifelong and Lifewide Learning	Learning should be continuous across the life course and integrated across formal, informal, and non-formal settings.	CD, 2025, 54–56
Equity and Inclusive Access	Education systems must counteract social disparities, ensuring fairness across socioeconomic, cultural, and geographic	CD, 2025, 24–25
Education for Sustainability and Global Citizenship	Learning should promote climate awareness, ecological responsibility, and civic participation in a globally interconnected world.	CD, 2025, 67–72
Technology Integration and Digital Transformation	Systems should leverage AI, data science, and digital ecosystems while ensuring equity in access and ethical use.	59–66
Socio-Cultural and Ethical Sensitivity	Curriculum should reflect cultural diversity, promote dialogue, and support social cohesion and ethical reflection.	CD, 2025, 73–75

The evolving mindset of youth towards learning, coupled with the need for more focus on global issues, are the two factors that have shaped skills for the 21st century. Turner (2015) noted that Generation Z, which encompasses individuals born between 1990 and 2012 and currently

represents the largest demographic of undergraduates, is fully capable of accessing the internet and digital tools. Therefore, their learning and info engagement is distinct from how things used to be.

It is student-driven and involves the use of modern technologies which means that educators have to change their teaching styles to meet the new approach of 21st century learning.

The use of ESD for teaching practices in interior design education is a good example of this transformative change. Teaching interior design goes beyond the creation of spaces that are aesthetically and functionally, it must also teach the principles of designing ecologically, culturally, and socially responsible spaces in line with global education priorities stated in the OECD's Shaping Education Trends 2025. These principles are aimed at enabling students to critically assess their actions and thoughtfully evaluate the consequences of design decisions.

Choosing eco-friendly materials while taking user requirements and material behavior into account is an essential part of this process. This promotes a comprehensive view of the design environment and multifaceted thinking.

This method has become a cornerstone of interior architecture education, especially when it comes to the idea of design-based value creation (Kang and Guerin, 2009). It has also brought sustainable development objectives into line with the direction of design practice.

The OECD's trend-shifting education priorities and UNESCO's sustainable education approaches serve as a foundation for the educational model created in this study.

Methods: Course Structure

While examining all these studies on "sustainability in education," it was observed that when concentrating on interior architecture education, which does not only focus on the creation of aesthetic and functional spaces but also enables students to recognize and apply environmental, cultural, and social sustainability values, the courses and curriculums to be designed regarding space creation align with most of the criteria already mentioned.

Internalizing these approaches through education enables students to recognize the longterm effects of their design decisions, analyze and question them, select environmentally sensitive materials with a sense of environmental responsibility, consider user and material behavior, and think in a multifaceted way. This approach is also consistent with the increasingly

important concept of “creating value through design” in interior architecture education (Kang & Guerin, 2009).

The second-year undergraduate course titled Design Details and Finishing Materials, offered as part of the Interior Architecture program at Çankaya University, is not only about technical drawing or application; it is also designed as a critical course in terms of analysis, bringing design to life, feasibility, sensitivity to user needs, and producing sustainable decisions.

Conventional courses on details and materials are mostly based on lecture-focused format that relies heavily on general detail templates, catalog examples, and didactic presentations. Even though such methods are technically informative, they often encourage students to passive learning over active learning and overlook the interpretive and contextual nature of detailing in practice.

The new course that this paper presents is structured around conventional lecture, analysis, drawing, and application principles of standard fine structure detail typologies, it also incorporates UNESCO's Education for Sustainable Development (ESD) Goals and the basic education criteria defined by the OECD's “Trends Shaping Education 2025,”

The authors suggested an alternative teaching approach named as The “See, Decode, Synthesize”, designed and based on reverse engineering logic, This approach is supported by constructivist and connectivist learning theories. It emphasizes critical observation, collaborative interpretation, analysis, and sketch-based synthesis, mimicking real-life design processes and encouraging students to actively participate in knowledge creation. Instructors act as guides in a collaborative creative environment rather than passive transmitters of information.

The “See, Decode, Synthesize” model, a more sustainable methodology emphasizing active learning, visual interpretation, analysis, and the ability to transfer knowledge across different design scenarios, provides students with 14 weeks of training, 4 hours per week, under 5 main subject headings. Subject presentations are conducted at two-week intervals and cover suspended ceiling systems, partition wall applications, surface coatings and alternative solutions (green wall systems, various coating materials, etc.), raised flooring systems, and fixed furniture materials and details.

In the courses, standard detail solutions for each topic are first examined, with a focus on the analysis of material properties and joint details. After the positive and negative aspects of the materials are explained in detail, detailed information is provided to students through examples of implemented projects, and the detail solution approach is explained. After providing the theoretical foundation, students are given an example image and asked to produce application details for that image.

Students form working groups of 2-3 people, analyze the project images provided, and search for similar detail solutions by reviewing internet resources, manufacturer catalogs, and technical publications. During this process, teaching staff guide the groups and support the learning process by creating discussion environments.

After the weekly work is completed, the solution proposals prepared by the student groups are presented in the classroom the following week, and the detailed solutions, material selections, and joining techniques are discussed with all participants to reinforce the topics. Then, a new application example is given, and the process continues.

At the end of the first 8 weeks, assuming that the students have mastered all the topics, a written exam is administered to measure their theoretical knowledge. Subsequently, detailed analysis studies are conducted on the images prepared by the students for their own projects or provided by the instructors, and these studies are evaluated in critical sessions. In the final week of the training, a sketch exam is conducted, where students perform an application detail analysis using a new visual to assess their detail analysis and technical drawing skills.

The curricular design process began with a focus on global educational policies, emphasizing sustainability and 21st-century educational priorities. Throughout this trajectory, key criteria such as Critical Thinking & Problem Solving, Sustainability and Environmental Awareness, Lifelong Learning & Learning in Context were considered to ensure that the course structure effectively addressed these educational goals.

The Student-Centred and Flexible Learning, Digital Literacy & AI Integration and Collaborative and Reflective Learning methods are also affect the developmental sequence since the course allows students to approach problems with personalized strategies, enabling them to explore different material combinations and visual detailing styles. Sketch-to-digital progression encourages self-paced learning.

Table 3 shows how the current course design aligns with key policies. While assessing the sustainability and pedagogical coherence of the course curriculum, policy-based (ESD and OECD 2025) criteria were systematically evaluated in terms of their alignment percentages and accompanying justifications.

Table 3 Alignment of Course Process with ESD and OECD Principles

Principle	Approach	Course Alignment (%)	Justification
Critical Thinking & Problem Solving	ESD + OECD (21stcentury skills)	95%	Students are expected to interpret complex spatial problems, assess real-world applications, and generate technical solutions for interior systems This develops both analytical and decision-making skills.
Student-Centred and Flexible Learning	OECD (2025)	90%	The course allows students to approach problems with personalized strategies, enabling them to explore different material combinations and visual detailing styles.
Sustainability and Environmental Awareness	ESD + OECD	85%	Material selection tasks require consideration of ecological impact and user behaviour, thus reinforcing sustainable thinking through tangible detailing work.
Digital Literacy & AI Integration	OECD (2025)	80%	Students analyze and re-interpret AI-generated images for feasibility and detail quality, building awareness about emerging technologies in design processes.
Collaborative and Reflective Learning	ESD	75%	Peer critique sessions after each detail submission encourage collaborative improvement and reflective decision-making. Learning is enhanced through shared dialogue and iteration.

