DECEMBER '25

INTERNATIONAL COMPILATION OF RESEARCH AND STUDIES IN ARCHITECTURE, PLANNING AND DESIGN

EDITORS
PROF. DR. SERTAÇ GÜNGÖR
PROF. DR. MURAT DAL

SERÜVEN YAYINEVİ

Genel Yayın Yönetmeni / Editor in Chief • C. Cansın Selin Temana

Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi

Birinci Basım / First Edition • © Aralık 2025

ISBN • 978-625-8559-97-2

Serüven Yayınevi / Serüven Publishing
Türkiye Adres / Turkey Address: Kızılay Mah. Fevzi Çakmak 1. Sokak
Ümit Apt No: 22/A Çankaya/ANKARA
Telefon / Phone: 05437675765
web: www.seruvenyayinevi.com
e-mail: seruvenyayinevi@gmail.com

Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 47083

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Contents

Chapter 1

RECYCLING WASTE PLASTICS AS BUILDING MATERIALS: APPLICATION AREAS, MATERIAL PERFORMANCE, AND ARCHITECTURAL USE POTENTIAL

Yasemin KAPLAN[1] , Mustafa DERELİ[2]

1 Mimar, Necmettin Erbakan Üniversitesi, Fen Bilimleri Enstitüsü, yaseminkaplan900@gmail.com, ORCID:0009-0007-0971-5124

2 Doç. Dr. Necmettin Erbakan Üniversitesi, Güzel Sanatlar ve Mimarlık Fakültesi, Mimarlık Bölümü, mustafa.dereli@erbakan.edu.tr, ORCID: 0000-0003-4678-873X.

1. INTRODUCTION

The increased production demand brought about by the industrial revolution has led to a major waste problem by exceeding the renewal capacity of natural resources. The construction products sector, being an important part of the manufacturing industry, causes serious damage to the environment due to its high energy consumption. Although the production and use of petroleum-based polymers provide aesthetic and functional advantages in the construction sector, the amount of waste from these materials is increasing and causing environmental pollution (Kayılı & Çelebi, 2020).

The recycling of plastic waste is becoming increasingly important in terms of environmental sustainability and economic efficiency. Today, humanity is experiencing the "plastic age" with the rapid increase in the production and consumption of plastic materials. The ease of production, low cost, lightness, flexibility, and suitability for human health of plastics ensure their widespread use in many areas of life. However, because plastics are petroleum-derived and do not biodegrade in nature, waste management and recovery practices have become a critical priority, especially in the context of dwindling petroleum resources and oil crises. This situation necessitates the development of effective recycling strategies to minimize the environmental impact of plastic waste and ensure the sustainable use of economic resources (Vatan, 2002).

In waste management, the "reduce-reuse-recycle-dispose" principle and the "cradle-to-cradle" approach are important. Waste management is classified as reducing waste production, reuse, recycling (downcycling), incineration for energy recovery, and storage. The priority is to reduce the amount of waste as much as possible. Waste should be reused for the same purpose if there is no loss of performance; if there is a loss of performance, it should be recycled or used for different purposes. Non-recyclable waste should be incinerated to generate energy or stored in a controlled manner. To reduce plastic waste, usage efficiency should be increased, and waste plastics should be collected and added to new products at a rate of 30% to prevent mechanical performance degradation. This rate may increase with technological advances (Kayılı & Çelebi, 2020).

In this regard, the main objective of the study is to draw more attention to plastic waste and contribute to the development of sustainable recycling technologies in the construction sector. The study aims to explore the potential of waste plastics to be used as construction materials, particularly due to the expansion of oil and the oil crises, and the critical importance of waste management and recovery practices.
This study comprehensively addresses the use of waste plastics as construction materials in light of recent developments. This comprehensive approach is detailed under the headings Application Areas of Recycled Plastics in Construction Materials and Material Properties and Performance Evaluation. Evaluations based on current sources in the literature aim to examine recycled plastics as building materials in terms of their functional, environmental, and architectural aspects.

Within this scope, a comprehensive literature review was conducted using publications obtained from international databases such as Scopus and Google Scholar. The study comparatively examined the applications of different types of plastics in building components such as concrete, brick, insulation, and 3D printing; under subheadings such as application area, method of use, types of plastics used, material performance, analyzed/identified advantages and problems, and architectural use potential.

This structure enabled the analysis of the technical adequacy and design potential of recycled plastics at both the engineering and architectural scales.

Additionally, the study evaluated case studies of structures using recycled plastic materials in architectural projects through case analysis. The examined examples include: the Conceptos Plásticos modular housing system in Colombia, the Self-Care Community Center in Jakarta, the Hawaii Kona Village resort complex, and the EcoARK Pavilion in Taipei. These projects were examined under headings such as project name, location/country, type of plastic used and production method, building type and dimensions, sustainability and innovation features, and were evaluated in an architectural context.

All data obtained has been organized through comparative tables presented at the end of the study; the technical, environmental, and social impacts of recycled plastics in the construction sector have been revealed through a holistic approach.

Additionally, the findings obtained in the study were discussed in line with a multidimensional analysis. The discussion process was conducted under headings such as material performance and technical feasibility, environmental sustainability and circular economy impacts, socio-economic implications, technical limitations and areas for development, and the need for standardization. In the evaluations conducted under these headings, mechanical and thermal performance data, sustainable design examples, social participation projects, and sectoral applicability conditions were examined comparatively. Thus, the role of recycled plastics in the construction sector was interpreted in technical, environmental, and social contexts. The discussions were based on empirical data and case studies found in the literature, ensuring the integrity of the study's evaluation.

2. USE OF WASTE PLASTICS AS CONSTRUCTION MATERIALS THROUGH RECYCLING

Various types of waste plastic are being researched for use in building materials. The most prominent of these are:

- Polyethylene Terephthalate (PET), especially post-consumer PET (PCPET) (Athithan & Natarajan, 2024)
- High-Density Polyethylene (HDPE) (Lamba vd., 2022)
- Low-Density Polyethylene (LDPE) (Lamba vd., 2022)
- Polypropylene (PP), including those obtained from used face masks (Lamba vd., 2022)
- Polyvinyl Chloride (PVC), especially from PVC windows or pipes (Ait Khouya vd., 2025)
- Expanded Polystyrene (EPS), as recycled EPS (Navarro vd., 2025)
- Polystyrene (PS), especially high-impact polystyrene (HIPS) (Lamba vd., 2022)
- Mixed plastics and general plastic waste (Lamba vd., 2022)
- Waste plastic banners (polyester-based synthetic fiber) (Jin vd., 2025)
- PET/HDPE blends obtained from plastic bottles (Lamba vd., 2022)
- Packaging waste (chocolate, milk, grocery packaging, chip bags, etc.) (Lamba vd., 2022)
- Filter residues obtained from liquid-fed pyrolysis (Romani vd., 2025)

Plastic waste is processed using various methods depending on the material and application. These methods include shredding (e.g., converting posters into fibers) and grinding (e.g., converting posters into fibers) (Jin vd., 2025), granulation (e.g., converting PP/sand/fly ash mixture into granules), melting and mixing (e.g., mixing PP, sand, and fly ash mixture at 165 °C and pressing at 180 °C) (Karedla vd., 2024), fiberization (PP fibers, HDPE fibers, fibers from plastic food trays) (Kaya vd., 2025) surface modification (chemical coating to increase the compatibility of PP fibers with the matrix), and sorting/classification (including artificial intelligence and robotics) (Das & Ali, 2025).

2.1. Application Areas of Recycled Plastics in Building Materials

Waste plastics are integrated into various construction materials in different forms (aggregate, fiber, binder, additive, main component):

- Concrete and Mortars: Plastics are used in concrete and mortar mixtures as aggregate (fine or coarse aggregate), fiber reinforcement, binder modifier, additive, or partial replacement of sand. Various types such as PET, HDPE, LDPE, PP, PVC, PS, mixed plastics, and e-waste plastics have been incorporated into concrete or mortar in different proportions and sizes. While some studies indicate that the use of plastic aggregate reduces compressive strength, others have achieved acceptable or improved results at certain ratios or with surface modification (Lamba vd., 2022). Machine learning models have been used to predict properties such as the compressive strength of concrete containing recycled plastic aggregate (Sapkota vd., 2024). The mechanical performance of recycled HDPE fiber-reinforced mortar has also been investigated (Songkhla vd., 2025). Sustainable cement mortars containing recycled plastic have been developed by improving matrix-aggregate compatibility (Table 1) (Firoozi vd., 2024).
- Bricks and Blocks: Waste plastics are evaluated as aggregate or main components in brick and block production. Thermoplastic bricks show potential for energy-efficient building solutions due to their thermal insulation properties (Kadupu vd., 2025). The production and testing of bricks made from PET bottles and M-Sand, as well as bricks and blocks made from waste plastic and sand mixtures, have been conducted. The thermal performance of unfired clay bricks containing HDPE and PET waste plastic additives has been observed to improve (Mourid vd., 2025). It has also been noted that plastic waste powder has the potential to improve the mechanical properties of unfired clay bricks. Furthermore, lightweight sand-plastic composites have been produced using plastic waste and sand (Table 1) (Mekideche vd., 2025).
- Insulation Materials: Plastic waste can be used as insulation material in lightweight mortars or panels. The potential of recycled EPS to improve the thermal performance of lightweight wall mortars has been investigated. The potential for reevaluating waste plastic banners by shredding them into fibers for use as high-performance building insulation materials has been examined. The thermal conductivity of these materials (low values such as 0.0426 W/m·K) and their potential for performance enhancement with phase change materials (PCM) have also been identified (Table 1) (Jin vd., 2025).
- 3D Printing (Additive Manufacturing): 3D printing technologies such as large-format additive manufacturing (LFAM) or fused particle manufacturing (FPF) offer potential for producing structural components using recycled thermoplastics and composites. Using waste plastics as secondary raw materials for 3D printing contributes to sustainability goals. Recycled materials

such as polycarbonate and PC/ABS have been used for FPF-based 3D printing (Table 1) (Romani & Levi, 2024).

- Other Applications: Recycled plastics are also being researched for use in ceiling tiles and floor tiles/paving stones. Filter residues obtained from liquid-fed pyrolysis have been evaluated as new structural composite materials. Eggshell powder and glass fiber reinforced recycled PE/HDPE have been investigated as non-structural building composites. The mechanical performance of recycled PVC window profiles has also been investigated (Table 1) (Ait Khouya vd., 2025).

Table 1 Comparative Evaluation of Application Areas of Recycled Plastics in Building Materials

Application Area	**Usage Method**	**Types of Plastic Used**	**Material Performance**	**Analysis/Identified Advantages & Issues**	**Architectural Application Potential / Project Applications**
1. Concrete & Mortars	Aggregate, fiber, additive, binder modifier	PET, HDPE, LDPE, PP, PVC, PS, mixed plastics, e-waste plastics	Compressive strength may increase or decrease; surface modification is effective	High plastic content may reduce workability; prediction studies using machine learning are available	Potential for use in low-load-bearing elements in urban infrastructure (benches, planters, paving stones)
2. Bricks and Blocks	Aggregate, main component	PET, HDPE, plastic powder	Increased thermal insulation, lightness, mechanical improvement	Performance improvement in unfired clay bricks; low water absorption	Holds potential as an alternative building block in energy-efficient housing projects
3. Insulation Materials	Fiber, filler, panel	EPS, PE, plastic sheets	Low λ (0.0426 W/m·K), performance enhancement with PCM	Compatibility with phase change materials; lightness	Recyclable facade insulation systems; temporary structures and low-cost shelters
4. 3D Printing (Additive Manufacturing)	Secondary raw material (thermoplastic), granules	PC, PC/ABS, HDPE, mixed plastic	Large-format production; good formability	Shape distortions such as warping; recycling quality is important	Temporary pavilions, modular systems, rapid production elements (see structures such as WASP)
5. Other Applications	Coating, flooring, composite	PVC, PE, glass fiber reinforced PE/HDPE	Abrasion resistance, fire resistance, bend control	Suitability for non-structural elements	Floor covering, interior elements, recycled urban furniture

2.2. Material Properties and Performance Evaluation

The performance of construction materials containing recycled plastic is examined in detail from various perspectives:

- Mechanical Properties: Compressive strength, tensile strength, flexural strength, shear strength (important in composites), hardness, impact resistance, and workability are important parameters (Lamba vd., 2022). The type of plastic, its content, and the method of application have different effects on mechanical properties. For example, a 1:2 ratio of washed PCPET mixture in PET/M-sand bricks showed a compressive strength of 40.29 N/mm² (Athithan & Natarajan, 2024). Surface-modified PP fibers obtained from used masks have been found to improve the workability and strength performance of cementitious systems (Kaya vd., 2025). It has also been determined that difficulties such as post-processing warping may occur as the plastic content increases (Karedla vd., 2024).
- Thermal Properties: Thermal conductivity (λ)10..., thermal diffusivity, thermal resistance (R), and specific heat (Cp) values are determined, especially for insulation applications. The thermal conductivity of waste plastic poster insulation material was measured as 0.0426 W/m·K (Jin vd., 2025). Improvements were observed in the thermal performance of bricks containing HDPE and PET additives. Thermal stability is investigated using methods such as Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) (Mourid vd., 2025). The thermal insulation properties of thermoplastic bricks offer potential for energy-efficient buildings (Kadupu vd., 2025).
- Durability: Tests are conducted for water absorption, shrinkage, freeze-thaw resistance, fire resistance, abrasion resistance, and overall durability. Plastic sand bricks have been reported to exhibit low water absorption (1.033% - values between 1.10% and 2.08% are found in the specified source) (Athithan & Natarajan, 2024; Lamba vd., 2022).
- Processing Characteristics and Material Behavior: It has been observed that plastics, especially when used in high proportions, can create difficulties during processing, such as post-molding warping. The ease with which thermoplastics soften and take shape when heated is an advantage for their use as binders (Karedla vd., 2024).
- Consistency and Variability: Variability in the mechanical properties of materials is being studied, and recent studies have indicated that it is influenced by factors such as polymer compatibility, blending efficiency, and processing conditions.

The use of waste plastics in construction materials plays a critical role in alleviating the plastic waste problem and promoting sustainable construction practices (Athithan & Natarajan, 2024). Tools such as Life Cycle Assessment (LCA) are important for evaluating the environmental impacts of these materials. The use of recycled plastic as a secondary raw material supports the circular economy.

Research indicates that waste plastics have broad potential for use in the construction industry as aggregate, fiber, binder modifiers, and insulation materials (Haba vd., 2025). However, it is emphasized that specific standards are needed to ensure the quality and safety of these innovative materials, expand their application areas, and ensure their acceptance in the market (Mourid vd., 2025).

3. EXAMPLES OF USING RECYCLED PLASTIC WASTE IN ARCHITECTURAL PROJECTS

3.1. Housing Production Using Recycled Plastic Bricks: The Conceptos Plásticos Example

Conceptos Plásticos, based in Colombia, has developed an innovative building system based on the use of recycled plastic in the construction industry. The company offers a system that allows a team of four to build 40 m² homes in five days using Lego-like interlocking plastic bricks. This system is based on modular building elements that are fire-resistant and provide thermal and acoustic insulation, produced by melting and molding waste plastic.

Offering fast and economical solutions, particularly for communities displaced by social issues, this system was used in 2015 to build temporary shelters for 42 families in Guapi, recycling 200 tons of plastic. The designs were developed to suit Colombia's seismic conditions and equipped with ventilation and lighting to meet climatic requirements (Valencia, 2017). This initiative won an award in the social impact category at The Chivas Venture competition in 2016, attracting global attention (Image 1).

Image 1 Housing with Plastic Bricks (archdaily)

3.2. Self-Care Community Center: Architectural Use of Plastic Waste Collected from the Ocean and Recycled Plastic Ropes in Jakarta

According to a report published by Alyn Griffiths in Dezeen (2025), the interdisciplinary design studio Space Available has designed a community-based self-care center in Jakarta, Indonesia. This center, called the “Self Care Community Center (SCCC),” was brought to life in collaboration with Sidarta and Sandaja and Andika Wahyu. The project aims to support the individual and collective well-being of city residents, with the repurposing of the space based on recycling and community participation.