Lifelong Learning & Learning in Context	SD + ECD 025)	0%	The problem-solving process mimics real-world design practice and emphasizes transferable detailing strategies, fostering professional readiness beyond the course.
Equity and Inclusion in Learning Processes	ECD	5%	By using neutral, universally accessible visual sources and realworld applications, the course reduces entry barriers and promotes learning equity across students from different backgrounds.
Global Citizenship & Ethical Responsibility	SD	0%	Though not a central focus, students are encouraged to consider social responsibility in design decisions, especially in
Cultural Sensitivity and Contextual Design	OECD	55%	Visual references and user-centered scenarios sometimes integrate cultural context, though this varies by case.

In the curriculum, students are expected to interpret given visuals to assess complex detail problems, suggest real-world applications, and generate technical solutions for interior systems (e.g., suspended ceilings, raised floors). This method develops both analytical and decision-making skills while meeting approximately 95% of the expectations outlined in these key policy frameworks.

Sustainability and environmental awareness is other important issue that can be found in both education strategies. Tasks related to material selection during detail design necessitate

the consideration of ecological impact and user behavior, thereby reinforcing sustainable thinking through practical detailing. During the material selection process, students assess ecological and functional aspects alongside durability, maintenance, feasibility, and applicability. Through this approach, the new method addresses the overarching theme of sustainability, which is emphasized by both key policy frameworks, at an 85% alignment rate.

Findings and Discussion

As visualized in Figure 1, the course demonstrates strong alignment (≥75%) with key educational principles such as critical thinking, flexible learning, and sustainability. However, areas such as global citizenship, equity, and cultural sensitivity fall below the desired threshold, indicating potential for further curriculum enhancement. These gaps are addressed through specific revision strategies outlined in the justification column.

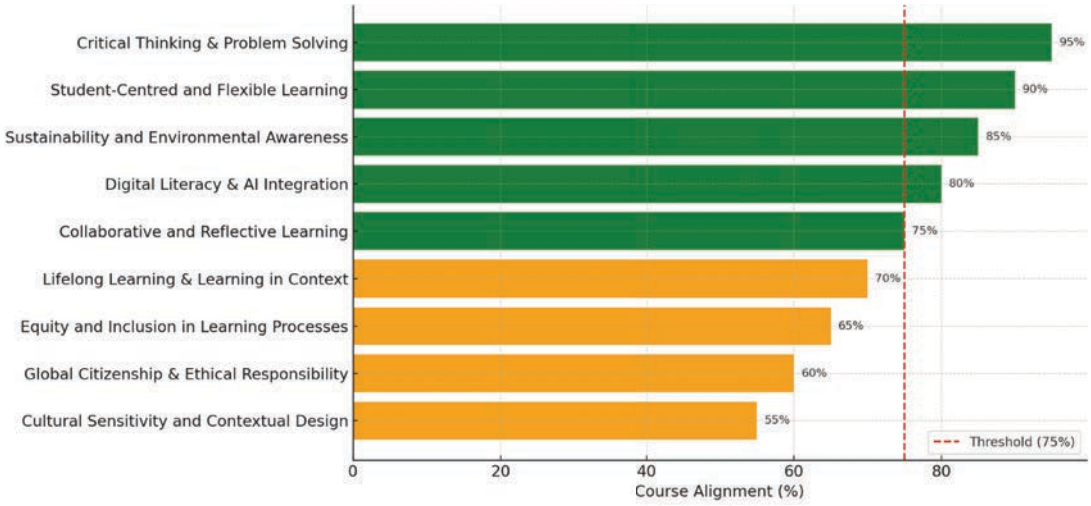

Figure 1. Course process with ESD and OECD Principles

Conclusion

Structured around collaborative discussion and creating various design solutions from the same visual input, the course, structured around active learning, peer collaboration, and sketch-based detail synthesis, effectively supports critical thinking, sustainability awareness, and digital literacy. Based on initial analyses, the designed course is consistent with fundamental learning competencies such as problem-solving, material sensitivity, and contextual design decision-making, as well as predicting the outcomes of decisions made.

Although the course demonstrates a strong theoretical foundation and pedagogical integration, some shortcomings are observed in areas such as cultural contextualization, global

citizenship, and equal access. Future iterations will aim to address these shortcomings by offering region-specific user profiles, various case studies, and interdisciplinary collaborations with industry stakeholders. The integration of learning theories will help design learning experiences that are critical for problem solving and analyzing the outcome of solutions, developing sustainability awareness in all areas, and existing effectively and ethically in an increasingly digital world.

Additionally, increasing the accurate and efficient use of artificial intelligence tools for visual analysis and encouraging student-driven research can further support connective learning goals.

High grades were neither an expectation concerning the outcomes of the new model and methodology in course instruction, nor were they statistically apparent. Still, the course evaluation proved the model's track as an objective path, and the level of success in examinations came out as a realistic indicator representing students' competency in out-of-thetemplate real-world situations. Overall, the new "See, Decode, Synthesize" approach is apparently a promising shift that complies with broader frameworks of sustainable education perspective in teaching detailing in interior architecture.

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CULTURES OF GLASS. HERITAGE-BASED INNOVATION AND SUSTAINABILITY IN EDUCATION.

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Cultures of Glass. Heritage-Based Innovation and Sustainability in Education

Abstract: This paper presents the GLASS Cluster as a case study in sustainability education, where heritage and innovation meet. It illustrates how glass cultures can support the training of architects and designers through collaborative and antifragile learning. The study draws on ESF+ projects, Erasmus+ BIP, GlassLAB workshops, and design hackathons developed with enterprises, as well as on the analysis of publications, exhibitions, and governance frameworks such as the Committee for Glass Scholarships. The findings highlight capacity building for young researchers, the transfer of artisanal and industrial knowledge through digital tools, and a replicable pedagogy that links local heritage with global sustainability goals.

Keywords: Sustainability in Education, Heritage and Innovation, Collaborative Learning.

Introduction

Glass, as both a material and a cultural heritage, provides a fertile ground for rethinking sustainability education in architecture and design. In this perspective, the GLASS Cluster was established at Università Iuav di Venezia in June 2023, after activities on glass had become increasingly numerous and proactive since 2021, the United Nations International Year of Glass. It is conceived as an international platform for the discussion, study, design development, and dissemination of knowledge on glass, its history, innovations, processes, and production tools. The GLASS Cluster operates at the intersection of research, education, and entrepreneurship, addressing the environmental, social, and economic dimensions of sustainability in the built environment, artefacts, and production processes.

The initiative stems from the recognition that the glass sector (particularly in the Venetian context) faces a highly complex international scenario. Energy costs, climate change, shifting global balances, and successive crises (health, energy, economic), together with growing geopolitical instability, have reshaped both production and cultural landscapes. In such exceptional times, glass emerges not only as a material but also as a medium through which to interrogate and anticipate the trajectories of future history.

Responding to these challenges requires educational models that embrace contamination between disciplinary areas, valorisation of inter-scalar relations (from products to architecture, from production to territory), and the transfer of scientific, technological, and cultural knowledge into both academic and professional practice. Within this framework, the GLASS Cluster has progressively structured its activities as collaborative learning laboratories, fostering dialogue among universities, enterprises, and local communities.

This paper positions the experience of the GLASS Cluster within the broader debate on sustainability in education. By presenting its activities, institutional agreements, and future perspectives, the contribution highlights how heritage-based innovation and collaborative knowledge transfer can serve as effective tools to educate future architects, planners, and designers towards sustainability.

Background

The European Green Deal, presented in 2019, sets the ambitious target of making Europe the first climate-neutral continent by 2050. Despite the disruptions caused by the COVID-19 pandemic and the geopolitical instability linked to the ongoing conflict, the Green Deal should remain a cornerstone of the EU agenda. Environmental sustainability is a cultural topic rather than a political target: while deadlines and strategies may evolve, the shared objectives are not questioned. This resilience reflects the strength of deeply rooted cultural values: they may be recalibrated and reformulated, but not abandoned.

In this perspective, the notion of antifragility introduced by Nassim Nicholas Taleb provides a useful interpretative framework. Antifragile systems are not only able to resist shocks but can actually benefit from them, adapting and strengthening over time. Cultural systems (such as those related to materials, crafts, and design) demonstrate this capacity when they evolve through crises, transforming challenges into opportunities for innovation. Education for sustainability must, therefore, cultivate antifragile approaches, preparing future professionals to operate within uncertain and rapidly changing contexts.

The glassmaking tradition of Murano offers a paradigmatic case study. As one of the few productive activities still rooted in the Venetian lagoon, it embodies the intersection of material culture, identity, and local economy. The development of more dynamic and shared knowledge about Murano glass can start from various points of view: mapping active furnaces, documenting techniques and materials, and visualising the deep links between craft practices, cultural heritage and contemporary industrial supply chains. In addition to preserving knowledge, this type of research can promote storytelling, inform public policy, generate new forms of demand and support cross-sector synergies, for example with the fashion and design industries.

A constantly updated and accessible information and design-sharing activity would thus become a powerful educational instrument: raising awareness among citizens and tourists, providing students and researchers with an interactive platform for learning, and facilitating

intergenerational knowledge transfer in a sector that risks extinction. The challenge for Murano is to invert the historical logic of secrecy that protected its craft for centuries and embrace openness, communication, and collaboration. In doing so, the GLASS Cluster could be a driver of sustainability education, starting from Venice, where heritage and innovation converge to regenerate the cultural, social, and economic design of glass.

Figure 1. Part of the Iuav University material library, these artefacts (both artisanal and industrial) were exhibited in Vetro Futuro 2025 as educational resources for students and researchers, highlighting the continuum between tradition and design innovation. (Brown, 2002).

Method. Case Study GLASS Cluster

The GLASS Cluster operates as a living laboratory that aligns sustainability education with heritage-based innovation, coupling individual capacity-building (grants, scholarships, research contracts) with collective, challenge-driven learning (hackathons, Erasmus BIP, exhibitions, educational labs) and with stable institutional frameworks. Between 2019 and 2025 the Cluster activated a structured pipeline of opportunities for early-stage researchers and young professionals, ranging from short scholarships to 12-month research grants across chemistry, design, history, and technology of glass. These included, among others, the ESF-backed “Murano Pixel” (2021) track on transforming Murano glass waste into new materials and

product systems (2019-'21); three parallel 12-month grants in 2024 on Industrial Glass (design and technology), Handcrafted Glass (design and history), and
Innovative Glass (physics, chemistry, engineering) under "Patrimonio Vetro" (Regione Veneto, ESF, 2024-'25); and a suite of three two-month 2025 scholarships explicitly aimed at describing glassmakers and glass masters cultures using videos. In the same framework, the "Patrimonio Vetro" project together with Iuav's line-2 research funds supported the production of twenty short documentaries dedicated to artisanal, artistic, and industrial glass. Available online from mid-October 2025, they represent the first step towards a knowledge archive that the GLASS Cluster will curate and expand over time.

In 2025-26 and 2024-25, the Cluster consolidated these lines through "Vetro Futuro" (thanks to Università Ca' Foscari Venezia support, Università Iuav di Venezia line 1a funds and to the contribution of Iuav Foundation) and "Le culture del vetro" (Università Iuav di Venezia line 2 funds). The programme also foregrounded collaborative, time-boxed formats that turn Venice and Murano into a "living classroom": Vetro Futuro hackathons (2022-24) during The Venice Glass Week; GlassLAB workshop series (2023); and the Erasmus+ BIP "Over-Time Glass" (2024), combining on-line teaching with on-site studios and design exercitations. The theoretical and curatorial stance matured during the conference "Antifragile Glass" (2022, International Year of Glass), which framed glass cultures as antifragile systems capable of learning from shocks and crises.

A second layer concerns governance and long-term scalability. The collaboration between Università Iuav di Venezia, Università Ca' Foscari Venezia and Fondazione Musei Civici di Venezia (2021-24) and the joint programme "Le università per il Vetro Futuro" (2023-'25) provided the backbone for sharing spaces, archives, and events. The GLASS Cluster also works in continuous collaboration with Consorzio Promovetro Murano and the Distretto del vetro artistico di Murano e del vetro del veneziano, whose role has been crucial in linking the Cluster's educational activities with the broader cultural, productive, and territorial strategies of the glass sector. Building on this, 2025 saw the launch of the Committee for Glass Scholarships during The Venice Glass Week: a multi-institutional alliance (Corning Museum of Glass, Fondazione Giorgio Cini, Laguna~B, Pentagram Stiftung, Università Ca' Foscari Venezia, Università Iuav di Venezia) conceived as an operational platform to catalyse scholarships, high-level training, co-teaching, summer schools, seminars, exhibitions, and residencies, while mapping collaborations and opening a calls platform hosted by Corning Museum of Glass. The Committee's identity is explicitly international, intergenerational and

interdisciplinary. It links museums and enterprises, universities and foundations, artisans and curators, students and designers. It also stresses the position of Venice as an international "city campus" where investment in research, mobility and cultural production is treated as essential to re-weaving relations between tradition and innovation, education and work, local and global. In fact, between 2019 and 2025, the GLASS Cluster promoted over fifteen research grants and scholarships, from short-term collaborations to annual research positions, mainly funded through ESF+ and Iuav research lines.

Figure 2. Developed within ESF+ projects in collaboration with local enterprises, these test pieces demonstrate circular strategies for reusing waste glass in new material applications. Some are preserved in the Iuav material library, others were showcased during The Venice Glass Week 2025. (Luca Pilot, 2025).

Finally, the Cluster's public-facing productions connect education to technological imagination. The Vetro Futuro exhibition organised in 2025 The Venice Glass Week (12-26 Sept.) and in VITRUM (16-19 Sept., Milan) articulates glass as both technique and culture. The exposition shows how shifts in production unlock new meanings and uses in architecture and design. It uses design sprints to test future scenarios: truly "transparent" glass whose supply chains and life cycles are knowable; traceable chains that valorise artisanal and industrial processes. These themes are treated not as distant utopias but as near-term, research-supported pathways, and they serve the educational aim of training designers to navigate ethical-technical

choices beyond mere cost/performance, towards culturally and environmentally meaningful decisions.

Collaborative Learning

A distinctive feature of the GLASS Cluster is its capacity to embed enterprises directly into the educational process, transforming companies from external stakeholders into active partners of learning. Every project supported by the European Social Fund (ESF and ESF+) involved firms, ensuring that research topics were grounded in industrial, artisanal and cultural needs. In the first ESF project, the Cluster collaborated with Stefano Bullo Vetrate Artistiche, Carlo Moretti, and Costantini Glassbeads, while the second involved Veneto Vetro, rehub (Iuav spin-off), and Barbini Specchi. These partnerships were not marginal: companies co-defined the research themes, offered access to production processes, and tested the proposed solutions. In this way, ESF grants and scholarships became a structured platform for capacity building, enabling postgraduate researchers to confront real-world problems in close dialogue with industry and also bring businesses closer to the most innovative projects that can only arise thanks to the freedom of thought of students and researchers..