The center, created by converting a building previously designed by architect Andra Matin, consists of various spaces such as a meditation room, a waste recycling workshop, an art and design gallery, a restaurant-bar, a listening library, and a community reading area. The building's exterior facade and interior furniture were produced in collaboration with local artisans using 11 tons of plastic waste. The facade features organic-shaped openings reminiscent of the fruits of the trees that give the Kemang area its name (Image 2).

Image 2 Self Care Community Center (Dezeen)

The project highlights the potential of plastic waste in architectural production while implementing the principles of reuse and sustainability on both a structural and social level. The design approach aims to create a transformative and inclusive living space where urban individuals can connect with nature and each other.

3.3. Walker Warner Architects' Kona Village: Sustainable Island Architecture Using Recycled Plastic Materials

Designed by Walker Warner Architects on Hawaii's Big Island, the Kona Village resort complex, redesigned after the 2011 tsunami disaster, blends traditional Pacific Island architecture with modern sustainable practices. The project incorporates wooden frame structures and thatched roofs made from recycled plastic, taking into account the region's natural and cultural context. This material selection aims to reduce environmental impact while preserving the aesthetic identity of the facility. The design creates a layout that fits the horseshoe-shaped terrain, and the buildings are positioned to take advantage of natural breezes, providing natural ventilation and reducing the need for air conditioning. Kona Village accommodates a total of 150 guest rooms and various social amenities; the facility's sustainability approach is supported by LEED Gold certification, and energy requirements are largely met by photovoltaic panels. Additionally, material salvage projects from old facilities have been carried out to raise awareness of recycling (Image 3) (McKnight, 2024).

Image 3 Kona Village Holiday Complex (Dezeen)

3.4. EcoARK Pavilion: An Example of Sustainable Architecture Built with Recycled PET Bottles

Located in Taipei, Taiwan, the EcoARK Pavilion is a pioneering example at the intersection of architecture and sustainability. Developed by MINIWIZ LTD., the structure was built using an innovative building material called Polli-Brick™, made from 100% recycled PET (polyethylene terephthalate) bottles. Serving as the main exhibition area for the 2010 Taipei International Flora Expo, the pavilion is now used as a public cultural space and museum.

The most striking feature of EcoARK is that it was constructed using approximately 1.5 million recycled plastic bottles. Despite being 50% lighter than conventional buildings, this structure demonstrates high resistance to Taiwan's climate conditions, which carry risks of earthquakes and fires. The Polli-Brick™ material can form strong wall systems without the need for chemical binders, thanks to its lightness, semi-transparent structure, natural insulation properties, and interlocking modular form (*MINIWIZ: Turning Waste into Resources. Circular Taiwan*, t.y.). Furthermore, the building's energy performance is enhanced by using solar energy collected during the day via integrated photovoltaic panels for nighttime lighting. Rainwater harvesting systems and natural ventilation strategies are other important design elements that reduce the building's ecological footprint (Figure 4).

Figure 4 EcoARK Pavilion (circular Taiwan)

The EcoARK Pavilion represents a successful application of circular economy principles at the architectural scale, having been constructed according to the principles of "Reduce, Reuse, Recycle." This structure, achieved through a combination of recycling, material innovation, and modular design, aims to raise awareness of environmental sustainability not only on a technical level but also on a symbolic level. Therefore, EcoARK is considered one of the pioneering structures that set an example in terms of sustainable architecture and material-based innovations.

Table 2 Comparative Evaluation of Examples of the Use of Recycled Plastic Waste in Architectural Projects

Project Name	**Location/Country**	**Plastic Material Used and Production Method**	**Structure Type and Dimensions**	**Sustainability and Innovation Features**	**Other Notes**
Conceptos Plásticos	Colombia	Modular Lego-like plastic bricks produced by melting and molding waste plastic	40 m², rapid housing production by a 4-person team within 5 days	Fire-resistant, thermo-acoustic insulation, seismic and climatic conditions adaptation	A fast, economical solution for those displaced by social issues; 200 tons of plastic recycled
Self Care Community Center (SCCC)	Indonesia (Jakarta)	Plastic waste collected from the ocean and recycled plastic ropes	Community centers; various spaces (meditation, workshop, gallery, etc.)	Use of plastic waste in facades and furniture, community participation, social sustainability	Collaboration with local artisans, emphasis on local identity with organically shaped openings
Walker Warner Architects - Kona Village	Hawaii, USA	Reed roofs made from recycled plastic	Resort complex; 150 guest rooms and social amenities	Natural ventilation, energy efficiency, LEED Gold certification,	A blend of Pacific Island architecture and sustainability, redesigned after the tsunami

				material recovery	
EcoARK Pavilion	Taipei, Taiwan	Polli-Brick™ (modular, interlocking) made from 100% recycled PET bottles	The pavilion used approximately 1.5 million PET bottles	50% lighter, earthquake and fire resistant, natural insulation, photovoltaic panels	Circular economy, energy efficiency, rainwater harvesting, and natural ventilation systems

4. DISCUSSION

4.1. Material Performance and Technical Feasibility

The findings examined here indicate that waste plastics show promising results when used as a building material from a technical standpoint. Particularly in terms of mechanical properties, the compressive strength values of 40.29 N/mm² obtained in PET/M-sand bricks show performance close to that of conventional bricks. This finding is also supported by Athithan and Natarajan (2024), demonstrating the applicability of recycled plastics in flexible applications.

In terms of thermal performance, the thermal conductivity value of 0.0426 W/m·K for plastic filter materials demonstrates performance comparable to conventional moisture materials. This value, obtained by Jin et al. (2025), shows that plastic waste has significant potential in energy-efficient building designs.

4.2. Environmental Sustainability and Circular Economy Impacts

The use of plastic waste as a building material provides multi-dimensional benefits in terms of sustainability. Expanding on the example of the EcoARK Pavilion, converting 1.5 million PET bottles into building materials contributes to waste management solutions and increases resource efficiency. This approach aligns with the Ellen MacArthur Foundation's circular economy principles and represents the successful performance of the “Reduce, Reuse, Recycle” principles in an architectural setting.

In the case of Conceptos Plásticos, the recycling of 200 tons of plastic waste enables the socio-economic emergence of plastic recycling in solving local waste management problems. Particularly in the context of variable diversity, the recycling of plastic waste can continuously contribute to social sustainability.

However, Life Cycle Assessment (LCA) is critical for the comprehensive evaluation of the reactions of recycled plastics. The limited capacity in this area indicates that future research should focus on this direction.

4.3. Socio-Economic Impacts

The Jakarta Self-Care Community Center example demonstrates that plastic waste recycling is not merely a technical solution, but can also provide dimensions of community participation and social sustainability. The evaluation of 11 tons of plastic waste collected in collaboration with local businesses reveals the potential of regional recycling models for the community.

The Kona Village project demonstrates that recycled plastics can be accepted even in the luxury tourism sector and can meet international sustainability standards such as LEED Gold certification. This is an important indicator of the market acceptance of plastic recycling.

4.4. Technical Limitations and Areas for Development

The samples examined in the study reveal that certain technical limitations also exist in plastic recycling. In particular, it has been determined that the processability of plastics can decrease at high rates and may lead to limitations in certain durability applications. This situation, also emphasized by Lamba and colleagues (2022), indicates the need for optimization of material components and improvement of surface modification techniques.

The use of machine-generated models in material performance prediction will enable the production of more precise material designs in the future. These technological developments will increase the industrial applicability of plastic recycling.

4.5. Standardization and Quality Assurance Requirements

The need for specialized characteristics, as emphasized by Mourid and colleagues (2025), represents a critical barrier to the widespread adoption of plastic recycling. It is understood that current building material standards are insufficient for recycled plastics, and new quality assurance results have been obtained for sectoral acceptance.

The use of 3D printing technologies (LFAM, FPF) in plastic recycling, in conjunction with the advanced approaches proposed by Romani and Levi (2024), requires the emergence of technical results such as warping and the provision of quality standards.

5. CONCLUSION

This study comprehensively demonstrates the potential use of recycled plastics as construction materials and their importance in the context of sustainable architecture. Literature reviews and case studies reveal that plastic waste can be successfully utilized in various construction elements such as concrete, bricks, and insulation materials. The mechanical and thermal performance of recycled plastics can increase the durability and functionality of building materials with appropriate processing techniques and material modifications. Furthermore, these applications contribute to sustainability goals by reducing resource consumption and improving waste management.

However, for plastic waste to be widely used in the construction sector, material standards must be established, environmental impacts must be analyzed in detail, and user awareness campaigns must be conducted. Along with technological developments, increasing the proportion of recycled plastics and discovering new application areas are critical for the circular economy and environmental sustainability. Ultimately, the use of plastic waste as a building material makes a strong contribution to sustainable architectural practice, both environmentally and economically.

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Chapter 2

RESEARCH GENEALOGIES AND EPISTEMOLOGICAL TRAJECTORIES IN MODULAR CONSTRUCTION, CONSTRUCTION TECHNOLOGY AND ENERGY-EFFICIENT BUILDING RESEARCH (1970–2020)

DAMLANUR İLİPINAR [1]

1 Dr. Research Assistant, Karabuk University, Faculty of Architecture, 0000-0001-6523-3487

1.INTRODUCTION

The development of scientific studies is seen as a cumulative process progressing step by step. Scientific studies, which develop and grow through a layered approach, do not follow a linear path, especially since the industrialization period, with the blurring of sharp boundaries, the increasing interrelationships between different fields, the emergence of interdisciplinary studies, and the proliferation of studies in social sciences. This study focuses on the evolution of developments in the field of 'Modular structure, construction technology, and energy-efficient buildings' by examining the research conducted on this topic. It investigates how the boundaries of the field have evolved in relation to technological advancements and changing industrial priorities. It explores how these boundaries are shaped by the interaction and relationships between research agendas, production technologies, construction practices, and broader socio-economic conditions.

The aim of this research is to present a historical and epistemological analysis of the scope and methodology of research in the field of 'modular structure, building technology, and energy-efficient buildings' from the 1970s to 2020, based on doctorate thesis produced in this area. Within this long time period, the study critically examines the question: How was knowledge in this field produced and structured over time? This question also answers the reasons and mechanisms behind methodological changes and transformations in the research area.

Doctoral dissertations serve as cornerstones in the production of academic knowledge. Therefore, the three key terms selected for this study – 'modular structure, construction technology, and energy-efficient buildings' – were searched in the ProQuest Doctoral Dissertations and Doctoral Studies database. To find long-term research trends in these areas, doctoral dissertations were scanned starting from 1970. This covered a 50-year period to illustrate the technological, industrial, and environmental aspects of the field. For each 10-year period, three dissertations corresponding to the specified term were selected. Through these three doctoral studies selected for each 10-year period, the dominant research methodologies, epistemological frameworks, and methodological trends over time were determined. The historical development of knowledge production in these areas was examined, and doctoral research was positioned within significant global trends such as energy crises, digitalization, and emerging technologies. Furthermore, the study observed whether an epistemological shift occurred through the examined dissertations and analysed the development of research tools, methodologies, and analytical capabilities.

2.REVIEW ON THE EPISTEMOLOGICAL FRAMEWORK AND SCIENTIFIC RESEARCH TRADITIONS

The epistemological approach, when analysing scientific fields, addresses two questions: What is knowledge, and how is knowledge produced and justified? These questions continue to influence the development of research problems and shape scientific research traditions in various fields. However, with the proliferation of interdisciplinary studies and the prominence of research in the social sciences, the answer to the question of how knowledge is produced has begun to diversify and change. In this context, the question of whether knowledge is based on an objective external reality or on context-dependent interpretations frequently dominates epistemological debates. At this point, different perspectives have been examined. Foundationalism argues that knowledge is based on an external reality accessible through observation, measurement, and empirical analysis. From this perspective, scientific validity relies on methodical research and repeatable results. On the other hand, anti-foundationalist approaches challenge the idea of absolute foundations. They argue that what we know is shaped by context, how we interpret it, and historical conditions. The rise of anti-foundationalist views has increased epistemological diversity, making it difficult to distinguish which

field is which, particularly since the 1990s, with the blurring of boundaries between specific areas and the proliferation of interdisciplinary studies. This diversification revived interest in the problem of distinguishing scientific knowledge from non-scientific claims, and different perspectives developed in this area. Karl Popper's focus on falsifiability and Thomas Kuhn's ideas about paradigms and scientific revolutions had a major influence on early debates. While Popper argued that scientific progress occurred through assumption and refutation, Kuhn characterized scientific evolution as an oscillation between stable stages of "normal science" and paradigm shifts triggered by unresolved anomalies. Imre Lakatos later introduced the concept of research programs, arguing that scientific progress should be assessed not through the examination of isolated theories, but through the comparison of competing research programs over time.

These perspectives offer a valuable framework for examining long-term research trajectories. They do not view methodological change as a sign of an epistemological rupture; instead, they see scientific progress as a process that builds upon itself over time as tools, problems, and evaluation criteria change.

3.RESEARCH GENEALOGIES on MODULAR CONSTRUCTION, CONSTRUCTION TECHNOLOGY, ENERGY EFFICIENT BUILDINGS

Research genealogies offer a structured framework for analysing the evolution of knowledge fields over time through recurring themes, keywords, methodologies, and disciplinary connections. This study analyses doctoral research in the fields of modular construction, building technology, and energy-efficient building studies from the 1970s to the 2010s to identify breaks in research focus and epistemological orientation. According to a comprehensive review of the ProQuest database, the increasing importance of modularization, technological innovation, and energy efficiency in the building environment is reflected in the continuous increase of doctoral dissertations on these topics. The research objectives, methodologies, and core epistemological assumptions of selected dissertations were examined in ten-year periods. Global trends, including energy crises, technological advancements, and changes in construction practices, were considered as contextual factors influencing research objectives. To support this approach, four main technical stages – industrialization and standardization, computerization and automation, digital integration and performance optimization, and data-driven intelligent systems – were identified. These stages provide a contextual framework for analysing shifts in research direction over time.

Figure 1 illustrates four main stages: industrialization and standardization, computerization and automation, digital integration and performance optimization, and data-driven intelligent systems. These stages provide a foundation for understanding the research genealogies discussed in this section. Thus, the parallelism between the timeline of change and transformation observed when examining studies in each 10-year period will also be investigated.

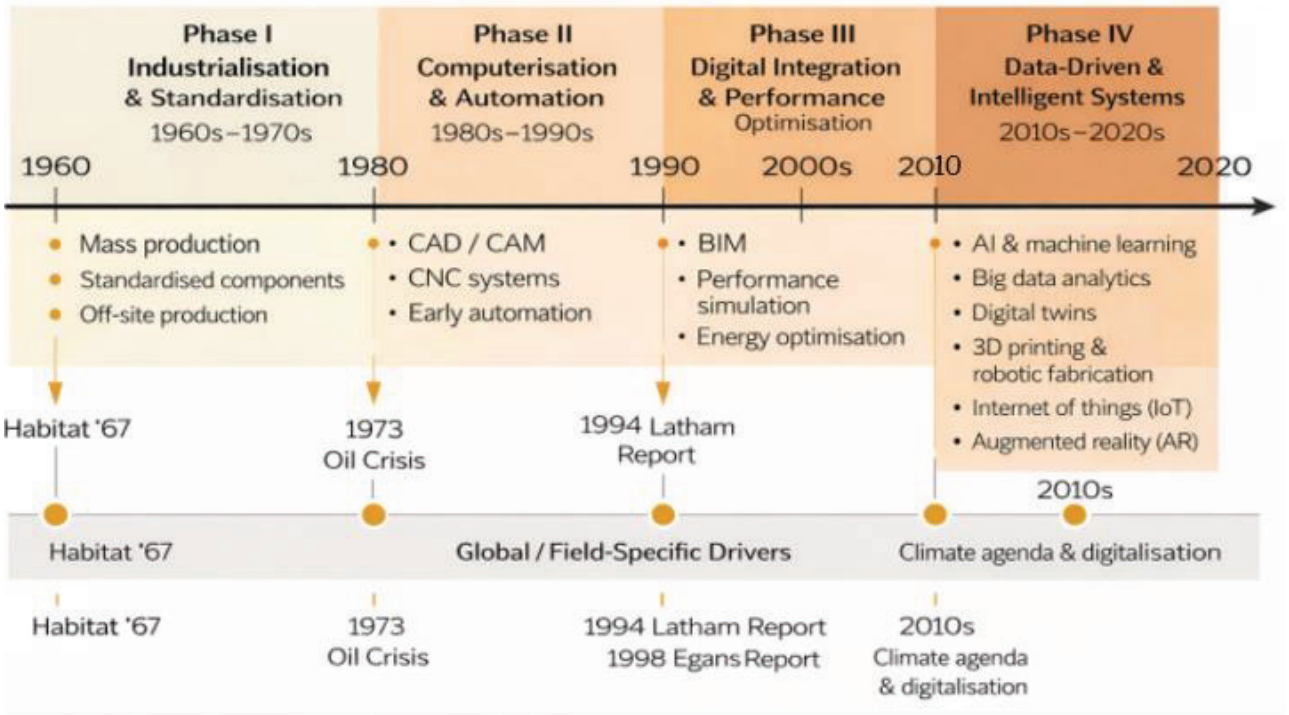

Figure 1. Technological paradigms and research drivers shaping 'modular construction' and 'energy efficient building' research (1960-2020)

3.1. The Changes in Scientific Research Traditions and Trends from the 1970s to the 2010s

Research genealogies in modular construction, building technology, and energy-efficient building studies reveal distinct thematic and methodological patterns across successive decades. For each decade between the 1970s and 2010s, doctoral dissertations indexed in the ProQuest database were examined, and three representative studies were selected based on thematic relevance and institutional affiliation. Rather than offering detailed case-by-case descriptions, this section highlights the dominant research concerns and methodological trends that characterized each period. Table 1 shows the theses selected to observe the long-term development of research agendas in the fields of modular construction, building technologies, and energy-efficient building studies, as well as the changes and transformations in technological paradigms and research methods. As summarized in this table, the number of theses has continuously increased, highlighting the importance of interest in this field.

In the 1970s, research in this field was largely influenced by energy efficiency concerns and industrialization, particularly the 1973 oil crisis. Theses from this period (Kosaner, 1979; Romancheck, 1979; Sedlak, 1975) employed predominantly empirical and experimental research strategies, including case studies, prototype development, simulations, and analytical testing. The focus of the studies concentrated on industrial building systems, building facade performance, and alternative construction materials, reflecting an early engagement with off-site manufacturing and energy-conscious design.

The increasing availability of computer-aided design and early automation techniques in the 1980s created new research opportunities in the field of construction. Selected theses from this decade (Graham, 1988; Sotoodeh-Khoo, 1988; Grobler, 1988) adopted quantitative research methods, including numerical analysis, computer programming, optimization techniques, and survey-based research.

Table 1. Overview of doctoral dissertations by decade, keywords, epistemological position, theoretical perspective and research methodology in modular construction, construction technology and energy-efficient building studies (1970–2020)

DECADE	KEYWORDS	NO OF DISSERTATION	SOURCE (Full reference of the dissertation from ProQuest)	EPISTEMOLOGY	THEORETICAL PERSPECTIVE	METHODOLOGY/ METHODS	ANNOTATIONS for Decades
1970's	Modular construction Construction technology Energy efficient buildings	Architecture: 9 All: 641	▪ Kosaner, Y. (1979). *A study of industrialised building systems with special reference to Turkey.* The University of Manchester (United Kingdom)	Objectivism	Positivism	Comprehensive review and classification Case Study	-Maintaining industrialization in building systems
			▪ Romancheck, R. (1979). A Study Of The Residential Energy Envelope To Assess Energy, Economic, And Environmental Factors In The Selection Of Residential Energy Systems. (volumes I And II). Drexel University. Philadelphia, Pennsylvania.	Objectivism	Positivism	Simulations Measurements Experimental Data	
			▪ Sedlak, V. F. (1975). Folded surface structures: The potential use of paperboard for low-cost enclosures. University of Surrey (United Kingdom)	Objectivism	Positivism	Literature Review Survey Prototype manufacture Analytical tests Experimental investigations	
1980's	Modular construction Construction technology Energy efficient buildings	Architecture: 52 All: 1.167	▪ Graham, C. W. (1988). *The HUD-Code and modular housing industries: variable identification for technological, marketing, and management orientation indices.* Texas A&M University. (USA)	Objectivism	Positivism	Exploratory data analysis Survey Questionnaire	-Developments in the computer programming -Automation studies in the construction industry
			▪ Sotoodeh-Khoo, H. (1988). Integrated real-time expert systems and sensor-based data-acquisition in the automation of construction equipment and operations. Stanford University (USA)	Objectivism	Positivism	Analytical model Optimization Experimentations	
			▪ Grobler, F. (1988). Object-oriented data representation for unified construction project information. University of Illinois at Urbana-Champaign	Objectivism	Positivism	Computer Programming Knowledge-based review Data Analysis &Progressing	
1990's	Modular construction Construction technology Energy efficient buildings	Architecture: 141 All: 3.600	▪ Al-Homoud, M. (1994). Design optimization of energy-conserving building envelopes. Texas A&M University (USA)	Objectivism	Positivism	Simulations Optimizations Linear- Dynamic Programming	-Searching for new technologies -Establishing a new paradigm for design and building energy optimization
			▪ Malkawi, A. M. (1994). Building energy design and optimization: Intelligent computer-aided thermal design. Georgia Institute of Technology (USA)	Objectivism	Positivism	Simulations Optimization Transfer Function	
			▪ Mathew, P. A. (1996). Integrated energy modeling for computational building design assistance. Carnegie Mellon University. (USA)	Objectivism	Positivism	Quantitative Analysis Simulations Case Study	
2000's	Modular construction Construction technology Energy efficient buildings	Architecture: 276 All: 8.098	▪ Kassab, M. S. M. (2008). Enhancing the energy -efficient design of office buildings using a based-simulation design support system. University of Calgary (Canada)	Objectivism	Positivism	Case Study Simulations Quantitative Analysis	-New cross-research fields -Integrating technology, construction industry and building performances
			▪ El Ghandour, W. (2007). Integrated information-based construction simulation system. University of Alberta (Canada)	Objectivism	Positivism	Literature Review Review Ontology Surveys Simulations	
			▪ Primikiri, E. (2004). Thermal building performance optimization using spatial archetypes. University of Michigan (USA)	Objectivism	Positivism	Simulations-Optimization Case Study Analytical calculations	
2010's	Modular construction Construction technology Energy efficient buildings	Architecture: 305 All: 11.412	▪ Sheffer, D. A. (2011). Innovation in modular industries: Implementing energy-efficient innovations in US buildings. Stanford University (USA)	Objectivism	Positivism	Quantitative analyses with technical interviews Case Studies Analytic Data	-Increasing the number of dissertations about innovations and technological developments in the construction industry -Increasing the number of used tools and implementations of innovations on buildings
			▪ Kawecki, L. R. (2010). Environmental performance of modular fabrication: Calculating the carbon footprint of energy used in the construction of a modular home. Arizona State University (USA)	Objectivism	Positivism	Scientific measurements Observations- Data collection	
			▪ Jafar Ramaji, I. (2016). An integrated building information modeling (BIM) framework for multi-story modular buildings. The Pennsylvania State University (USA)	Objectivism	Positivism	A comprehensive Literature Review Site visits and interviews/ Observations	

In the 1990s, with increasing global awareness, environmental issues, energy efficiency, and sustainability studies became significantly important. The theses examined (Al-Homoud, 1994; Malkawi, 1994; Mathew, 1996) investigated techniques related to energy optimization, computational modelling, and performance-based analysis aimed at reducing energy consumption. With the increasing use of computer technologies, simulation-based methods and optimization algorithms, supported by statistical and analytical data analysis, became dominant. It was observed that quantitative methodologies maintained their prevalence and strengthened the objective orientation of research applications.

In the 2000s, research agendas expanded further thanks to advanced simulation tools and system integration. Studies encompassing multiple disciplines, connecting automation, information systems, and construction technology, began to appear. The methods employed in the study maintained a quantitative nature, based on various approaches such as advanced computational models, analytical calculations, and optimization techniques.

Between 2010 and 2020, studies on modular construction and energy-efficient buildings were characterized by increasingly data-intensive and performance-oriented approaches, driven by the development and widespread use of digital tools. Doctoral dissertations examined during this period (Kawecki, 2010; Sheffer, 2011; Jafar Ramaji, 2016) continued to rely primarily on quantitative methodologies, including scientific measurements, data collection, analytical modelling, and case-based analysis. While advanced digital tools such as Building Information Modelling (BIM), automation technologies, and manufacturing technologies expanded the analytical capacity of research, the underlying epistemological orientation remained largely objectivist.

3.2. Definition of Epistemological Positions

This section clarifies the epistemological positions, theoretical perspectives, and associated research methodologies that underpin the analysis of research genealogies in modular construction, construction technology, and energy-efficient building studies. Establishing these conceptual contrasts is key for properly interpreting the epistemic orientation of the selected doctoral dissertations across different decades.

Epistemological perspectives, generally situated on a continuum from objectivism to subjectivism, embody varying assumptions regarding the essence of reality, the nature of knowledge, and the researcher's function in knowledge creation. Objectivism posits the existence of a reality that can be accessed through systematic, objective scientific methodologies and is separate from human perception. Structured analytical frameworks, empirical observation, experimentation, and the gathering of knowledge through quantifiable and repeatable processes are characteristics of objectivist research. Feast and Melles (2010) emphasize that objectivist epistemology prioritizes the logical development of theories based on actual data and looks for solid foundations to enable scientific investigation. Subjectivism, on the other hand, views reality as socially and interpretively produced. According to this viewpoint, various interpretations of reality may coexist and knowledge is shaped by the meanings people give to their experiences. Subjectivist methods emphasize context-dependent, historically and culturally situated understandings rather than absolute or universal facts. Coherence, plausibility, and interpretative consistency—rather than congruence with an actual external reality—are used to evaluate knowledge. As a result, subjectivist research traditions frequently use qualitative research techniques including discourse analysis, interpretive inquiry, and interviews. Feast and Melles (2010) define constructionism as a third epistemological perspective that goes beyond this binary divide and is especially pertinent to design and interdisciplinary research contexts.

By contending that knowledge is created through interactions between researchers and the social world, constructionism bridges the subject-object gap. Constructionism holds that knowledge is created through common meanings, language, and social activities rather than presuming a fixed external reality or entirely subjective interpretation. According to this viewpoint, truth is created through interpretive processes that are ingrained in certain institutional and cultural settings rather than discovered. Consequently, constructionist studies often use qualitative and interpretive approaches including ethnography, grounded theory, and phenomenological research.

Crotty conceptualizes the research process as consisting of four interconnected elements: epistemology, theoretical perspective, methodology, and methodologies in order to operationalize these epistemological disparities within research practice (Feast and Melles, 2010). This framework offers a methodical framework for connecting specific research techniques to philosophical presumptions about knowledge. Table 2 summarizes the connections between epistemological stances, related theoretical viewpoints, and frequently used approaches and techniques based on this model.

Table 2. Knowledge Framework by Crotty (Feast and Melles, 2010)

Epistemology	Theoretical perspective	Methodology	Methods
Objectivism	Positivism Post-positivism	Experimental research Survey research Etc.	Sampling Measurement and scaling Statistical analysis Questionnaire Focus group Interview Etc.
Constructionism	Interpretivism • Symbolic interactionism • Phenomenology • Hermeneutics Critical Inquiry Feminism	Ethnography Grounded theory Phenomenological research Heuristic inquiry Action research Discourse analysis Feminist standpoint research Etc.	Qualitative interview Observation • Participant • Non-participant Case study Life history Narrative Theme identification Etc.
Subjectivism	Postmodernism Structuralism Post-stucturalism	Discourse theory Archaeology Genealogy Deconstruction Etc.	Autoethnography Semiotics Literary analysis Pastiche Intertextuality Etc.

Table 2 shows that positivist and post-positivist theoretical stances are most closely related to objectivist epistemology. Asserting that trustworthy information can only be acquired by scientific techniques based on observation, measurement, and experimentation, positivism is based on the idea of separating science from metaphysics. According to this paradigm, the goal of scientific investigation is to find generalizable, universal truths that are thought to exist apart from the researcher. Thus, the methodological underpinnings of positivist research strategies are empirical and quantitative research methodologies, including surveys, measurement-based approaches, statistical analysis, and experimental studies.

3.3 Evaluation of the Epistemological Positions of Selected Dissertations

Although building science is typically found in architectural departments, scientific and engineering-oriented methodologies of inquiry have long influenced the field's study. The natural and applied sciences are strongly related to the three keywords this study looked at: energy-efficient buildings, construction technology, and modular construction. Because of this, an analysis of PhD dissertations written between the 1970s and the 2010s shows a consistent and obvious agreement with objectivist epistemological stances.

The primary research methodologies over the decades under examination are quantitative. Throughout the dataset, experiments, simulations, analytical modelling, optimization strategies, and performance-based assessments are frequently used. Positivist theoretical stances, which hold that knowledge is observable, quantifiable, and independent of the researcher, immediately align with these methodological preferences. This is not an accidental pattern. Instead, it represents the epistemological underpinnings of construction-related research, where technical performance and empirical verification continue to be primary objectives. Interestingly, more information on this epistemic coherence may be found in the disciplinary distribution of PhD research. The number of dissertations has increased significantly over time, especially in the fields of architecture and civil engineering, as Figure 2 illustrates. Contributions from information systems, management, and other multidisciplinary fields have become more prominent since the 1990s.

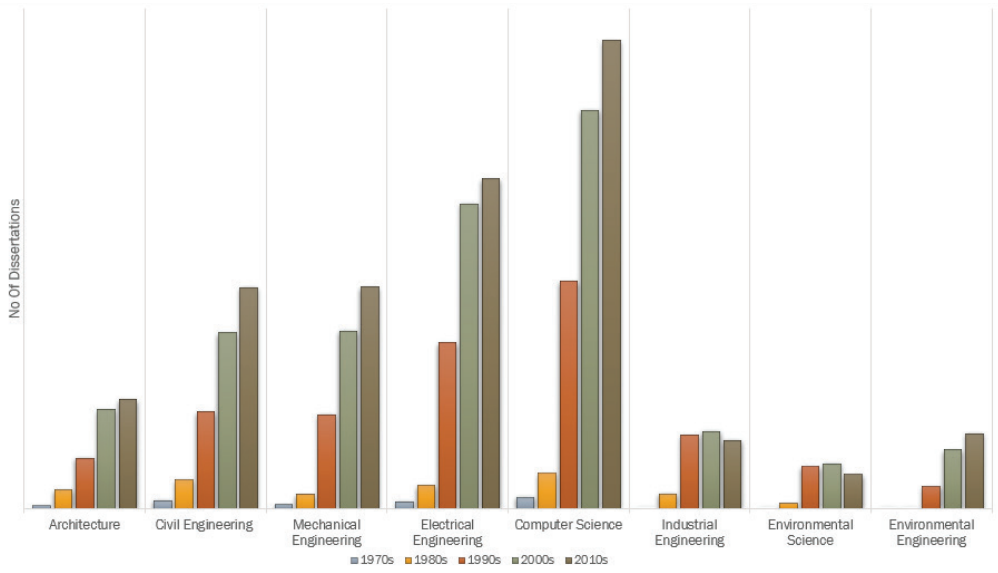

Figure 2. Distribution and comparison of different subjects according to years in the dissertations

This observation is further supported by a closer look at topic groupings. Three broad research concerns—standardization, technical advancement, and environmental performance—were used to analyse the chosen dissertations. These concerns were reflected across topic areas such as management, ecology, energy, information technology, robotics, and artificial intelligence. Energy-related research has been around since the 1970s, as seen in Figure 3, but ecological topics only became well-known after the 1990s, coinciding with the growth of sustainability discourse in the built environment.