The GlassLABs stresses this approach. Organised as intensive two-day workshops, they began with company visits, where students observed missions, production chains, and manufacturing techniques, and continued in university laboratories where tutors guided them to formulate design concepts and prototypes. Companies such as Rehub, IamPiavevetro, Veneto Vetro, and Pilkington Italia posed real challenges of waste recycling, customised windows, interactive material libraries, and heated glass systems. Students tackled them through design proposals. The immediacy of the tasks, the direct confrontation with technical constraints, and the expectation of concrete outputs created a powerful pedagogical environment. Students learned not only to design but to negotiate values, articulate innovation, and translate production processes into sustainable solutions.

This collaborative model is not episodic but systemic. Through ESF projects, hackathons during The Venice Glass Week, exhibitions, and joint research agreements, enterprises continuously interact with students and researchers. The reciprocity is clear: students gain authentic professional experiences, while companies access a flow of fresh ideas, exploratory prototypes, and potential collaborations. By crossing the boundary between academic study, artisanal knowledge and industrial practice, the GLASS Cluster fosters a

culture of mutual learning in which enterprises contribute to shaping the next generation of designers and architects, and students reimagine the future of the glass sector.

The educational value of this method lies in its ability to cultivate capacity to act in uncertainty and students teach to academic, researchers and enterprises that to address complex problems where technical, environmental, and cultural dimensions intersect the solution has to be found in sustainability: in this way design choices reconcile tradition and innovation, performance and meaning, local context and global pressures. Overall, more than 120 students took part in Cluster activities between 2022 and 2025. And the collaborative approach of GLASS Cluster is not only a teaching strategy, but a sustainability strategy: it regenerates both knowledge and practice, ensuring that education is antifragile and that Cultures of glass remain vital.

Figure 3. Developed by Rehub (Iuav spin-off) and named by its co-founder Matteo Silverio, Revero is a 100% recycled glass obtained from Murano waste. As a partner in the recently completed ESF+ project, Rehub represents a virtuous example of research and innovation, turning discarded materials into new resources for sustainable design education. (Luca Pilot, 2025).

Conclusions: Towards an International Dialogue

Over the last years, the GLASS Cluster has progressively defined the Venetian approach to sustainability education through the lens of glass. By combining research grants, collaborative workshops, hackathons, exhibitions, and conferences, the GLASS Cluster has articulated a strategy where heritage and innovation, tradition and technology, students and enterprises converge. This method is not only about learning "with glass," but about learning "through glass": an educational strategy that places materials, processes, and cultural identity at the heart of sustainability.

The results are tangible. A solid network of partners has been established, involving enterprises, artisans, and master glassmakers, whose knowledge and challenges have become part of the students' training. Publications such as Antifragile Glass (2021), GlassLAB (2023), Over-Time Glass (2025) and Vetro Futuro (2025) have consolidated a shared corpus of texts and case studies that already serve as reference tools for teaching and research. Institutional agreements together with the Committee for Glass Scholarships launched in 2025, provide a framework for continuity and growth, ensuring that the GLASS Cluster is not an isolated initiative but a recognised educational ecosystem.

Now, the Cluster is ready to open a new phase, one based on international dialogue and collaboration. The perspective is to extend the model tested in Venice to a global scale: co-developing curricula with foreign universities, activating internships and residencies for students and young professionals, promoting summer schools and intensive programmes, and building research platforms that connect academic work with industrial and cultural innovation worldwide. By sharing methods, publications, and experiences, the GLASS Cluster seeks to create an educational commons where glass cultures can inspire sustainable design education beyond local boundaries.

In this sense, glass becomes more than a material or a sector: it is a medium for dialogue between disciplines, institutions, and communities. The GLASS Cluster's commitment is to continue strengthening this dialogue, positioning Venice as a city campus (Galli, 2025) and laboratory for sustainability, and contributing to an international network of universities, enterprises, and cultural institutions dedicated to shaping antifragile, innovative, and sustainable futures.

Figure 4. Curated by Giulia Conti and Alessandro Virgilio Mosetti, the exhibition presented outputs from research grants, GlassLAB workshops, hackathons, and collaborative projects coordinated by the GLASS Cluster, offering visitors an overview of ongoing educational and design innovation activities. (Luca Pilot, 2025).

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NEED (NEW EMPATICH EDUCATIONAL DESIGN) SUSTAINABLE PRACTICES

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NEED (New Empatich Educational Design) Sustainable Practices

Abstract: NEED (New Empatich Educational Design) is an Italian project for orientation and tutoring funded by the Ministry of University and Research, coordinated by the Vanvitelli University. The Project involves 18 university locations with the participation of the University of San Marino. It promotes education in design using methods, processes, and tools that respond to the needs of 'a new lifestyle' through the empathetic and technological relationship between nature and artifice. NEED structure of places/laboratory for students, researchers and teachers, open to local stakeholders and aimed at education in sustainable and transdisciplinary design, to allow the construction of educational paths that strengthen skills, digital technologies. The focus is development of soft skills, through the connection between Schools, Universities, the Territory, Enterprises, and Organizations. The ROOT DESIGN and SOUND DESIGN collections are represented by 300 artifacts born from the observation of Nature and created according to the principles of ecodesign, described here as methods usable in sustainable design.

Keywords: sustainable, empatich, educational, ecodesign, roots

Introduction

This text tells the story of the NEED Project “New Empathic Educational Design” an innovative research and teaching project funded by the Ministry of Education, coordinated by the Vanvitelli University. The Project has as partners the University of Perugia, the University of Genoa, the University of Sassari, the University of 'G. d'Annunzio' Chieti-Pescara, the 'Mediterranea' University of Reggio Calabria, the Polytechnic University of BARI, the University of BOLOGNA, the University of CAMERINO, the University of FERRARA, the Polytechnic University of Milan, the University of Naples "Federico II", the University of Palermo, the University of Parma, the University of Rome "La Sapienza", the Polytechnic University of Turin, the University of Tuscia, the University of Florence, with the participation of the University of San Marino. NEED provides suggestions and practices to those approaching the design project, a sort of operational guide, identifying a matrix of objectives to refer to for the conformation of new design objects that are necessary, functional, sustainable. The experience in the field of educating young students on a daily basis to the design project, premising that the action of education is understood in the sense of breeding feeding and pulling out, extracting drawing and for those who work in design a cannot be separated from the action of producing, promoting, generating, realizing has led to the selection of some topics to identify a design method that can meet the needs of "a new lifestyle" structured on the "empathic" relationship between nature and artifice, territory and design through interdisciplinary contributions and knowledge.

It is well known that those who design in the field of architecture possess a series of treatises, manuals, stories, many magazines, from which it is possible to deduce built examples and quotations, refer to the typological classification relating to functional performance (e.g. houses, churches, hospitals, etc.) or to the distributive-formal character of spaces (courtyard, tower, in-line buildings). This does not happen in the field of design where there is only a few stories that are certainly known to us, a few magazines from which it is possible to understand some solutions produced for use and consumption. NEED, in line with the "Reskill and upskill" flagship of the National Recovery and Resilience Plan (PNRR), Next Generation EU program, provides for the learning of new skills (reskilling) and the improvement of existing ones to access more advanced tasks (upskilling), enhancing innovation and promoting social inclusion. NEED promotes design education with methods, processes and tools, responding to the needs of "a new lifestyle" through the empathic and technological relationship between nature and artifice. NEED structure places/laboratories for pupils, students, researchers and teachers, open to local stakeholders and aimed at transdisciplinary design education, to allow the construction of educational paths that strengthen skills, digital technologies and the construction of soft skills, strongly connected between School, University, Territory, Companies, Institutions with new educational opportunities thanks also to the training of teachers, improving digital skills using educational platforms; promoting self-assessment tools in manual and digital learning environments.