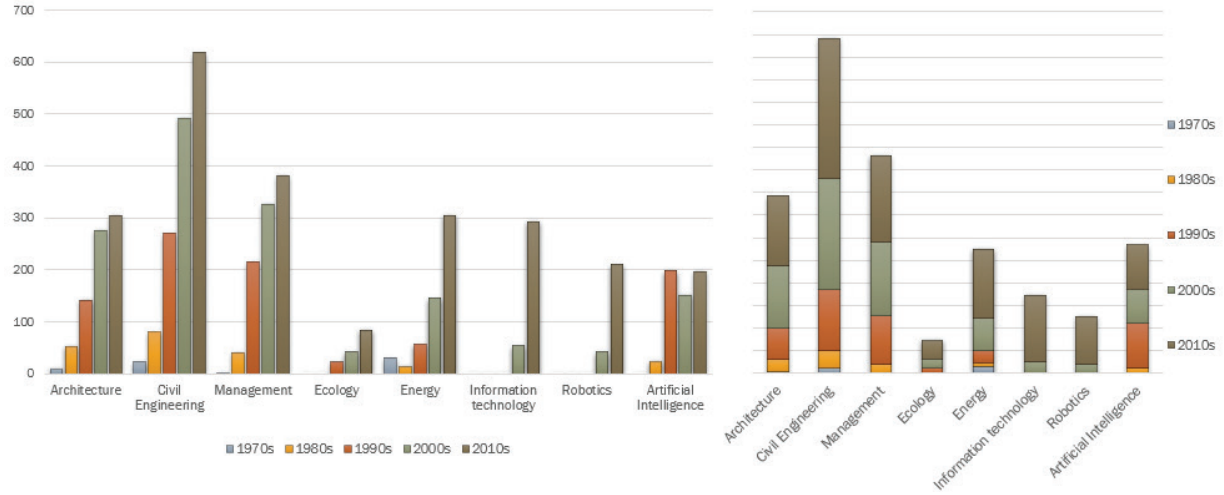

Figure 3. Comparison of different subjects with each other and epistemological position of selected dissertations

Technological themes follow a similar trajectory. Early references to artificial intelligence appear as early as the 1980s; however, research focused explicitly on information technologies and robotics became more pronounced after the 2000s. The big jump that happened in the 2010s is due to the fast growth of digital tools and their use in construction research. These new technologies mostly made it easier to analyse data, not change the basic ideas that guide research. This relationship is especially clear when you look at both the scope of the discipline and the epistemological position. As summarised in Figure 4, civil engineering accounts for the highest number of dissertations, followed by architecture and management-related studies. Despite this disciplinary expansion and thematic diversification, the core methodological approaches remain largely unchanged. Surveys, prototype

development, analytical testing, experimental investigations, simulations, optimisation processes, and case studies continue to dominate.

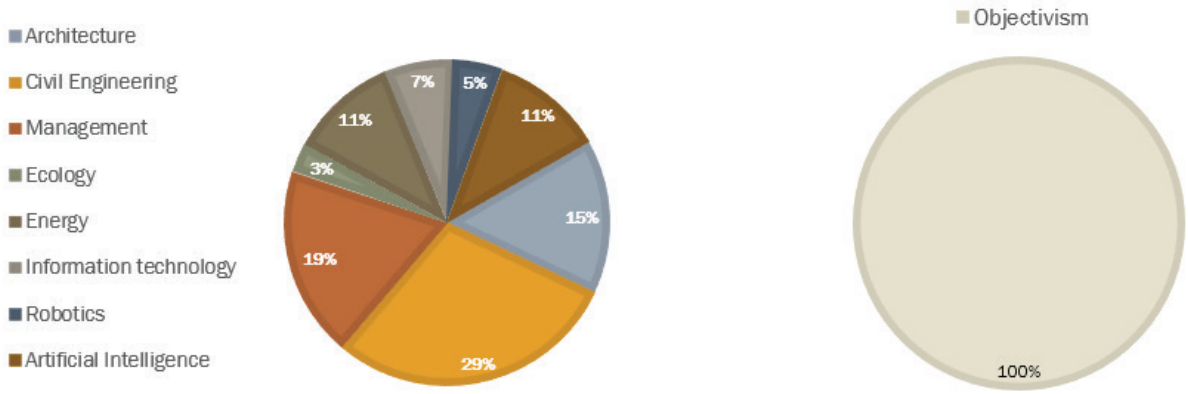

Figure 4. Comparison of different subjects with each other and epistemological position of selected dissertations

Taken together, these findings indicate that the expansion of research domains in modular construction and energy-efficient building studies reflects methodological and thematic diversification rather than an epistemological shift. The epistemological positioning of the selected dissertations remains consistently objectivist, with positivism serving as the dominant theoretical perspective across all examined decades.

3.4 Definition of Problem Area Considering Global and Field Specific Events

Modular construction, construction technology, and energy-efficient building studies have research genealogies that are intricately linked to both global and field-specific advancements. Research priorities in this field have not developed in a vacuum; rather, they have been influenced by international agendas, technological advancements, and historical occurrences that have redefined the scope of inquiry and the framing of research problems over time. As previously demonstrated by the timeline of significant socioeconomic and technological advancements (see Figure 1), shifts in the focus of research clearly correlate with significant worldwide events and changes in the construction sector. The oil crisis of the 1970s was a major turning point that made academics pay more attention to energy efficiency, alternative building materials, and building systems that are focused on performance. During this time, research on modular construction became more in line with definitions of energy-related problems. This showed that people were worried about resource scarcity and efficiency.

In the years that followed, automation and digital technologies had a bigger and bigger effect on construction research. Beginning in the 1980s, when early automation systems and computer-aided design tools became available, research problems slowly changed. Previously material and component-focused investigations have shifted to computational analysis, process optimization, and system efficiency. These advancements strengthened the significance of quantitative and simulation-based techniques and broadened the range of methodological tools available to researchers. Global worries about resource efficiency, environmental impact, and sustainability grew during the 1990s and early 2000s. Redefining research topics and promoting the methodical incorporation of environmental factors into construction research were made possible in large part by international reports, regulatory frameworks, and performance standards. As a result, topics such as energy optimisation, lifecycle performance, and integrated building systems gained increasing visibility within academic studies.

Digitalization, data processing, and rapid advancements in intelligent systems have continued to shape research problems in recent decades. The convergence of construction technology with information systems, artificial intelligence, and automation has resulted in new research areas focusing on data-driven decision-making, performance monitoring, and system integration. While these developments have significantly increased the scope and complexity of research topics, it is important that they largely follow accepted scientific frameworks. By enhancing analytical capacity and methodological rigor, they have strengthened existing approaches rather than altering current epistemological perspectives.

4. Conclusion

This chapter aimed to trace the research genealogies and epistemological trajectories of doctoral research in the fields of modular construction, building technology, and energy-efficient building studies from the 1970s to the 2010s. The analysis shows that while research topics, tools, and interdisciplinary intersections have diversified, the fundamental epistemological orientation has remained predominantly objectivist. A comparison of theses from different decades reveals a unsurprising consistency in their epistemological stances. Throughout the period examined, despite significant diversity in research topics, analytical tools, and interdisciplinary interactions, the dominant epistemological orientation has remained objectivist. The consequence of this continuity is that researchers still employ quantitative, performance-based methods. This stability is closely related to the strong links between the chosen research areas and the natural and applied sciences, where technical verification and empirical measurement are central components of scientific research.

Although architecture is often considered a design and craft-centered discipline, the standardization processes of construction systems have long been influential in the field of building sciences studied within this area. These influences date back to the Industrial Revolution and became more pronounced in the 20th century (Gözen, 2011). According to Eisenman, World War II marked a significant shift from mechanical production paradigms to information-based and electronic systems. The logic of production in many sectors, including construction, changed with the emergence of digital computing technologies in the 1960s, followed by the development of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). These digital technologies have been widely incorporated into construction and architecture research in the following decades. The use of simulation tools, optimization strategies, and performance-based evaluation techniques has gained importance in academic research. These developments have facilitated the growth of research agendas and encouraged the development of interdisciplinary fields linking information systems, building performance, and construction technology. However, this expansion, viewed through the prism of Kuhn's concept of normal science, can be seen not as a fundamental epistemological break, but rather as a cumulative development within an established scientific paradigm. The results show that advances in construction technology and digital tools have led to increased methodological sophistication rather than a fundamental shift in epistemology. Research in this field has evolved through incremental advancements within established scientific paradigms, consistent with Kuhn's concept of normal science. Consequently, the proliferation of interdisciplinary research areas has enhanced analytical capabilities while maintaining consistent assumptions about knowledge production in construction science.

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Chapter 3

PSYCHOLOGICAL HEALTH IN SPACES WITH LIMITED DAYLIGHT: THE INTEGRATION OF LIGHT BOX THERAPY INTO INTERIOR LIGHTING DESIGN

Erkan AYDINTAN[1] , Burcu KENANOĞLU[2] ,

Fatemeh KHABİR[3]

1 Erkan Aydıntan, Prof. Dr., Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture, ORCID: 0000-0001-8097-2384

2 Burcu Kenanoğlu, Master's Student, Karadeniz Technical University, Faculty of Architecture, Department of Architecture, ORCID: 0009-0005-4079-4524

3 Fatemeh Khabir, Master's Student, Karadeniz Technical University, Faculty of Architecture, Department of Interior Architecture, ORCID: 0009-0001-0989-7542

1. INTRODUCTION

Today, as a result of population growth and irregular urbanisation, people who spend most of their time indoors are unable to benefit sufficiently from daylight. This situation can affect the circadian rhythms of indoor users (Doğan, 2021, p. 526). On the other hand, there are some treatment methods that can be applied to prevent such negative effects. One of these is 'Bright Light Therapy (Light Therapy)'. The use of light for therapeutic purposes is based on the physiological need of living beings to adapt to the Earth's daily rotation. Living organisms have biological rhythms that repeat approximately every 24 hours. The most obvious indicators of this are the sleep/wake cycle and the daily changes in cortisol levels and body temperature that occur with melatonin secretion (Reddy et al., 2023). Research shows that bright light therapy administered in the early morning hours helps improve mood and, consequently, reduce depressive symptoms, regulate circadian rhythms, enhance the effects of antidepressant medications, and improve sleep quality. Therefore, bright light therapy is considered an effective treatment option due to its high response rates in seasonal affective disorder (SAD) (Terman et al., 1989; Wirz-Justice et al., 1996).

On the other hand, preventive approaches that exist outside of these types of therapies are also noteworthy. These approaches, which are important for taking precautions against problems caused by indoor environments that do not receive sufficient light, promise a more comfortable recovery process for the patient by preventing the progression of the disease. Today, there is an industrial product called 'Light Box Therapy' that mimics natural light and can be defined as a preventive approach. Some studies have shown that this therapy can be used as a preventive health service to administer bright light treatment (Meesters et al., 2001). Research has revealed that light box therapy applications have positive effects on the mood and productivity of employees (Chrysikou, 2014). Consequently, this study focuses on the potential use of this preventive approach in the field of interior lighting design, with the aim of providing a supportive effect on the natural cycle of physical and behavioural changes, primarily mental, that the body undergoes in a 24-hour cycle.

The health-promoting aspect of built environment design is presented through the concept of 'Therapeutic Architecture'. The fundamental aim of therapeutic architecture is to utilise the healing properties of spaces, taking into account the effects of the physical environment on patients' health (Chrysikou, 2014). Although studies on therapeutic architecture are limited today, recent research has revealed the positive effects of therapeutic architecture-based design on patients' recovery process. At this point, the study presents a perspective on how light box therapy can be integrated into interior lighting design as a preventive health service in line with therapeutic approaches (Figure 1).

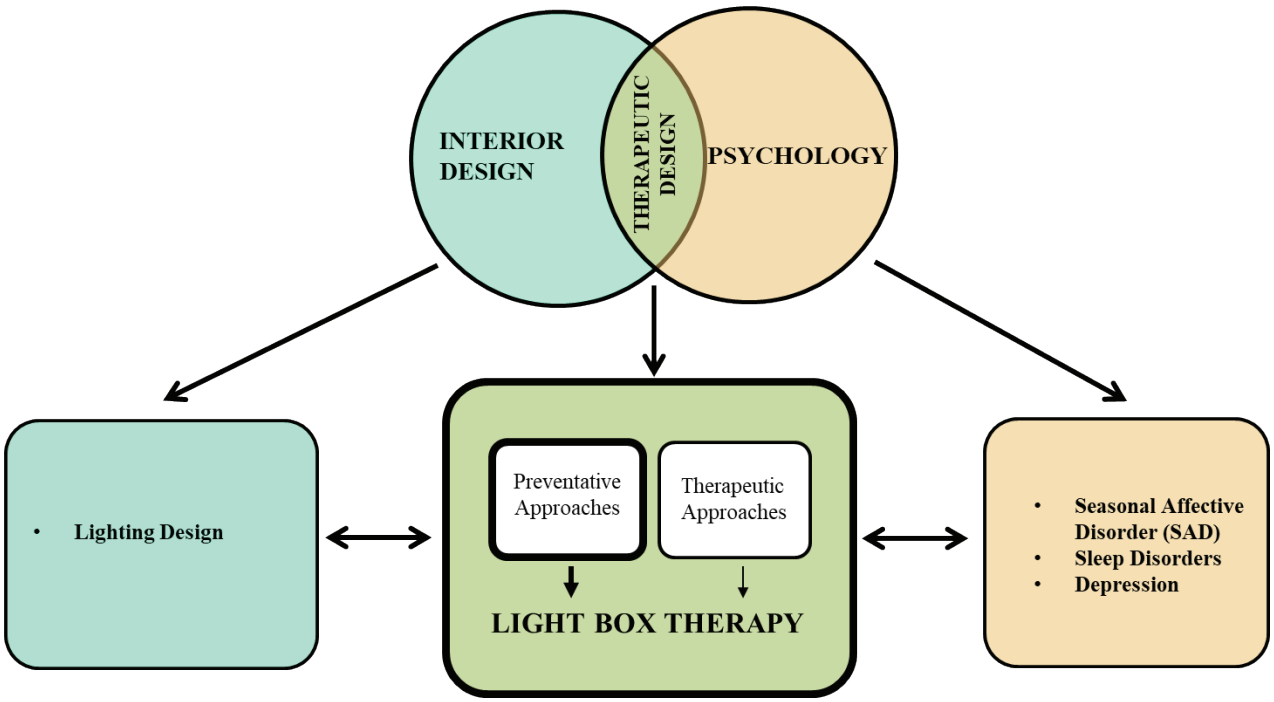


Figure 1: The relationship between interior design and user psychology within the therapeutic architecture axis

This study, which brings together the fields of interior architecture, medicine and industrial products to present a unique approach, aims to create foresight in terms of enhancing the quality of design by defining a new axis of thought for designers. It is expected that the proposal put forward will assist in the development of design strategies aimed at preventing psychological disorders. Although there are some academic studies in the literature on the relationship between circadian rhythms and space, no source has been found that specifically links light box therapy to interior lighting design. This indicates a need for further research examining the reciprocal effects between light box therapy and spatial design.

The need for this type of research can be explained from another perspective as follows: According to Dr Schwartz, antidepressant medications generally take several weeks to take effect and can cause unpleasant side effects (Schwartz, cited in Julie Corliss, 2022). Considering that drug treatments can have various side effects, preventive health approaches are becoming increasingly important for the health of individuals and communities. On the other hand, such measures also help reduce healthcare costs. In addition to light box therapy, there are other studies that attempt to address biological needs (Stacy, 2021). Like these applications, light boxes can be integrated into lighting design to support the regulation of circadian rhythms in users located in spaces where sufficient daylight is not available. Based on this, the study aims to determine the potential for combining light boxes and interior lighting design.

The study adopted a qualitative research method, and spatial contexts were determined in line with purposeful sampling strategies. Accordingly, indoor spaces and activity areas (resting, circulation, waiting, working, eating and drinking, sleeping, and social interaction areas) that could be meaningful to examine in terms of seasonal affective disorder (SAD) were included in the scope of the research. These areas were also selected using a critical situation sampling approach, based on situations where the psychological effect of light could be prominent. In terms of spatial components and elements, the study was based on maximum diversity sampling. Space components were categorised as walls,

flooring, columns, beams, roofs, and stairs; space elements were categorised as partition walls, windows, doors, and fixtures (Özdemir, 1994, p. 13). The integration of light boxes that could be included in lighting design in action areas was expressed through representative visuals. At this point, artificial intelligence-supported visualisation tools were used, and each design output was evaluated.

Developing a discourse on the integration of the light box product into interior components, the rationale and implementation method for using an AI-supported visualisation technique to create virtual space visuals would be beneficial in terms of articulating the study's methodology. In recent years, various studies on the integration of artificial intelligence technologies into the design process have revealed the potential of artificial intelligence in visual production. For example, in their study, Zhou and Wang (2024) created personalised interior visuals using the Stable Diffusion and Dreambooth models together. This method has offered faster and more customisable design possibilities, overcoming the limited flexibility of traditional techniques. On the other hand, Patil and colleagues (2024) introduced an artificial intelligence assistant that produces aesthetic designs for interiors based on data received from the user by developing a GAN (Generative Adversarial Networks)-based system. The significance of this study lies not only in its technical solutions but also in its ability to offer recommendations regarding visual appeal and design language. Furthermore, Yıldırım and Demirarslan (2021) focused on the use of Coohom, a cloud-based software, in the field of interior architecture, evaluating the contributions of such tools to the design process. Consequently, the reasons for preferring artificial intelligence in this field include its ability to generate diverse and repeatable visuals based on a large database, process these visuals quickly and flexibly, its low cost, its objective approach, and its high processing speed.

In this study, artificial intelligence support was utilised to demonstrate the use of the light box in conjunction with spatial components within the context of lighting design. In the first stage, a light box product was designed with artificial intelligence support, then functional usage areas were defined for each specified spatial component/element, resulting in a spatial composition. Subsequently, the form of the light boxes featured in these visuals was reviewed, and artificial intelligence was employed to make them more original in terms of preference.

The generated visuals were evaluated using qualitative content analysis methods. During this process, each action-space relationship was examined to identify spatial components that would best support the functionality of the light box. This is because actions play a decisive role in spatial arrangements. This is evident in both practical and academic studies (Demirarslan et al., 2023). The fundamental criterion in this study is ensuring suitable physical conditions for the light box to achieve its therapeutic effect. For example, selections were made by prioritising action areas where the user could spend more time, and attention was paid to designing the light box on spatial components that could meet the recommended usage distance, and the implementation potential of each design was evaluated. In this context, an answer was sought to the question, ‘How can light box therapy be integrated into interior lighting design?’ At this point, in order to obtain complementary information from experts on the characteristics of light boxes, manufacturers were contacted, including discussions with a representative from Lumie (Figure 2).

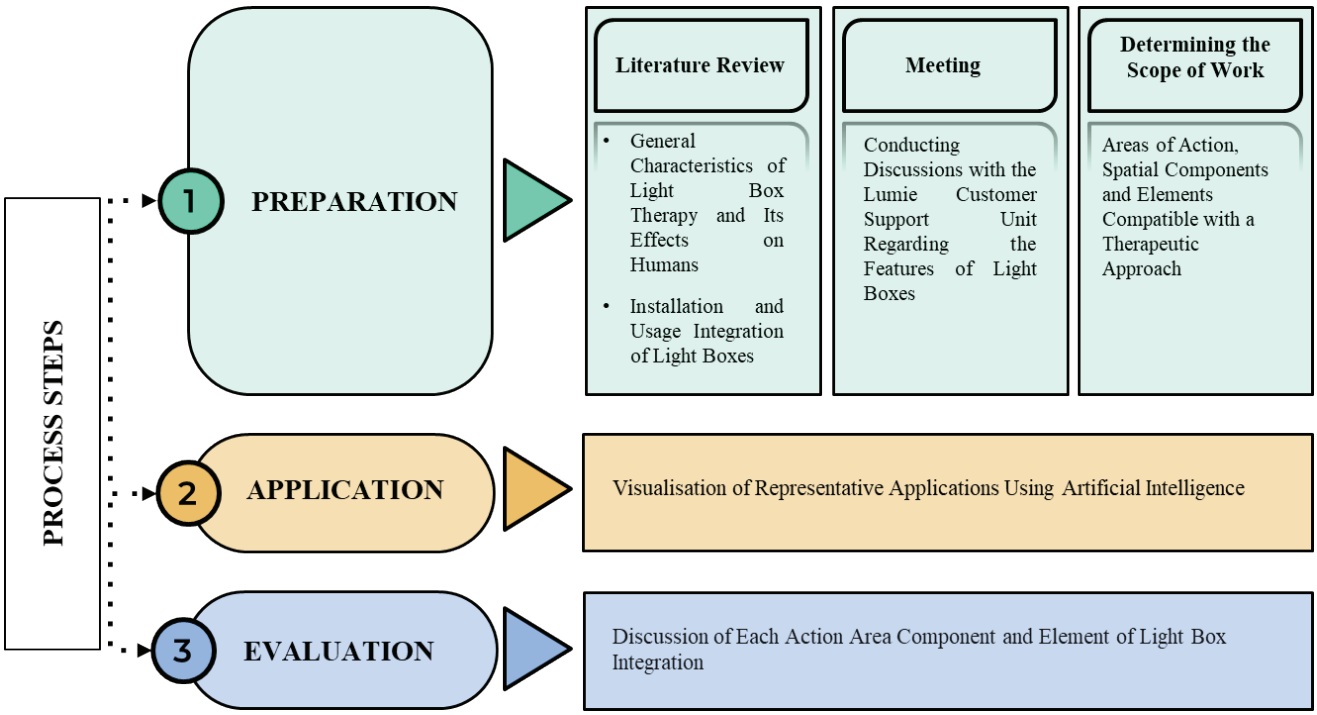


Figure 2: Research Design

2. THEORETICAL FRAMEWORK

2.1. General Characteristics of Light Box Therapy and Its Effects on Humans

People who do not get enough daylight experience disruption to their circadian rhythms, negatively affecting their sleep patterns and mood. Light therapy, in particular, has emerged as an effective method for treating seasonal affective disorder (SAD), sleep disorders and certain types of depression. This therapy aims to regulate individuals' biological clocks through artificial lights that mimic direct sunlight. The therapy's working principle is based on the principle that biological rhythms, especially circadian rhythms, are sensitive to natural light (Kukhta et al., 2023). This type of therapy has significant potential not only for treatment but also as a preventive health service. Studies have shown that individuals experiencing winter depression, such as SAD, and who undergo light therapy, especially at the onset of depression, experience a reduction in depressive symptoms and improved sleep quality (Terman et al., 1989; Meesters et al., 2001). Similarly, it has been shown that when applied in the morning, light boxes suppress melatonin production, making people feel more energetic, and increase serotonin production, enabling individuals to wake up and improving their mood (Kukhta et al., 2023; Campbell et al., 2017).

Light therapy also offers an effective treatment option for jet lag, shift work syndrome, and certain types of depression (Boyce, 2003). According to Wirz-Justice et al. (1996), when applied regularly, this therapy may be effective in preventing depression in the long term. Supporting this idea, Figueiro et al. (2001) noted that this method, when used in conjunction with traditional drug treatments in some cases of depression, can provide additional benefits to treatment.

2.2. Installation and Usage Integration of Light Boxes

At this point, it would be useful to discuss how light boxes work and what to consider for their proper use. Light boxes, produced in various models, are essentially an industrial product, an auxiliary tool that provides the aforementioned benefits when used in spaces (Table 1). Following discussions with

the Lumie Company Customer Support Unit representative, it was understood that there are certain points to consider to ensure that this device does not lose its effectiveness when integrated as an interior design element. Accordingly, when the distance between the device and the user increases, the surface area must also be increased to maintain the therapeutic effect. The therapeutic effect is primarily dependent on the amount of light reaching the user, and when the distance increases, it is important to extend the application time to achieve the same effect.

Table 1: Light Box Product Examples

			
Brand: Lumie, Model: Brazil (URL-1).	Brand: Verilux, Model: HappyLight® Touch Plus (URL-2).	Brand: HIBOITEC, Model: GLD-BaiJian-White01 (URL-3).	Brand: Verilux, Model: HappyLight® Alba (URL-4).
			
Brand: Carex, Model: TheraLite Aura (URL-5).	Brand: Verilux, Model: HappyLight® Halo (URL-6).	Brand: Carex, Model: Bright Health 360° Mood and Energy Enhancing Light (URL-7).	Brand: Carex, Model: Day-Light Classic Plus (URL-8).

Light boxes that artificially mimic natural daylight must meet specific technical and ergonomic criteria. These requirements include factors such as light intensity, spectral distribution, ultraviolet (UV) filtering capacity, and user ergonomics (Ask Mayo Expert, 2021). Light intensity is a crucial factor in light therapy boxes. Research suggests that for therapy to be effective, light boxes should generally provide light at a level of 10,000 lux (Galima et al., 2020). This intensity helps regulate the body's circadian rhythm and suppress melatonin secretion by mimicking the sunlight of the morning hours.

2.3. Areas of Action Compatible with the Therapeutic Approach

Indoor spaces with limited access to daylight are areas where natural light intake is restricted and artificial lighting systems are often required. For example, basements and ground floors are typically areas with limited window openings and no direct connection to the external environment. This

situation restricts natural light intake, making the use of artificial lighting necessary even during daytime hours (Campbell et al., 2017). Similarly, corridors and interior spaces located within buildings cannot benefit sufficiently from daylight because they are positioned far from the facade walls (Chrysikou, 2014). Inner courtyards also present limitations in terms of natural light intake. Structures that can only receive light from a single direction, in particular, restrict the light source, thereby increasing the importance of artificial lighting solutions in the lighting design of interior spaces. Rooms and clinical areas located inside hospitals, care homes and rehabilitation centres are at a disadvantage in terms of natural light intake and therefore require therapeutic lighting solutions (Dismont, 2024). Today, light boxes integrated into hospital rooms support treatment and contribute to the healing process of patients (Terman et al., 1989; Ulrich, 1991). Light therapy-focused designs that combine aesthetics and functionality in relaxation areas such as spas and wellness centres support both physical and mental healing (Van Bommel et al., 2004). Light therapy can be administered as individual or group therapy in areas with limited access to daylight; group therapy sessions conducted in common areas of hospitals provide a healing atmosphere for individuals (Campbell et al., 2017). Offices and workspaces without windows or distant from natural light sources also fall within the category of areas with insufficient daylight.

3. FINDINGS AND DISCUSSION

Within the scope of this study, the question of how the light box, which essentially appears as an industrial product, can be integrated into the lighting design of a space was explored, taking into account its operating principle, characteristics, requirements for use, and the function of the space where the product will be used.

At this point, the focus was on installation and usage sensitivities and the compatibility of the space components/elements with the device placement. This situation was then evaluated in terms of specific areas of action.

3.1. Installation and Usage Integration

In the integration of light box therapy into spaces with different functions within the lighting scheme, correct placement, timing, usage strategies, and health and safety requirements come to the fore.

- Positioning: Light boxes should be strategically placed in areas with limited natural light. To increase the effectiveness of the therapy, light boxes should be at the user's eye level (Terman et al., 1989). The light box should indirectly illuminate the eyes from a distance of 40-60 cm, as direct light can negatively affect the effectiveness of the therapy (Campbell et al., 2017). On the other hand, as the viewing distance increases, the surface area of the light box should also be increased proportionally.

- Timing: Light box therapy should be administered in the morning hours to best demonstrate its effect on biological rhythms. It is recommended that users be exposed to the light box for 20-30 minutes daily. This helps regulate the circadian rhythm and stabilises the sleep-wake cycle (Wirz-Justice et al., 1993). Regular use will increase the benefits of therapy and promote faster recovery (Meesters et al., 2001). Therefore, this device can be used more efficiently in areas of activity where these durations can be achieved within natural usage.

- User Control: Light intensity and colour temperature can be adjusted via touch control panels or mobile applications. This allows users to enjoy a personalised experience according to their light

therapy needs (Küller & Wetterberg, 1993). At the same time, users can control the effects of the light box to achieve greater comfort and flexibility in the space.

• Health and Safety: The light wavelengths used in light box therapy must comply with biological safety standards. This is important to ensure the therapy is safe and effective (ANSI/IES RP-27.1-15).

All these points regarding installation and use should be taken into account in the lighting design process for an indoor light box system.

3.2. Integration with Interior Components and Elements

Based on the finding that light box therapy can be used in spaces with limited access to daylight to balance biological rhythms, prevent depression, and improve overall psychological health, data has been collected on its use in relation to interior components and elements within the framework of its integration into space lighting design. At this point, only the components and elements suitable for the functionality of the light box were included in the design process using artificial intelligence and visualised.

Accordingly, when the space components are evaluated separately, it can be said that walls are one of the most suitable surfaces for providing the therapeutic effect of the light box, as they allow the user to interact directly at eye level. Similarly, ceilings are also suitable, particularly for providing general ambient lighting or indirect light diffusion. Floors, while having limited effect for direct light therapy, demonstrate complementary qualities for creating atmospheric lighting or indirect reflection. Seating groups, coffee tables, reading corners, etc., are seen to have practical and flexible surfaces where light boxes can be integrated due to their proximity to the user and portability. However, load-bearing elements such as columns and beams are not considered suitable for light box integration due to their limited surface area. When doors and windows are evaluated, it is concluded that their movable structures prevent the steady diffusion of light and pose a security risk. Finally, when considering the integration of light boxes into interior lighting design, it is understood that users find it difficult to benefit effectively from light therapy in corridors and vertical circulation elements such as staircases, as they are only present in these areas for short periods and are in motion.

In line with these assessments, the study visualises the structural components—walls, ceilings, flooring—and the structural elements—light box integration—as spatial elements for illustrative purposes.

3.3. Integration into Areas of Action

Indoor spaces and activity areas that could be meaningful to examine in terms of seasonal affective disorder (SAD) were addressed within the scope of the study. During this process, the duration of users' interaction with the space, their spatial behaviour patterns, and the functionality of the light box application were taken into consideration. The selection process also took into account the need for direct exposure to light for a specific period of time, which is one of the basic requirements for the treatment of seasonal affective disorder (Terman et al., 1998). At the same time, the distance of the light box from the user, its location, and its continuous use were also effective in the evaluation.

At this point, assessments were made regarding the areas for rest, waiting, circulation, work, eating and drinking, sleeping, and social interaction.

• Rest Areas: These are areas where users spend long periods of time in a stationary position, allowing for psychological relaxation. The effectiveness of bright light therapy depends on the user being able to remain in a fixed position and exposed to light for a certain period of time, making these areas suitable for SAD treatment (Terman et al., 1998). Furthermore, the light level used can reduce melatonin secretion. Indeed, even light levels as low as 100 lux can suppress melatonin under certain conditions (Lam et al., 1999). Therefore, the timing of use in relaxation areas should be reviewed.

• Waiting Areas: In these areas, where people spend passive time in public spaces such as hospitals and offices, users are usually seated. The light box treatment protocol recommends a specific usage distance (Ask Mayo Expert, 2021). As waiting areas are suitable for maintaining this usage distance, light box integration into these indoor spaces is possible.

• Circulation Areas: As circulation areas are spaces where users are in motion for indefinite periods of time, it is not possible to control the duration of the light box's effect. In addition, variations in distance can make the process uncontrollable. Cajochen et al. (2000) stated that even brief exposure to a brightly lit environment can increase alertness. Considering that circulation areas can be used at any time of the day, it should be noted that their use may be uncontrolled and inadequate. Therefore, circulation areas are not suitable for therapeutic use.

• Work Areas: Work areas are areas that require intense attention and focus. 10,000 lux lighting is used in SAD treatment (Ask Mayo Expert, 2021). This level of brightness can distract workers. This is supported by studies reporting that high light levels negatively affect the visual comfort of office workers (Veitch et al., 2000).

• Eating Areas: Lighting level and colour can directly affect eating behaviour. Research shows that colour temperature and light level have significant effects on appetite, taste perception, and eating time (Wansink et al., 2012). Therefore, the light used in SAD treatment has the potential to cause discomfort in these areas.

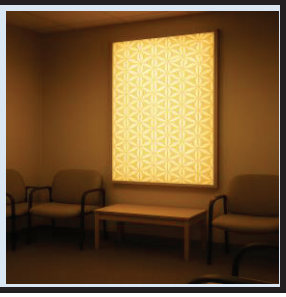
• Sleeping Areas (Bedroom, etc.): Light therapy for SAD treatment should be applied in the morning. Exposure to bright light in the evening or at night suppresses melatonin secretion and negatively affects sleep patterns (Cajochen et al., 2000; Terman et al., 1998, Lam et al., 1999).