NEED proposes 5 specific actions on the themes of training and teaching 1"Enrollment orientation" aimed at students of the Schools; 2. “Tutoring activities” aimed at university students, doctoral students, and professionals in the business, cultural, and artisan sectors.; 3"Laboratory practices" aimed at students of schools and universities.; 4"Self-assessment and knowledge recovery for entry to the University" aimed at enrolled students.; 5"Professional growth of high school teachers" aimed at school teachers, introducing the necessary focus on greater personalization in counseling and tutoring activities. NEED, in the perspective of a path that involves high school students and universities through co-design activities, aims to bring out the talents of students and promote their well-being, through collaborative learning and sharing knowledge of sustainable practices in the design process in an empathetic and innovative way.

Figure 1. The collections ROOT DESIGN e SOUND DESIGN for NEED, 300 poetic artifacts are example sustainable practices of the Project.

Literature Review

In the background of the activated process, different disciplines and studies play a fundamental role: the NEED project starts from a broad theoretical background with the aim of defining a design method that is attentive to the theme of sustainability. First of all, by defining the usefulness of carefully observing the environment that surrounds us in order to respond to latent needs and requirements (what function the new objects should respond to); by knowing the formal sequences already known (what shape they should have); by breaking down into parts to model (which distribution would be the best) cataloguing the materials to make (feasibilityecology).

The correspondence that we are going to illustrate between this system of analysis and the Vitruvian categories, the subject of Vitruvius' Book I, is evident if applied also to design objects "... everything that is industrially produced or otherwise artfully made that surrounds us in our daily environment, often also including natural elements that are in turn manipulated.

These are different objects in terms of the nature of the materials, their functions, the way in which they were constructed, their intended use, etc." Therefore, declining the famous triad *sub specie design*, we could say that *firmitas* (solidity) can correspond to feasibility, analysis of the structure necessary and sufficient for the conformation of the product, to *utilitas* (function, intended use) the function, appropriate use of the product in the relationship between man and environment; to *venustas* (beauty) the form, understood as an external connotation, the result of a clear and conscious design evolution, attributing to the *form* also the meaning given by Frampton as a type intended as an initial prefiguration.

Gio Ponti said that usually to those who said that form corresponded to functionality, form is our ideal contribution independent of function, and originates from concepts of essentiality and truth, almost employing an economic principle; while functionality is a matter independent of form: if Olivetti, we consider it the perfect form of today's typewriters: Does this have anything to do with functionality ? The other typewriters also work very well, and the Olivetti of the past wrote very well.

Kahn also envisions three fundamental values: form, order and design "Form is the organizational idea in the first approximation (...) it is the starting structural hypothesis (...) the form, through the elaboration of design, which takes place under the continuous control of order, tends to mature and refine itself to the point of beauty (...) in a series of passages of which the first, that of form, is the initial creative moment, while the subsequent ones take place supported by the indirect control of formal logic. Does the form hold, says Kahn(...) the design? (Kahn L.I. 1998). He continues to enrich and clarify the initial intuition until the image is determined" in other words Kahn invents in the first phase of each design a type, "an elementary structure" with main and irreducible elements placed in support.

Also at the base of NEED there is the design approach of Bruno Munari, the scientificbotanical knowledge of Stefano Mancuso, the morphological aspect associated with J.W. Goethe, the current principles of ecodesign. In support of the Project NEED there is the entire work of Bruno Munari characterized by a great attention to functionality, but also by a strong interest in aesthetics and visual experience. In particular, in the book *Drawing a Tree*, it explores the creative process of drawing through a playful and stimulating approach that, thanks to its innovative imprint, guides the reader to discover how to represent a tree in a simple and enjoyable way, using geometric shapes and essential lines. The book does not just provide stepby-step instructions, but encourages the exploration of different techniques, styles, and personal interpretations, without obstructing the space for creativity. The reference to scientific-botanical knowledge is paraphrased from the thoughts of Stefano Mancuso, a

world-renowned botanist in the field of plant neurobiology. He is a proponent of a more inclusive form of intelligence, defining it as the ability to solve problems, clarifying that the animal and plant kingdoms do not use the same methods as humans for problem-solving, since many organisms, such as plants, do so just as efficiently without needing to move. Plants have distributed throughout their entire bodies all those functions that animals have instead concentrated in organs. In other words, a plant sees with its entire body, feels with its entire body, breathes with its entire body, and thinks with its entire body" (Mancuso, 2023). Connected to the changes that plants undergo, it is possible to introduce the theme of morphological variation discussed by J.W. Goethe. In his *Essay on the Metamorphosis of Plants* (1790), he explores the concept of metamorphosis, understood as the continuous transformation of flora through a principle of organic development. Finally, at the core of the NEED Project is the fundamental reference to ecodesign, aimed at transferring skills for the development of innovative processes, products, and services according to the principles and approaches of design for sustainability, the wellbeing of people and the environment, through five design actions: recycle, reuse, repair, reduce, rethink (Morelli, 2024). Therefore, having established that design objects can be regulated by the famous Vitruvian triad which in this case is composed of feasibility, function and form, and carefully examining the six categories, we can say that: décor is the perfected appearance of the object that is obtained when each of its elements has been well calculated and conforms to convenience, to custom, to nature and can be defined with the contemporary term of ecology; that oixonomy means the use of scarce resources to better satisfy individual and collective needs by containing expenditure, through a system of organization of activities put in place by a set of parties, making it clear that the "economic principle" is linked to the functional question, which becomes the link with the formal aspect**;** dispositio, ordinatio and symmetry shape the object in a weighted, proportional and harmonious manner. The combination of all these characteristics, concinnitas, with the communicative ability, in showing others the comforts and goodness of an object, are such as to arouse its empathic role.

Methods

The method of the NEED Project for the development of the five main actions: 1. 'Enrollment Orientation'; 2. 'Tutoring Activities'; 3. 'Workshop Practices'; 4. 'Self-assessment and Knowledge Recovery for University Entry'; 5. 'Professional Development of High School Teachers' is characterized by the following flagships: ORIENTATION AND LISTENING through the establishment of help desks and meetings with students and the activation of a

NEED Portal to enable shared activities between locations at the national level; RECOVERY of manual workshop activities; RELATION between cultural resources and artisanal skills; CONNECTION through an ORIENTATIONAL MAP of schools with a focus on the university structure; INTEGRATION of students' technological skills within artisanbased companies; GROWTH through an EDUCATIONAL NETWORK on design-related topics involving companies, institutions, etc., starting from advisory committees and defining new skills and professions for the labor market; LEARNING of digital skills using educational platforms; and the creation of a COMMUNITY HOLDER, based on the assumption that design is an integral part of the strategic cultural heritage of our country.

Findings and Discussion

Interesting results from the NEED supply chain Project were achieved during the Workshop held from October 4 to 10, 2024, at OfficinaV, the creative hub of the Department of Architecture and Industrial Design "Vanvitelli," located in the historic silk factories of San Leucio (CE). The event was attended by the Presidents of CUID, Francesca Tosi, and SID, Lorenzo Imbesi, faculty representatives from the 18 participating universities, 100 students, tutors, and PhD candidates from the 18 Italian universities**.** "There is no identity without transformation. My direction is the other from myself," was the starting point for building a large artifact-map on the themes of inclusion, beauty, and cultural, artisanal, and landscape resources. The event was both a moment of exchange and a space for evaluation and exploration of methods, processes, and tools—also experimental and innovative—aimed at responding to or, better yet, educating towards a "new way of life" through an empathetic relationship between nature and our culture. The goal was to develop a systematic and coherent approach within the culture of design to address some of the fundamental problems of our time problems of a complex society that can no longer be ignored.