• Social Interaction Areas: It is difficult to control individual light exposure in social interaction areas due to the large number of people present. SAD treatment requires individualised dosage, duration, and distance (Lam et al., 1999). Therefore, social areas are not suitable for therapeutic light application. Furthermore, different users' varying light sensitivities may cause discomfort in shared areas.

In summary, when action areas are evaluated separately, it is understood that light box therapy can be integrated into rest and waiting areas as a preventive approach for seasonal affective disorder; however, its use is not appropriate in work, eating, sleeping, circulation, and social interaction areas.

In this regard, visualisations have been created showing how the light box product can be integrated into the spatial components and elements determined by artificial intelligence for rest and waiting areas (Table 2). At this point, the light box has evolved from being purely an industrial product into a design object. One of the most distinctive features that makes the light box a design object is its light visual patterns, which add character to the surface without diminishing the effect of the light.

Table 2: Images Generated by Artificial Intelligence

	WALL	CEILING	FLOORING	FIXTURES
REST AREAS				
WAITING AREAS				

The integration of light boxes into walls, ceilings, and fixtures for rest areas has been found to be more effective in terms of light box efficiency. However, in flooring applicatiobetween the eye and the product, which is necessary for the light box to deliver effective results, is insufficient. Ceiling applications can be effective when sufficient height is available. This height can be achieved by using the light box as a panel and bringing it to the required distance as needed within a smart system. Wall and fixture integrations can be said to be advantageous in terms of both applicability and design versatility.

In waiting areas, wall integration can be used in the same way as in rest areas. However, the variable number of users is an important consideration here. In a single wall integration, it is anticipated that each user may not be able to benefit sufficiently from the light box. For this reason, designs that create a fragmented appearance on the wall can be successful in this action area if they are implemented in a way that focuses on each user. In fixtures and ceiling applications, it may be possible to reach each user in a more controlled manner. Although flooring has the potential to benefit each user equally, it may be insufficient in terms of providing the ideal distance conditions.

4. CONCLUSION

Within the framework of the therapeutic architectural approach, various assessments were made regarding the integration of light boxes into interior lighting design as a supportive measure to reduce the risk of seasonal affective disorder (SAD). It was concluded that certain spatial components and elements were more advantageous than others in terms of efficiency for the two separate areas of action identified for the integration of light box products. Positive results were obtained for walls, ceilings, and fixtures in rest and waiting areas. However, it was understood that special adaptations for multiple use were required for walls in waiting areas. For example, minute-based personalised durations may be required when there are multiple users. For both areas of action, the spatial component ‘flooring’ has weaknesses in terms of integration compared to others.

In conclusion, the use of smart technologies across all areas of application can make the use of light boxes more efficient. This ensures that the product is integrated into everyday life. Furthermore, the areas of application for light boxes can be diversified in line with interior design. In this regard, more studies are needed to test the product's interior design applications. Studies in this area require contributions from engineering fields that can meet the technical requirements. For example, in light box applications integrated into movable furniture, how energy will be supplied or what characteristics the sensors should have are also problems that need to be researched in the field of engineering. In summary, as it lies at the intersection of interior architecture and industrial product design, the possibility of achieving such integration through interdisciplinary project planning should be discussed.

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Chapter 4

GLOBAL NORMS, LOCAL REALITIES: REASSESSING THE CHILD-FRIENDLY CITIES PARADIGM THROUGH SAFE ROUTES TO SCHOOL

Gözde EKŞİOĞLU ÇETİNTAHRA [1]

1 Assoc. Prof. Dr. Gözde EKŞİOĞLU ÇETİNTAHRA, Dokuz Eylul University, Faculty of Architecture, gozde.eksioglu@deu.edu.tr, ORCID: 0000-0001-9746-495X

1. INTRODUCTION

In recent years, the transformation observed within childhood studies has revealed that children's experiences in cities signify far more than individual developmental processes; rather, these experiences are shaped by social, spatial, and political dynamics. A growing body of research demonstrates that contemporary cities are increasingly becoming environments that generate constraints for children, are characterized by heightened perceptions of risk, and where mobility predominantly occurs under adult supervision (Shaw et al., 2015; Shaw et al., 2013; Ekşioğlu Çetintahra & Gökmen, 2025). Rising levels of urbanization, increased motor vehicle ownership, changes in the accessibility of public spaces, and the growing dominance of security discourses in everyday life collectively redefine children's relationships with the urban environment at both physical and cultural levels (Pain, 2006). These processes contribute to the narrowing of the spatial boundaries of childhood, a decline in children's visibility within public space, and a substantial restriction of their independent mobility.

One of the domains in which this transformation becomes most apparent is children's everyday journeys between home and school. The concept of the **safe route to school** does not merely denote a technical field of intervention aimed at ensuring children's physical safety; rather, it represents a multidimensional developmental framework that prioritizes children's independent mobility, processes of autonomy development, and participation in public life (Hillman, 1990). The child development literature has long demonstrated that mobility constitutes one of the fundamental determinants of children's cognitive, social, and emotional development. Piaget's theory of cognitive development emphasizes that children learn about their environment through active exploration, and that skills such as spatial understanding, problem-solving, and decision-making are shaped through this exploratory process (Piaget, 1952). Bronfenbrenner's Ecological Systems Theory highlights the decisive influence of children's immediate environments (such as the school route, neighborhood, or street) on developmental processes (Bronfenbrenner, 1977). Similarly, the cultural-historical approach articulated by Cole and colleagues (1978) underscores the critical role of everyday practices carried out by children without direct adult guidance in fostering self-regulation and social learning (Cole et al., 1978). In this respect, walking along the school route is not merely a mode of transportation; it constitutes a fundamental developmental context through which children build environmental competence, establish social relationships, and gain autonomy.

These developmental perspectives also align with approaches that emphasize learning through interaction with the environment. Gibson's "concept of affordances" demonstrates that children's abilities to read environmental cues, navigate, and make sense of space are shaped not only by physical design but also by the psychological and perceptual opportunities offered by the environment (Gibson, 2014). Ginsburg et al. (2007) and Spencer and Blades (2006) show that children's free movement in outdoor environments is directly associated with play, creativity, risk assessment, and the development of self-confidence. This indicates that safe route to school experiences provide children not only with safe mobility but also with a holistic learning environment that supports the development of autonomy and the acquisition of environmental competence. Therefore, in line with the concept of "developmentally appropriate risk," walking along the school route should be considered one of the most fundamental indicators of children's relationships with the urban environment.

This theoretical framework clearly demonstrates why policies that support children's independent mobility in cities cannot be limited solely to infrastructural arrangements. The fact that children's abilities to become familiar with their surroundings, navigate, and manage risk are closely tied to everyday mobility experiences has heightened the importance of the child-friendly city approach. Led by UNICEF, the child-friendly city approach offers a normative framework that places children's rights (such as safety, participation, play, accessibility, and inclusivity) at the center of the urban policy agenda (UNICEF, 2018; Riggio, 2002; Çamaş & Çetintahra, 2025). According to UNICEF's guidelines, a child-friendly city is an urban structure in which all children can fully realize their rights, access safe and accessible public spaces, and participate in decision-making processes (UNICEF Türkiye, n.d.). However, the literature also includes critiques suggesting that this approach is largely grounded in Western planning cultures and does not always fully account for contextual differences (Nieuwenhuys, 1996). Therefore, while child-friendly city principles present a universal objective, they do not constitute a model that can be applied uniformly across cities with diverse socio-spatial dynamics.

At this point, the tension between **global norms and local realities** becomes particularly evident. Safe route to school policies constitute a field in which global norms are most concretely articulated yet are simultaneously reshaped by multidimensional local factors such as socio-spatial inequalities, cultural norms of childhood, societal perceptions of safety, traffic practices, parental behaviors, and governance capacities (Ansell, 2009; Cordero-Vinueza et al., 2023). Indeed, the international literature demonstrates that children's independent mobility is significantly constrained by high traffic volumes, inadequate pedestrian infrastructure, fear of crime, and parents' protective attitudes shaped within the "risk society" (Hillman, 1990; Karsten, 2005). In low-income neighborhoods, infrastructural inequalities, traffic safety problems, and perceptions of social insecurity further restrict independent mobility; by contrast, in higher-income and pedestrian-priority areas, such mobility tends to occur at much higher levels (Shaw et al., 2013). Studies conducted in the Turkish context similarly reveal that parental overprotectiveness, societal perceptions of safety, traffic intensity, and irregular urbanization substantially limit children's independent mobility (Tandoğan, 2018; Seyhan & Acar, 2024). For these reasons, safe route to school approaches should be understood as a dynamic policy domain that encompasses both the universal principles articulated by international models and the complex realities of local contexts, including urban morphology, social inequality, cultural practices, and governance capacity.

This study aims to address this tension from a theoretical perspective by offering a comprehensive conceptual foundation that brings together the literatures on children's geographies, independent mobility, developmental autonomy, urban governance, cultures of safety, and policy transfer. In the following sections, the chapter first examines how the child-friendly city approach has been institutionalized at the global scale; it then reviews theoretical approaches to children's independent mobility; subsequently, it discusses the position of safe route to school models within the international literature and the processes through which these models are transferred across contexts. Within the scope of this discussion, practices from Switzerland are taken as an analytical reference point, as they provide a context in which child-friendly city and safe route to school policies have long been institutionalized, embedded within local government practice, and systematically documented. Finally, by examining how this normative framework is reshaped in contexts characterized by high socio-spatial diversity, such as Turkey, the chapter presents a multidimensional theoretical discussion on children's presence in the city.

2. LITERATURE REVIEW

2.1. The Child-Friendly City Approach and the Formation of a Global Norm

The child-friendly city approach constitutes an international policy framework that aims to ensure children's equal, safe, and inclusive participation in urban life from a rights-based perspective. The institutional foundations of this approach were laid with the 1989 United Nations Convention on the Rights of the Child (UNCRC); with the recognition of children not only as vulnerable individuals in need of protection but also as subjects whose views should be considered, the position of children within urban life began to be reconsidered (United Nations, 1989). UNICEF's launch of the Child Friendly Cities Initiative (CFCI) in 1996 further advanced the implementation of the UNCRC at the local government level, thereby framing children's everyday spatial experiences as a matter of governance (UNICEF, 2018). This initiative translated multidimensional principles—such as access to safe environments, the right to participation, social inclusion, spatial justice, the right to play, mobility, and access to basic services—into standards for local governance (Riggio, 2002; Derr & Tarantini, 2016).

The CFCI is not merely a technical planning guideline but also **a normative policy paradigm** that produces a particular set of universal values related to childhood. As noted by James and Prout (2003), childhood is a socially constructed category in modern societies, and what is "in the best interest of the child" is largely shaped by cultural norms. From this perspective, the CFCI constitutes a powerful yet contested mechanism of norm production, precisely because it seeks to establish **universal standards for childhood**. The literature emphasizes that these standards are closely associated with Europe's pedestrian-oriented planning culture, strong welfare state structures, public space practices characterized by low perceptions of insecurity, and rights-based governance models (Malone, 2017; Khakzad Shahadashti, 2022). Consequently, the CFCI should be understood not only as a set of goals concerning children, but also as a global discourse that defines a particular spatial order, social policy framework, and conception of childhood as a "universal norm" (Ansell, 2009).

The globalization of this framework has also given rise to various critiques across different contexts. Nieuwenhuys (1996) and Bartlett (2002) argue that child-friendly city models are largely Western-centric, treat childhood as a homogeneous category, and insufficiently account for cultural differences. For example, standards developed on the basis of European cities—where children's independent mobility is more common, pedestrian priority is emphasized, and perceptions of risk are relatively low—do not generate the same effects in contexts characterized by rapid urbanization, high traffic intensity, heightened perceptions of social insecurity, and dominant norms of parent-controlled childhood (Karsten, 2005; Aitken, 2005). Therefore, the global adoption of the CFCI also necessitates an examination of how cities operating under diverse cultural, economic, and spatial conditions reinterpret and reconfigure these norms.

The emergence of the CFCI as a global norm can be explained through the intersection of international, political, economic, and disciplinary dynamics operating at multiple levels. First, the rise of rights-based governance paradigms since the 1990s has strengthened the responsibility of local governments to implement children's rights, thereby bringing children's urban needs onto the policy agenda (Cornwall & Nyamu-Musembi, 2004; Riggio, 2002). The recognition of children as rights-bearing subjects has encouraged the adaptation of the Convention on the Rights of the Child to local scales and has contributed to cities becoming spaces in which rights are "spatialized" through efforts

to improve children's quality of life (UNICEF, 2018). In parallel, the institutionalization of policy transfer by UNICEF and similar international organizations—through guidelines, certification processes, capacity-building meetings, and transnational network structures—has played a decisive role in the diffusion of the child-friendly city approach across different countries (Stone, 2012; Dolowitz & Marsh, 2000). These networks generate not only knowledge exchange but also "normative pressure" through comparison, measurability, and performance indicators among local governments (Hajer, 2003; Clarke & Bainton, 2015).

During the same period, the increasing prominence of discourses such as "livability," "quality," "green city," and "sustainability" within a neoliberal urban competitive environment has elevated the strategic importance of child-friendly cities in terms of brand value, city image, and visibility within global rankings (Kearns & Forrest, 2000; McCann, 2011). This has led the CFCI to function not only as a social policy framework but also as a component of urban competition and economic marketability, positioning child-friendly cities as part of an urban "showcase." Many cities have adopted child-friendly practices to improve their standing in quality-of-life indices, attract tourism and investment, gain access to international funding, and enhance prestige (Khakzad Shahadashti, 2022).

At the same time, the renewed emphasis within the planning discipline on principles such as public interest, accessibility, spatial justice, safety, and equality has supported the standardization of criteria, including pedestrian priority, low-speed mobility, public space quality, speed management, and environmental safety (Appleyard, 1980; Gehl, 2013). The growing adoption of public transport, sustainable mobility, and "15-minute neighborhood" approaches in cities has brought children's everyday mobility back onto the agenda of planners (Moreno et al., 2021).

The combination of all these dynamics demonstrates that the CFCI is not merely an ideal, but has increasingly become a powerful global norm that is institutionalized, supported by measurable indicators, and disseminated through transnational networks. This norm is conveyed through symbolic, technical, and governance-related contents, and sustains its presence by producing adaptability, comparability, and performance assessment across different contexts. Therefore, the global diffusion of the CFCI necessitates a discussion of how diverse understandings of childhood, societal values, urban morphologies, and governance capacities in different countries and cities relate to this norm. In order to understand how these globally produced norms intersect with lived experiences of childhood, it is necessary to examine the theoretical foundations of independent mobility—one of the most fundamental practices through which children engage with the city.

2.2. Independent Mobility of Children

Globally produced child-friendly city norms conceptualize children's participation in urban life not merely as a right or a policy objective, but as a process that unfolds through everyday spatial practices. Accordingly, the measurable indicators of a child-friendly city do not lie in abstract principles, but rather in the extent to which **children are visible within the city**, are able to follow their own routes, and can interact with their surroundings. Independent mobility is conceptualized precisely at this juncture as one of the primary domains through which global norms materialize within local space: children's capacity to move around the city without adult supervision serves as a scale at which child-friendly city ideals become tangible in everyday life.

Independent mobility is a core concept within the literature on children's geographies and refers to children's capacity to move freely within their everyday environments, to play, and to independently use routine routes such as home–school journeys without adult supervision (Hillman, 1990). This perspective emphasizes that children are not merely individuals in need of protection, but actors who actively experience, interpret, and interact reciprocally with their environments and spatial arrangements (Shaw et al., 2013; Aitken, 2005). For this reason, independent mobility is widely regarded as a critical indicator of children's visibility in public space, their access to spatial rights, and their participation in urban life.

Independent mobility holds multidimensional significance for child development, as it enables children to interact individually with their environments and directly supports developmental outcomes such as wayfinding, executive functioning, self-regulation, resilience, risk assessment, problem-solving, and social independence (Kitchin & Blades, 2002; Shaw et al., 2015). The developmental psychology literature demonstrates that children's engagement with their environments through controlled risks—such as crossing streets independently, determining their own routes, and generating solutions to unexpected situations—is essential for the development of self-efficacy and autonomy (Little, Wyver & Gibson, 2011). These findings are consistent with Locke's (1997) theory of self-efficacy, which conceptualizes children's ability to independently accomplish tasks and experience success as a determining factor in the development of autonomy. Accordingly, the home–school journey can be understood not merely as a transportation practice, but as a critical developmental process through which children acquire autonomy, environmental awareness, and regulatory skills.