From an organizational point of view, the workshop was divided into three phases, each conceived as a chapter of a new methodological horizon. The first step, with a performative and emotional approach, introduced the workshop themes through a performance by actors and musicians who brought to life "other natures," giving voice—through dramatized readings—to organic and inorganic entities, human and non-human animals, plants, stones, and cyborgs: "You must change your life" was the imperative that opened and closed the performance, marking a clear path toward a paradigm shift, starting from the awareness that "... Homo sapiens can no longer postpone, as the Anthropocene has already revealed itself as the violation of every inviolable limit, and now there is no choice

but to create a new anthropos or sink into the nihilism of which global civilization is but the mask" (N. Feltrin, F. Lovato, 2019).

The second step, using a brainstorming methodology, introduced a conceptual paper map necessarily linear and simplified on which students and tutors were asked to contribute by adding words, concepts, and actions, creating associations, connections, trajectories, and possible visions. The map identified three thematic areas: human animals – non-human animals / plant ecosystems / inorganic matter, along with a final section on migrations and directions. This gave rise to a working method that allowed for a shared operational calendar.

Synergies and affinities developed among the various university groups, enabling them to identify concepts and themes to work on: Cracked Earth, Morfis, Time, F.A.T.A., and Emplanthy. The following days were dedicated to developing these concepts and producing outputs which, though open to further exploration, highlighted both the urgency of addressing these issues in a systematic and critical way, and the high level of interest and debate they generated among the students, as well as the tutors' ability to engage and synthesize the work.

Figure 2. Workshop NEED held from October 4 to 10, 2024, at OfficinaV, the creative hub of the Department of Architecture and Industrial Design "Vanvitelli," located in the historic silk factories of San Leucio (CE).

Figure 3. *SOUND DESIGN – THE DRUM FOR PEACE*, held on June 3, 2024, at the Benedictine Abbey of San Lorenzo ad Septimum, home of the Department of Architecture and Industrial Design at the University of Campania "Luigi Vanvitelli."

Conclusion

In conclusion, NEED has activated a model of sustainable processes and practices by applying the principles of ecodesign within the activities of Design Laboratories embedded in undergraduate degree programs. In particular, for the ROOT DESIGN and SOUND DESIGN collections, 350 poetic artifacts (cf. *poieo*) were designed and prototyped, each linked to behavior and perception within the Plantae Kingdom. The first collection consists of 180 devices designed to allow visitors of the exhibition *RIZOMA – PLURAL LANGUAGES*, held at Vivai Vesuviani in Ottaviano (from June 22 to July 21, 2025), to hear well, see well, and feel well. These poetic objects stem from an in-depth exploration of the theme of roots and are each associated with a specific tree, chosen by the young designers as their personal reference plant. Meanwhile, 170 drums made by students in the *Sustainability Design Laboratory* within the Degree Course in Design and Communication at UNICAMPANIA, in collaboration with the SENSi-LAB Laboratory, were used in the concert *SOUND DESIGN – THE DRUM FOR PEACE*, held on June 3, 2024, at the Benedictine Abbey of San Lorenzo ad Septimum, home of the Department of Architecture and Industrial Design at the University of Campania "Luigi

Vanvitelli.” The concert featured internationally renowned musicians Antonio Onorato and Mario De Paola. The themes previously explored resonated throughout both natural and manmade spaces, through the testimony of each student, who expressed their design process also through their artisanal practice, resulting in the creation of unique design products.

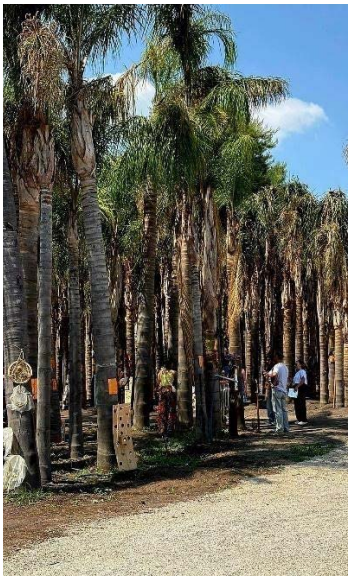

Figure 4. *ROOT DESIGN* exhibition *RIZOMA – PLURAL LANGUAGES*, Ottaviano (NA)

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TRACING MULTIMEDIA COLLABORATION IN ARCHITECTURAL EDUCATION: A RETROSPECTIVE FORENSIC STUDY OF A STUDENT COMPETITION TEAM

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Tracing Multimedia Collaboration in Architectural Education: A Retrospective Forensic Study of a Student Competition Team

Abstract: This paper explores the multimedia engagement strategies of a novice architecture student team participating in the 2025 Saint Gobain Architecture Student Competition. Drawing on cognitive and ethnographic frameworks, the study retrospectively examines how students navigate hybrid co-design settings using a range of analog and digital tools. Through interviews and artifact analysis, the research uncovers flexible non-hierarchical collaboration models and highlights the impact of tool selection, communication channels, and cognitive demands on design workflows. A visual reconstruction of the team's process across four phases (predesign, early design, development, and presentation) reveals how shifting media ecologies shaped their design decisions. Findings underline the importance of accessible tools, adaptive roles, and clear communication in multimedia supported collaboration. The paper concludes with implications for design education and suggests incorporating hybrid tool strategies into studio teaching.

Keywords: collaborative design, multimedia engagement, architectural education, novice designers, hybrid environments

Introduction

This study investigates how novice architecture students engage with multimedia tools during collaborative design processes in the context of student competitions. It explores their combined use of physical and digital media to manage design tasks, communication strategies, and representational outputs. The main objective is to reconstruct these multimedia interactions through a retrospective method and identify key design affordances, limitations, and workflow patterns across different phases of the competition project. The significance of this research lies in its contribution to the development of digital and interactive learning tools in sustainability education, with a particular emphasis on collaborative learning in architecture. While earlier studies have examined multimedia use in education broadly, there is limited research focused on student competition environments in architecture, where dynamic and multi-layered exchanges shape design outcomes. Foundational theories such as Mayer's Cognitive Theory of Multimedia Learning (2005) provide a base for this investigation, alongside more recent studies exploring online whiteboards and their role in design collaboration.

Unlike prior work on multimedia engagement in architectural education, this study emphasizes a forensic analysis of students' digital design artifacts including sketches, Miro boards, communication records, and screen captures. These materials were analyzed across distinct phases of design to identify patterns of multimedia engagement and team coordination. The scope of the study includes the retrospective analysis of one winning competition team, supported by access to their project archive and interview reflections. Limitations include partial availability of early draft materials that remain stored in personal devices and a lack of synchronized activity logs. Despite these constraints, the reconstruction offers valuable insights

into how novice peers navigate collaborative design through digital tools and can inform future developments in architecture education.