Independent mobility is also strongly shaped by spatial, social, and cultural factors. The literature demonstrates that these practices are not solely a function of children's physical capacities; rather, they are produced through parental perceptions of risk, concerns related to crime and safety (Pain, 2006), traffic intensity and road infrastructure (Tranter & Pawson, 2001), neighborhood typologies (Villanueva et al., 2014), gender norms (Karsten, 2003), socio-economic conditions (Schoeppe et al., 2015), and culturally embedded understandings of childhood (Shaw et al., 2015). Thus, independent mobility should be understood not as an individual skill, but as a context-sensitive socio-spatial process.

International comparisons reveal that levels of independent mobility vary significantly across countries. A study conducted between 1971 and 1990 demonstrates a dramatic decline in independent mobility in England, while showing that higher levels have been maintained in countries such as Germany, where pedestrian-oriented transport cultures prevail (Shaw et al., 2013). Similarly, Karsten (2005) and Timperio et al. (2025) demonstrate that urban morphology, neighborhood safety, accessibility, and parenting norms exert a decisive influence on independent mobility. Independent mobility thus functions as a tangible indicator of the relationship between urban infrastructure and social norms.

In this regard, independent mobility (one of the core analytical components of the child-friendly city approach) directly reflects the quality of infrastructure, societal perceptions of safety, and cultural norms of childhood. Children's ability to walk independently between home and school, use public spaces, and manage environmental risks constitutes concrete, everyday outcomes of international principles. Independent mobility, therefore, represents the practical arena in which global norms

encounter local realities, are negotiated, and are at times reshaped. At this point, safe routes to school approaches and children's behaviors provide observable forms of evidence for professionals and researchers alike.

The safe route to school approach refers to strategies aimed at reducing the risks children encounter along their everyday home–school routes and has been widely adopted at the international level. Safe Routes to School (SRTS) programs developed in the United States and Europe offer comprehensive models that incorporate components such as speed management, pedestrian and bicycle safety, infrastructural improvements, educational campaigns, and inter-institutional collaboration (McDonald et al., 2013). The Vision Zero approach, in turn, establishes a stringent safety framework that seeks the complete elimination of traffic-related fatalities and serious injuries. When combined with UNICEF's child rights–based perspective, these models frame the safe route to school not merely as a transport policy, but as a governance principle that supports children's spatial rights. However, how these models are implemented across different countries and cities is of particular significance within the policy transfer literature. Policies are not "directly imported" from one context to another; rather, they are "translated" through social norms, cultural values, institutional capacities, and spatial conditions (Dolowitz & Marsh, 2000; Peck & Theodore, 2010). Consequently, the safe route to school approach should be understood not as a universally applicable model independent of context, but as a normative framework that must always be adapted to local needs. This theoretical discussion provides the foundation for understanding the contextual variations that will be addressed in the following section.

3. Contextual Analysis

How children's mobility within the city is shaped is determined by the interaction of multilayered factors, including the quality of spatial structures, transport policies, societal perceptions of safety, parenting norms, and institutional capacities. As such, safe route to school practices should be approached not merely as a technical planning issue, but as a context-sensitive social and spatial process. Differences between school route practices in developed countries and the conditions observed in developing countries are critical for understanding why and how the child-friendly city approach needs to be localized.

3.1. Differentiation of Children's Mobility in Developed and Developing Countries

In developed countries, the primary factor supporting children's independent mobility is a long-established culture of pedestrian-oriented transport. In many European cities, particularly in Switzerland, the Netherlands, Germany, and Denmark, children's everyday journeys involve relatively low levels of risk due to continuous sidewalks, speed management measures, bicycle infrastructure, public space safety, and strong welfare state systems (Johansson et al., 2010; Gehl, 2013). An examination of practices presented by UNICEF as good practice examples shows that, in countries such as Switzerland, school route safety is supported through systematic risk analyses, 30 km/h zones, curb extensions, raised crossings, school frontage regulations, and institutionalized governance mechanisms.

From this perspective, children's independent mobility should be understood not only as a spatial outcome, but also as being closely associated with high levels of social trust, a child-oriented planning tradition, "supportive" rather than protective parenting norms, and a culture of institutional

collaboration (Shaw et al., 2015). In Europe, children's use of school routes on their own has been both culturally normalized and physically enabled.

By contrast, in developing countries, rapid urbanization, increased motor vehicle use, deficiencies in pedestrian infrastructure, and irregular settlement patterns exert a direct constraining effect on children's mobility (Blazek, 2015; Mitra, 2013). Traffic risks, perceptions of insecurity, and the lack of inclusive public spaces reduce levels of independent mobility. While parents often perceive children being alone in public spaces as risky, children themselves are increasingly distanced from independently experiencing the urban environment (Wall & Olofsson, 2008). For this reason, the distinction between developed and developing countries is grounded not only in economic differences but also in profound divergences in urban culture, social norms, and governance structures.

3.2. The Turkish Context

In contexts such as Turkey—characterized by rapid urbanization, high traffic volumes, and the dominance of car-oriented transport policies—the relationship between spatial arrangements and urban form directly shapes children's mobility and their experiences of public space (Kubat, 2010). Weak pedestrian priority, traffic congestion, discontinuous sidewalks, and irregular vehicle movements around school environments constitute the primary spatial barriers confronting safe route to school practices (Ozbil et al., 2021).

Traffic accident data in Turkey point to a significant level of risk for children. Statistics from the Turkish Statistical Institute (TÜİK) indicate that children constitute one of the most vulnerable groups in pedestrian-related traffic accidents. Irregular settlement patterns, vehicle dominance, and the lack of effective speed management substantially constrain the physical conditions necessary for children's independent mobility (Kaygısız, Şenbil & Yıldız, 2017).

One of the most influential cultural factors limiting children's ability to go outside independently is perceived crime risk. The visibility of violence against children in the media generates high levels of security-related anxiety among parents, which in turn restricts children's independent presence in public space. The literature demonstrates that the gap between perceived risk and actual risk is particularly pronounced in developing countries and plays a powerful role in shaping parenting behaviors (Pain, 2006).

Parenting culture in Turkey is shaped by norms emphasizing the need for constant supervision of children in public space. This approach, conceptualized within the "intensive parenting" literature, promotes risk avoidance and reinforces behaviors that limit children's autonomy (Garvin, 1997; Karsten, 2005). Studies conducted in Turkey reveal that parents' reluctance to allow their children to travel to school alone often stems not primarily from traffic or crime risks, but from socially embedded norms of control (Üzümcü, 2017; Uğur, 2018).

Multi-stakeholder school route committees, systematic risk maps, and design standards—commonly observed in Swiss reports—have not yet been institutionalized in Turkey. Although local governments may implement certain physical interventions around school environments, these measures are often fragmented, intervention-oriented, and characterized by low sustainability (Mitra et al., 2014). Collaboration among schools, law enforcement agencies, and municipalities is generally

project-based; however, safe route to school approaches require a comprehensive and continuous governance structure.

3.3. Components of Safe Route to School Approaches

Safe route to school practices constitute a holistic policy domain aimed at minimizing the risks children encounter along their everyday routes, integrating spatial, social, and governance dimensions. This approach should not be confined solely to physical interventions, but rather addressed in conjunction with social norms, institutional collaboration, and participatory processes that support children's independent mobility (Marzi & Reimers, 2018). UNICEF's good practice examples demonstrate that **safe route to school planning is not merely a technical engineering task**; instead, it requires an urban governance approach that places children's visibility in public space, autonomy, and freedom of movement at its core.

Spatial components represent the most visible and most widely implemented dimension of the safe route to school approach. The literature identifies low-speed zones, raised pedestrian crossings, curb extensions, sidewalk continuity, and the restriction of vehicle drop-off points as fundamental elements of safe pedestrian circulation (Johansson et al., 2010; Dumbaugh & Rae, 2009). In the cases of Basel-Stadt, Zurich, Bern, Allschwil, and Kloten, it is notable that all school surroundings have been designated as 30 km/h zones, supported by physical traffic-calming measures such as raised platforms and lane narrowings, enhanced visibility of pedestrian crossings, and the widespread implementation of "drop-off free zones" at school entrances. Such interventions create pedestrian-priority environments that support children's spatial mobility. These findings indicate that safe route to school planning aims not only to improve pedestrian infrastructure, but also to enhance children's priority in public space by limiting car use.

However, physical design alone is not sufficient. Social components are critical to the sustainability and cultural acceptance of safe route to school practices. The mapping of children's routes, school–family collaboration, student and parent education programs, and collective walking initiatives such as "walking bus" or "pedibus" are identified in the literature as key social strategies that strengthen both perceptions of safety and practices of independent mobility (Napier et al., 2011; Carver et al., 2014). In good practice examples (UNICEF Switzerland, n.d.), these social components are implemented in a systematic manner: walking school routes together with children and documenting them, aligning routes with risk analyses, organizing parent information meetings, and delivering traffic education for children through police–school collaboration have become institutionalized routines. These examples demonstrate that the safe route to school approach must strengthen children's everyday practices not only physically, but also socially.

Governance components constitute one of the fundamental factors determining the success of safe route to school practices. Multi-stakeholder decision-making processes, regular information flows between different institutions, and systematic risk assessment mechanisms are identified in the literature as essential elements for the effectiveness of school route policies (Bickerstaff & Walker, 2001; Pucher & Buehler, 2008). In good practice examples, school route committees composed of municipalities, school administrations, police units, and technical experts emerge as a common governance model. These committees meet regularly, evaluate routes, conduct risk scoring, and plan the necessary spatial interventions. Moreover, in cities such as Bern and Zurich, design standards and

implementation guidelines have been developed, enabling municipalities to maintain a consistent level of quality across all school zones. These governance arrangements demonstrate that safe route to school planning has moved beyond project-based, temporary interventions to become a sustainable institutional process.

This also demonstrates that safe route to school policy can be directly linked to children's spatial rights. The child-friendly city approach defines not only children's access to public space, but also their capacity to use these spaces independently as a domain of rights (UNICEF, 2018; Cordero-Vinueza et al., 2023). As such, safe route to school strategies require the integrated consideration of structural, social, and governance conditions that support children's participation in urban life. The holistic approach observed in Swiss cases enables children to be recognized as legitimate users of urban space and allows for their direct or indirect participation in decision-making processes. When child-centered design principles are combined with evidence on the developmental significance of independent mobility, safe route to school emerges not merely as a transport issue, but as a critical policy instrument for supporting children's presence in the city (Hillman, 1990; Shaw et al., 2015).

In conclusion, for safe route to school practices to be effective, spatial interventions must be addressed in conjunction with social and governance components. The holistic approach observed in Swiss CFCI reports (UNICEF Switzerland, n.d.) is consistent with the principles emphasized in the international literature and offers important lessons on how child-centered urban design can evolve into a sustainable governance model. As will be discussed in the following section in relation to the Turkish context, this holistic framework does not constitute a directly transferable "model," but rather a set of principles that must be adapted in a context-sensitive manner.

4. Context-Sensitive Conceptual Synthesis

Within the scope of this study, official reports on safe route to school practices implemented across different cantons and settlements in Switzerland were examined in order to conceptually discuss the safe route to school approach (UNICEF Switzerland, n.d.). These documents present a wide range of diversity in terms of population size, socio-spatial structure, transport infrastructure, and governance capacity. The sample—spanning large and dense urban centers (Bern, Basel-Stadt, Zurich), suburban-type settlements (Allschwil, Kriens, Kloten), and small-scale rural localities (Wauwil, Egg, Dulliken)—demonstrates that safe route to school practices cannot be reduced to a single spatial typology or a standardized model.

Across all reports, the safe route to school is addressed not merely as a set of physical infrastructure interventions, but as a holistic policy domain that integrates multi-actor governance and processes of social participation. Committees composed of municipalities, police units, school administrations, neighborhood representatives, and parents work in a coordinated manner throughout the stages of risk analysis, design, implementation, and evaluation. These processes enable different types of interventions—such as speed management, curb extensions, pedestrian priority measures, parking control, signage, enforcement, and communication campaigns—to be implemented in a complementary and mutually reinforcing manner.

A recurring element across the documents is the emphasis on continuous monitoring and data production. Through risk maps, speed measurements, pedestrian counts, traffic observations, and

annual evaluation reports, practices are systematically monitored, and interventions are refined based on the findings. Many reports indicate that children and parents are actively involved in these processes: children map their walking routes and identify risk points; schools organize community walks and information activities; and communication campaigns strengthen social acceptance.

The diversity of these practice examples demonstrates that the safe route to school approach is not the product of a single country's planning culture, but rather is realized through the reinterpretation of shared principles across different contexts. The reports underline that safe route to school is not a model, but a principle-based approach, and that success is determined not by design templates, but by context-sensitive, multi-actor, and learning-oriented systems.

A holistic evaluation of the implementation reports indicates that the safe route to school approach is shaped around four fundamental principles. First, **spatial sensitivity** requires that the morphological and functional characteristics of each school environment be analyzed individually. Elements such as speed management, pedestrian continuity, sidewalk widths, intersection geometry, parking pressure, and congestion around school entrances necessitate micro-scale interventions aligned with local spatial conditions. Accordingly, physical interventions are developed not based on abstract standards, but through risk analyses and design solutions tailored to each specific school environment.

Second, **institutional coordination** constitutes the decisive factor for success. Across all examined reports, formal committees are established that include representatives from municipalities, law enforcement agencies, school administrations, and community actors. This structure enables decision-making to be carried out in a continuous manner, ensures the monitoring of implementations, and institutionalizes communication among different stakeholders. Through these committees, the safe route to school is transformed from a project-based intervention into an institutionalized field of governance.

Third, **monitoring and evaluation** represent a core component that enhances the quality of implementation. Risk maps, speed measurements, pedestrian counts, traffic observations, and annual reports make the impacts of interventions visible. This process of data production generates a learning cycle that enables the continuous improvement of practices.

Fourth, **community participation** and social acceptance constitute the social and cultural dimension of the safe route to school approach. Children's involvement in mapping their walking routes, the inclusion of parents in decision-making processes, school-based activities, and communication campaigns strengthen the social resilience of these policies. This perspective demonstrates that independent mobility is not merely a physical capacity, but also a domain of social consensus. These principles are implemented at different scales and through diverse methods across the examined reports. While speed management, intersection design, and school frontage regulations are more prominent in large cities, community surveillance, group walking initiatives, and route continuity emerge as key instruments in smaller settlements. Accordingly, the safe route to school approach is grounded not in a fixed spatial model, but in a context-sensitive set of principles. For this reason, safe route to school practices cannot be understood as context-independent "transferable models"; rather, they require a framework in which international principles are blended with local conditions in a context-sensitive manner (Dolowitz & Marsh, 2000; Peck & Theodore, 2010).

The Swiss cases examined demonstrate that the fundamental principles determining the success of safe route to school practices are implemented through adaptation to local contexts. When these principles are compared with the Turkish context, both significant similarities and divergences emerge. Owing to rapid urbanization, high traffic volumes, car-oriented planning practices, and socio-cultural norms, Turkey exhibits distinctive dynamics with respect to safe route to school applications. Thus, it can be argued that safe route to school policies in Turkey cannot be realized through direct model transfer, but rather through the context-sensitive translation of underlying principles (Kaygısız, Şenbil & Yıldız, 2017).

Turkey's spatial reality is characterized by structural challenges that are decisive for the implementation of safe route to school policies. Discontinuities in pedestrian infrastructure, the lack of effective speed management, sidewalk narrowings, and irregular traffic conditions around school environments constrain the physical conditions necessary for children's independent mobility (Ozbil et al., 2021; Kaygısız, Şenbil & Yıldız, 2017). The spatial distribution of traffic accidents indicates a concentration of high-risk areas for children, particularly in metropolitan cities (Erdoğan et al., 2008). This underscores that the speed reduction strategies observed in the examined Swiss reports (e.g., 30 km/h zones, curb extensions, pedestrian-priority streets) and the creation of continuous pedestrian corridors constitute priority areas of need in the Turkish context. However, it is evident that infrastructural interventions alone are insufficient and must be supported by institutional coordination and social acceptance.