Literature Review

Multimedia engagement in design education builds on foundational cognitive learning theories. Mayer's Cognitive Theory of Multimedia Learning (CTML) emphasizes that learners understand more deeply when information is presented through both verbal and visual channels (Mayer, 2005). This dual-channel model is particularly effective when materials avoid redundancy and cognitive overload, which is crucial for novice architecture students still developing mental schemas. In studio settings, integrating text, diagrams, and digital tools helps reduce cognitive load and facilitates distributed cognition. In group work, collaborative cognitive load theory highlights how well-designed multimedia tools enable teams to offload mental processing across members, making room for design reasoning and creativity (Janssen et al., 2021). Research in design education increasingly points to the transformative role of hybrid toolkits. Novice designers benefit from varied platforms that support idea generation, feedback, and representation. For instance, Eren and Yılmaz show that students who combine analog sketches with digital tools expand their exploratory potential (Eren & Yılmaz, 2022). Similarly, Xiang and colleagues describe how digital platforms act as active collaborators, not just passive instruments (Xiang et al., 2020). These tools contribute visuals, simulate constraints, and generate feedback, becoming part of the iterative ideation loop. This aligns with Oxman's theory of composite digital design models that embrace diverse toolsets for divergent and convergent thinking modes (Oxman, 1994).

Yet, the positive outcomes of multimedia integration are conditional. Poorly designed platforms or an overwhelming number of tools may create disjointed workflows and lead to cognitive fatigue (Al-Rqaibat et al., 2025). In hybrid studios, where students manage tasks across platforms like Miro, Rhino, and Zoom, coordination becomes essential. Fragmentation in tool use can disrupt collaborative rhythm and dilute creative effort. Moreover, learning the tool itself imposes cognitive demands, diverting attention from actual problem-solving. Al-Rqaibat and her research team note that most educational programs still lack a unified framework for digital tool usage, causing students to improvise their workflows, which may limit shared understanding.

Multimedia platforms also have a direct impact on creativity. Emerging technologies such as augmented reality (AR), virtual reality (VR), and building information modeling (BIM)

offer immersive design experiences. Yu, Gu, and Ostwald highlight that VR can enable shared perception of space in remote collaborations, yet the integration of these tools into early conceptual design is still underdeveloped (Yu et al., 2022). Their review suggests a need for better support of fluid, nonlinear workflows typical of the early design stages. This concern is echoed by Sediadi and Semlali, notify the early overreliance on software, which can limit ideation to preconfigured tool constraints (Sediadi et al., 2022). Instead, they advocate for a balanced toolset that supports manual and digital modes equally.

The situated context of architectural competitions adds another layer of complexity to multimedia engagement. Unlike traditional studios, student competition teams often define their own workflows, tool preferences, and representational strategies. This autonomy encourages experimental practices but also introduces variability in digital literacy and media fluency among team members. As Legény et al. and Gunagama and Pratiwi suggest, competitions are increasingly seen as platforms for student agency, but the pedagogical implications of their digital behaviors remain underexplored (Gunagama & Pratiwi, 2019; Legény et al., 2018). Teams self-organize, distribute tasks such as modeling and rendering, and engage in remote communication across different tools, forming what Cerna and Müller call a "digital ecology" of practice (Cerna & Müller, 2021). Mapping these ecologies can provide insights into how students perceive and coordinate cognitive and representational tasks in high-pressure design contexts.

The hybrid, collaborative nature of design competitions reflects a shift toward rhizomatic problem-solving strategies in architectural education. This is especially important for novice teams that must learn to operate without the structured scaffolding of a design studio. As researchers led by Dorta and Emam stated in separate studies, investigating the natural behaviours of students in these fluid environments can reveal how they adapt, negotiate, and iterate in real time (Dorta et al., 2008; Emam et al., 2019). Multimedia engagement here is not merely about tool proficiency but also about wayfinding through complex, evolving design problems. Teams navigate between sketchbooks, Miro Online whiteboards, CAD files, and messaging apps, often selecting tools that best match the sub-task at hand. This adaptability underpins creative resilience and highlights the importance of designing learning environments that support fluid transitions between media without imposing linear or prescriptive workflows.

Method: Retrospective Forensic Analysis of a Competition Team

This study employs a retrospective forensic analysis approach to investigate the collaborative design process of a student team that participated in the Saint-Gobain Architecture Student Contest in 2025. The selected team was strategically chosen based on several criteria that enhanced the analytical depth of the research. These criteria included accessibility to team members, the researcher's social familiarity with them, and the team's internal diversity (comprising one graduate student, one fourth-year undergraduate student, and one third-year undergraduate student). The term 'forensic' ensures a critical perspective that leverages the full breadth of available design evidence to understand the socio-material ecology of co-design activities. Here, the word is used metaphorically, extending beyond its conventional medical or legal contexts, to describe an evidence-driven analytical approach that reconstructs collaborative acts and decision-making processes from archived design artifacts and retrospective reflections. Through the collection of retrospective data and interview notes, the study aims to yield a deeper and more meaningful interpretation of the team's multimedia engagements and collaborative design acts. The competition added significant cognitive and logistical complexity, as it required an internationally competitive, sustainable design solution emphasizing high energy efficiency and low carbon impact. The team's project was selected as the national winner and subsequently represented Turkey in the international final in Nord-Isère, France. The team worked under the mentorship of a single academic advisor (MP).

This methodological approach builds on the concept of cognitive historical analysis introduced by Nancy J. Nersessian in her foundational work on scientific reasoning (Nersessian, 1992). Nersessian investigated how scientists such as James Clerk Maxwell developed new theoretical models by adapting, transforming, and reasoning through representational structures over time. Her studies illustrate that historical episodes of scientific innovation are not simply linear narratives but involve intricate, context-specific cognitive strategies embedded in material practices and representational transformations. This approach reframes design and scientific thinking as processes of model-based reasoning within evolving social and technical environments, offering tools to trace how complex ideas take shape through iterative abstraction and situated cognition.

Fehmi Doğan further applied and extended this framework to the domain of architectural design by studying the Staatsgalerie project by James Stirling (Dogan & Nersessian, 2010). Using a cognitive historical perspective, Doğan illustrated how abstraction, collaboration, and distributed cognition converge in professional practice through design

diagrams, sketches, and narrative reasoning. By building on these foundations, this study introduces the concept of "Retrospective Forensic Analysis" as a novel method adapted for working with comprehensive and contemporary data sets. This method enables researchers to analyze collaborative design processes by reconstructing the situated reasoning and multimedia engagements of design teams based on available artifacts and retrospective accounts.

The research context centered on analyzing the workflow, communication strategies, and design decisions of the selected team within a competitive and temporally constrained environment. A key advantage of this study was the full access to the team's digital archive, which included sketches, 3D models, simulation outputs, visual representations, and final presentation files. This allowed for an in-depth forensic examination of their design process. The data collection and analysis techniques included semi-structured retrospective interview with one of the team members, systematic observation of archived digital design materials, and thematic multimedia coding of their design documentation. These methods were applied with the aim of identifying recurring patterns of interaction, decision-making moments, and cognitive strategies related to multimedia engagement. The study was conducted over the course of several months, beginning with the competition team's initial participation in November 2024 and extending through a data consolidation and analysis period that ended in May 2025.

To provide a structured reconstruction of the team's design journey, the process was segmented into four distinct phases: predesign, early design, design development, and final decision and representation. This segmentation was not derived directly from the chronological sequencing of the interview. Instead, it was informed by a cross-analysis of the content and context of the design artefacts and participant reflections. The phases were identified based on observable shifts in team dynamics, media usage, the complexity of design proposals, and the intensity of communication. For instance, the early design phase was defined by the presence of conceptual sketches and exploratory use of design platforms, whereas the design development phase featured detailed modelling and simulation outputs. The final phase was distinguished by the preparation of presentation materials for submission to the national jury. Together, these four phases constituted a practical framework through which the navigation of complex co-design environments by novice designers and their interactions with digital and analog media could be meaningfully examined.

Findings and Discussion

A retrospective reconstruction of the 2025 Saint Gobain Architecture Student Competition process, based on detailed participant accounts and access to the team's digital materials, reveals valuable insights into novice design collaboration, tool usage, and multimedia engagement. In the early stages, the student team utilized Miro to spatially organize conceptual ideas using bubble diagrams. This approach facilitated collective visualization and discussion of the emerging design narrative. However, as deadlines drew closer and production demands intensified, the team transitioned to more task-oriented software environments to meet representational requirements.

For precedent research, the students shared an online Pinterest board. This platform allowed all members to contribute relevant spatial and material references, which collectively served as a dynamic source of inspiration. One participant specialized in technical modelling, using Rhinoceros 3D extensively to develop and articulate three-dimensional spatial geometry. These outputs were iteratively exchanged among team members for further detailing. Presentation boards were primarily composed by another teammate using Adobe Illustrator and Photoshop, while a third member contributed written content including narrative descriptions. Although responsibilities were not fixed at the outset, task distribution gradually took shape around individual proficiencies and team needs.

Communication was managed mainly through WhatsApp, where sketches, screenshots, and draft materials were exchanged rapidly. The workflow frequently involved transitions between analog and digital tools. Hand drawn sketches were digitized, and digital models were manually annotated. Rather than following rigid coordination structures, the team's collaboration style was emergent, pragmatic, and shaped by the tools and constraints at hand.

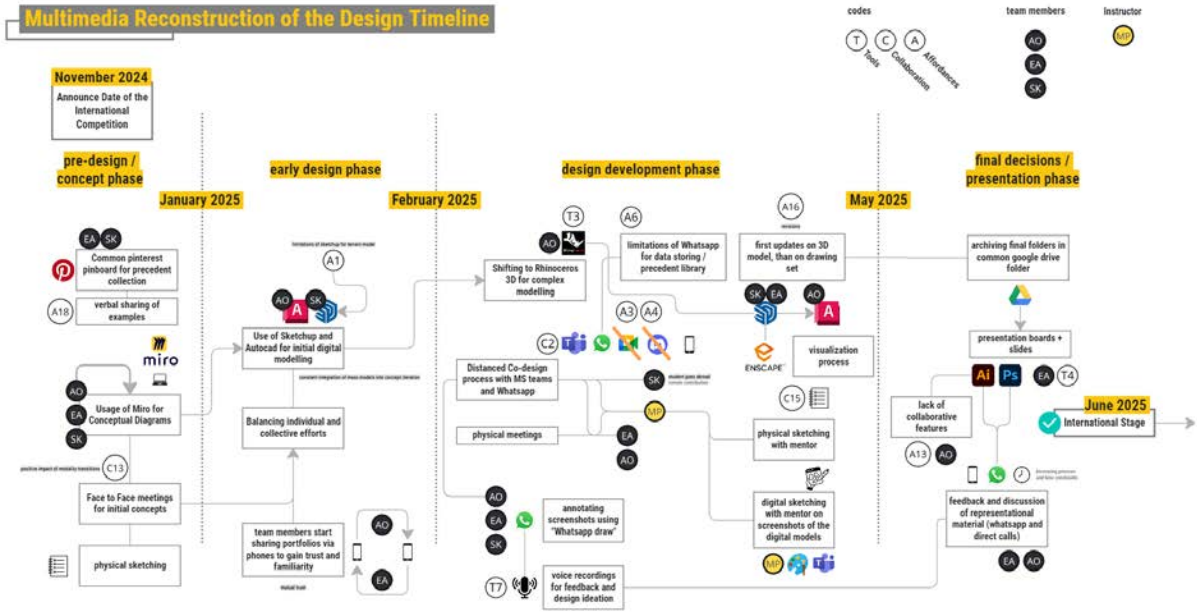

Figure 1. Multimedia Reconstruction of the Design Timeline of the Saint Gobain Architecture Competition 2025 National Stage Winner Team (Source: prepared by Author)

The “Chronological Multimedia Engagement Based Reconstruction” diagram above was developed to trace and visualize the evolving use of multimedia tools, communication platforms, and collaborative patterns across four phases of the student team’s project. These phases include early concept development, design iteration, refinement, and final presentation. This retrospective reconstruction was necessary to interpret a nonlinear and overlapping process that is typical of projects led by students with limited professional experience. The diagram consolidates fragmented activities into an extended timeline.

Through this temporal mapping, distinct shifts in media usage such as from Miro Whiteboard to Rhinoceros3D to Illustrator, modes of communication such as co located versus remote interaction, and decision points can be identified. Each interaction is tagged with codes such as Tools, Collaboration, and Affordances, revealing how the team negotiated shared understanding and task division over time. The diagram also highlights the cognitive function of tools. For example, it shows how Miro and Pinterest were used for early ideation and how Rhinoceros3D supported spatial refinement. The interleaving of digital and analog methods points to a multimodal wayfinding approach, where students moved between media types based on need rather than a predetermined workflow.

This process reflects a flexible and adaptive model of collaborative design among novice participants. The reconstruction not only illustrates tool choice and sequencing, but also reveals the decision-making logic and communication practices underpinning the team's performance. The findings suggest that novice designers, when given autonomy and minimal top-down instruction, develop organically distributed workflows shaped by the affordances of tools, deadlines, and emergent expertise. This approach offers a new lens for understanding collaborative design in educational competition settings and highlights the pedagogical value of tracing multimedia engagement across time.

Conclusion

This study examined the multimedia engagement practices of a novice architecture competition team through an ethnographically informed retrospective analysis. The findings revealed a fluid and pragmatic use of digital and analog tools shaped by task requirements, cognitive load, and communication preferences. Students demonstrated adaptive collaboration by distributing responsibilities based on individual strengths and relied on both physical and digital media to communicate ideas and manage progress. Communication tools such as WhatsApp and Microsoft Teams became essential in managing asynchronous workflows, though frustrations with fragmented feedback processes were noted. Despite the non-hierarchical structure of the team, clearly emerging roles and mutual respect facilitated smooth coordination. The iterative nature of design development and the preference for familiar modelling and presentation software reflected both strategic tool selection and the limitations of collaborative software options. One limitation of this study is its reliance on data provided by a single team member, which, although enriched by cross-reading with shared competition artefacts, may not capture the full scope of team dynamics or divergent perspectives.

To support these findings and visualize the workflow, a Chronological Multimedia Engagement Based Reconstruction was developed as the final output of the study. This reconstruction presents a four-phase timeline including predesign, early design, development, and final presentation. The visualization connects tools, participants, and representational outputs across time, offering insights into the dynamic and nonlinear progression of collaboration. It highlights how initial phases were shaped by low fidelity tools and physical meetings, while later phases increasingly depended on advanced modelling, digital coordination, and individual contributions. Notably, the reduction in shared tool use toward the

end of the process raises questions about the collaborative limitations of current software ecosystems. Overall, this research contributes a grounded understanding of how novice architecture students navigate cognitive, communicative, and representational challenges in hybrid learning environments. It also calls for more pedagogical support for media integration strategies that align with the evolving demands of collaborative design education.

Future research should expand this approach by incorporating multiple team perspectives to enhance the depth and validity of findings. Offering such methods in design education holds strong value, as it helps uncover the inner mechanisms of collaborative creativity and supports the development of more situated and responsive teaching practices.

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