In addition to spatial factors, cultural dynamics play a critical role in the Turkish context. Parenting culture is shaped by norms emphasizing the need for constant supervision of children in public space. These norms are reinforced by the high visibility of crimes against children in the media, leading parents to perceive "outdoor risk" as greater than it is (Pain, 2006). The international literature demonstrates that actual risk may be lower than perceived risk, yet perceived risk exerts a far stronger influence on parental behavior (Shaw et al., 2015; Pain, 2006). Studies conducted in Turkey similarly reveal that parents' reluctance to allow children to move independently is related not only to traffic or crime risks, but also to social acceptance, neighborhood norms, and culturally embedded values (Üzümcü, 2017; Uğur, 2018).

Governance capacity also constitutes a distinguishing factor in the Turkish context. Commonly observed in Swiss reports, school route committees, risk maps, annual monitoring and evaluation processes, and standardized design guidelines have not yet been institutionalized in Turkey. Collaboration among planning departments, traffic authorities, school administrations, and local police units is generally project-based and discontinuous (Wolfe & McDonald, 2016). Yet child-friendly city principles require children's safety to be addressed as an integrated field of governance (UNICEF, 2018). Consequently, in Turkey, safe route to school necessitates the concurrent development of not only physical interventions, but also institutional coordination and processes of social acceptance.

Considering Turkey's social, cultural, and spatial conditions, a context-sensitive model should be grounded in four fundamental principles. First, spatial sensitivity requires physical interventions adapted to local morphology, considering elements such as speed management, sidewalk continuity, intersection design, and congestion around school entrances in each school environment (Dumbaugh & Rae, 2009). Second, social acceptance and education encompass communication channels,

educational programs, and collective walking initiatives aimed at transforming the safety perceptions of parents and students (Carver et al., 2014; Napier et al., 2011). Third, graduated independence entails an approach that recognizes the developmental value of "controlled risks" and enables children to assume increasing levels of responsibility in an age-appropriate manner (Bandura, 1997). Finally, institutional coordination refers to the establishment of multi-stakeholder processes that enable continuous communication among municipalities, school administrations, law enforcement agencies, and neighborhood organizations (Bickerstaff & Walker, 2001; Pucher & Buehler, 2008).

Good practice examples from Switzerland demonstrate that when these four principles operate in a complementary manner, the safe route to school policy domain evolves into a sustainable and effective structure. However, the direct replication of this model in Turkey is not feasible; instead, the contextual adaptation of these principles is required. Accordingly, the findings of this section indicate that strategies for safe routes to school in Turkey should be addressed within a broader framework that goes beyond technical infrastructure improvements, encompassing the redefinition of childhood culture, the transformation of parenting norms, the strengthening of governance mechanisms, and the enhancement of children's active participation in urban space.

Despite these differences, there is considerable potential within the Turkish context. Urban regeneration initiatives and school environment improvement projects allow for rapid interventions at the neighborhood scale. Moreover, the proportion of children walking to school in many Turkish cities remains relatively high; when supported by infrastructural and safety improvements, this condition suggests a strong potential for the development of independent mobility capacities. In addition, strategic visions adopted by local governments around discourses such as "livability," "sustainable mobility," and "pedestrian priority" provide a favorable foundation for integrating safe route to school principles into municipal policies.

5. Conclusion

This study has examined the child-friendly city approach and safe route to school policies within a conceptual framework that foregrounds the intersection between global norms and local realities. The findings demonstrate that the safe route to school approach does not constitute merely a set of technical interventions, but rather a multilayered policy domain shaped by conceptions of childhood, parenting culture, societal perceptions of safety, spatial design, and governance capacity. For this reason, safe route to school should be regarded as one of the principal contexts through which the child-friendly city paradigm becomes concretized.

The international cases discussed within the scope of this study demonstrate that safe route to school practices cannot be reduced to a single model. The practices observed across settlements of different scales in Switzerland reveal considerable spatial, social, and institutional diversity: while speed management and intersection design are more prominent in large metropolitan centers, community surveillance, pedestrian continuity, and neighborhood participation play a more decisive role in smaller settlements. This diversity indicates that the success of safe route to school lies not in "model transfer," but in principle-based adaptation. The shared principles identified across these practices—spatial sensitivity, institutional coordination, monitoring and evaluation, and community participation—constitute the building blocks of the safe route to school approach.

When these principles are applied to the Turkish context, both significant opportunities and clear limitations emerge. Rapid urbanization, car-oriented planning practices, and discontinuities in pedestrian infrastructure in Turkey make it difficult for children to reach school in physically safe conditions. In addition, parenting culture and perceptions of safety generate social mechanisms that constrain children's capacity for independent movement in outdoor environments. At the institutional level, collaboration among planning authorities, law enforcement agencies, school administrations, and community actors is largely project-based and lacks continuity. These conditions indicate that the direct transfer of safe route to school practices to Turkey is not feasible; however, they can be reinterpreted and implemented through a context-sensitive framework.

Thus, safe route to school strategies for Turkey should not be limited solely to physical interventions; rather, they should also focus on strengthening social acceptance, transforming parenting norms, supporting children's participation in urban life, and establishing mechanisms of institutional coordination. Practices such as enabling children to define their own routes, group walking initiatives, community-based applications, and "graduated independence" approaches constitute important tools that reinforce both the developmental and social value of independent mobility. These strategies make it possible for children to exist as autonomous individuals in the city, while also ensuring that child-friendly city principles are translated into everyday practices.

In conclusion, the safe route to school is not merely a matter of traffic safety; rather, it constitutes a comprehensive field of transformation that intersects children's right to the city, spatial justice, cultures of social safety, and governance capacity. **Global norms are renegotiated and reproduced through engagement with local realities, and success is achieved through adaptability, social acceptance, and institutional continuity.** This study demonstrates that the child-friendly city approach and safe route to school policies in contexts characterized by high socio-spatial diversity, such as Turkey, must be addressed not only from a technical perspective but also through cultural and governance-oriented lenses. Future research may further illuminate the conditions under which safe route to school policies are most effective by jointly examining children's subjective experiences, parenting practices, spatial perceptions, and governance processes. In this respect, when safe route to school policies are placed at the center of children's relationships with the city, they have the potential to contribute to the development of a more autonomous, participatory, and inclusive urban life.

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Chapter 5

EURYMEDON (ZİNDAN) CAVE REVITALIZATION PROJECT: INTEGRATED ENVIRONMENTAL AND ARCHITECTURAL DESIGN FOR HERITAGE CONSERVATION

Seda ŞİMŞEK[1], Gamze AKYOL[2], Ömer Kamil ÖRÜCÜ[3]

1 Assoc. Prof. Dr., Suleyman Demirel University, Department of Architecture, sedatolaci@sdu.edu.tr, 0000-0002-1881-186X.
2 Lecturer Dr., Antalya Bilim University, Department of Interior Architecture and Environmental Design, gamze.akyol@antalya.edu.tr, 0000-0001-6108-9529.
3 Assoc. Prof. Dr., Suleyman Demirel University, Department of Landscape Architecture, omerorucu@sdu.edu.tr, 0000-0002-2162-7553.

1. INTRODUCTION

Zindan Cave (Zindan Mağarası), located approximately 2 km northeast of Aksu District in Isparta Province, represents one of the most remarkable intersections of natural, archaeological, and cultural heritage in the Western Taurus Mountains. Formed within Upper Triassic carbonates of the Karaçam Formation, the 765-meter-long cave developed along a north–south joint within the Isparta Angle, a tectonic zone defined by overlapping Antalya Nappes and platform carbonates (Bozcu, 2007) (Figure 1). Its geological structure of massive, brecciated limestones provided not only a natural cavity but also the foundation for human settlement, worship, and later, tourism-based interaction.

Fig 1. Zindan Cave interior photo

Archaeologically, Zindan Cave and its surroundings host an extraordinary stratigraphic record extending from the Hellenistic period to the Seljuk era (Dedeoğlu, 2005). Excavations conducted between 2002 and 2005 by the Isparta Museum unearthed monumental evidence of cultic architecture, inscriptions, and mosaic pavements. The most significant revelation was that the sanctuary in front of the cave—long believed to be dedicated to the river god Eurymedon—was in fact consecrated to Meter Theon Vegeinos, the Anatolian mother goddess Cybele (Alp, 2013). Inscriptions dedicated to both Cybele and Emperor Marcus Aurelius indicate that the site functioned as a combined imperial and divine cult complex during the late 2nd century CE.

Historically known as part of Tymbriada's territory, Zindan Cave functioned as a sacred gateway, accessed via a Roman bridge that remains partially preserved today (Dedeoğlu, 2005) (Figure 2). In later centuries, the area transformed into a Christian monastic settlement with basilical and triconch-planned churches, reflecting a sacred continuity of space. Its transformation from pagan sanctuary to Christian monastery underscores the site's enduring spiritual significance within Pisidia's sacred geography (Demirci, 2016)

Fig 2: Zindan Cave Entrance and the Roman Bridge

Ecologically, the cave harbors diverse arthropod fauna that act as indicators of environmental health (Çetin et al., 2021), while its landscape along the Eurymedon Valley forms part of a broader karstic ecosystem crucial to local biodiversity. Together, these attributes have made Zindan Cave a subject of environmental and touristic research in recent decades. Studies highlight its potential as a model for eco-cultural tourism in the Lakes Region (Göller Yöresi), combining conservation, education, and sustainable economic development (Özen et al., 2018).

Access to the cave entrance opening onto the valley and to the sacred area constructed in front of it is provided by a single-arched bridge that has survived to the present day in a well-preserved condition. Located within the territory of the ancient city of Tymbriada, the site was first documented by Kaya and Mitchell. In their publication, the architectural remains observable on the surface were assessed in conjunction with scattered architectural elements and inscriptions. On the basis of the river god statue discovered near the cave and the relief carved on the keystone of the bridge arch, the sacred area was interpreted as having been dedicated to Eurymedon (Kaya & Mitchell, 1985).

In addition to its historical and cultural depth, Zindan Cave holds ecological importance due to its unique subterranean biodiversity. Research conducted by Çetin et al. (2021) identified diverse arthropod species within the cave, emphasizing its role in regional ecological balance. This intersection of natural and cultural heritage establishes Zindan Cave as a key focus for integrated conservation planning in the Isparta region.

Recognizing this multidimensional importance, the Isparta Governorship and Aksu District Governorship commissioned the “Isparta Aksu Eurymedon Zindan Mağarası Revize Çevre Düzenlemesi Planı” through Süleyman Demirel University’s Faculty of Architecture. The project was executed in coordination with several public agencies, including the Isparta Museum Directorate, Antalya Cultural Heritage Preservation Board, and Provincial Directorate of Environment and Urbanization. This initiative represents a collaborative effort between academia and government aimed at protecting the cave while enhancing its accessibility and visitor experience.

Recognizing these intertwined values, Süleyman Demirel University's Faculty of Architecture, in collaboration with the Isparta Governorship and Aksu District Governorship, developed the "Isparta Aksu Eurymedon Zindan Mağarası Revize Çevre Düzenlemesi Planı" in 2019–2020. This project aimed to enhance visitor accessibility, preserve archaeological remains, and design low-impact architectural interventions around the cave. The project commenced in September 2019 and involved interinstitutional coordination with the General Directorate of Nature Conservation, DSİ, the Ministry of Culture and Tourism, and the Antalya Regional Board for the Protection of Natural Heritage. Following successive review and revision phases, the final version of the project was approved in February 2020 under Law No. 2863 on the Conservation of Cultural and Natural Properties.

An official letter addressed to Aksu District Governorship confirmed the completion and submission of the project ahead of schedule. The letter noted the inclusion of: Aksu Zindan Cave Environmental Revision Master Plan, Detail Drawings, Proposed New Structures Projects, Proposed Bridge Structural Report, Electrical Project Report (Energy Transmission, Internal and External Lighting)

2. PROJECT PLANNING AND DESIGN FRAMEWORK

The Zindan Cave Environmental Revitalization Project was guided by the principle of holistic conservation. The design aimed to balance natural, archaeological, and visitor-oriented interventions without compromising the ecological and historical integrity of the site (Figure 3).

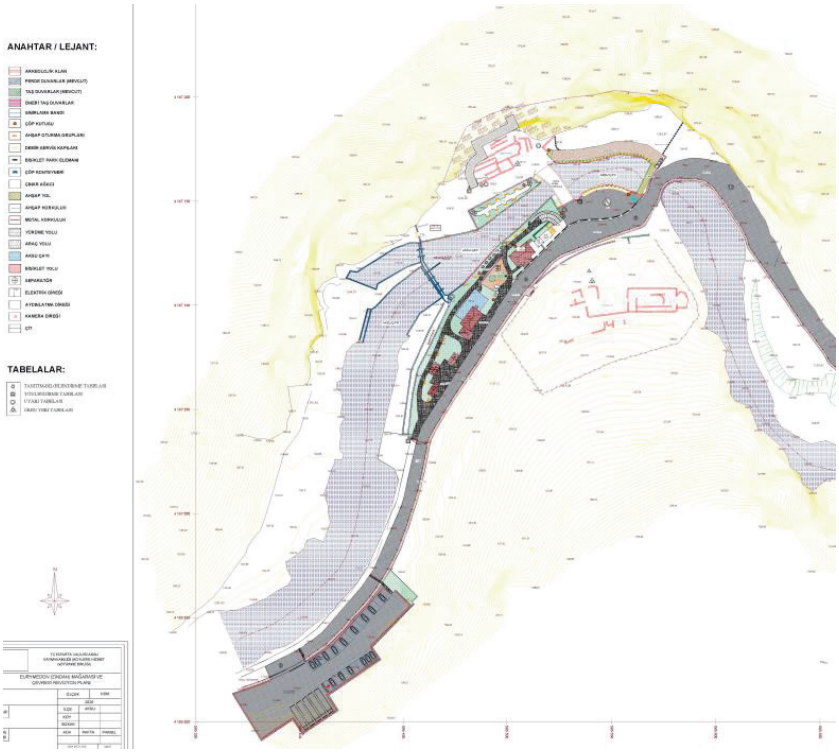

Fig 3. Öneri Yerleşim Planı

The design decisions for the project area were formulated within the framework of a holistic conservation approach, taking into account the site's 750-meter-long cave, the surrounding archaeological remains, the Roman Bridge, existing access and transportation conditions, and the adjacent river. Within this framework, the primary objective was to ensure

the sustainability and continuity of the site, the project, and both the natural and anthropogenic environments.

As the area is designated as a first-degree natural and archaeological protected site and is characterized by a high level of functional diversity, site-specific designs and details were developed for each zone exhibiting distinct spatial and environmental characteristics. Building upon this approach, the process was completed with the provision of academic expertise and field-based knowledge obtained from universities and public institutions.

The project was developed by an interdisciplinary team appointed by the Rectorate of Süleyman Demirel University. The working groups were organized into Architecture Team and Planning & Landscape Team, ensuring coordinated and expert-driven decision-making.

Architecture Team: Seda Şimşek Tolacı – Assistant Professor of Architecture (Restoration), Gamze Akyol – Architect/ Master Student-Prepared the architectural drawings, Mehmet Sargın- Master Student -3D Modelling

Planning & Landscape Team: Prof. Dr. Ali Türk – Professor of Urban and Regional Planning, Ömer Kamil Örücü – Assistant Professor of Landscape Architecture

Additional Expert Support: Prof. Dr. Mahmut Mutlutürk – Geological Engineering, Assoc. Prof. Dr. Fikret Özcan – Archaeology

3. MAIN DESIGN PRINCIPLES

Within the scope of architectural conservation, the project design places particular emphasis on three key elements of outstanding significance: Zindan Cave, the Roman Bridge, and the archaeological remains located at the cave entrance. Taking into consideration the river (water) deity associated with the historical narrative of the cave, the design approach was based on the principle of maintaining the strong physical and symbolic relationship between the site and the adjacent river.

Within the project area, two zones designated as first-degree archaeological protected sites contain significant remains: one located directly in front of the cave entrance and the other situated on the slope opposite the entrance. These zones include archaeological church remains, the Roman Bridge, and a floor mosaic identified as representing the River (Water) Deity at the cave entrance. Addressed through a holistic conservation framework, the project developed a unified design concept that prioritizes the restoration and preservation of the Roman Bridge, the presentation of the cave interior to visitors through minimal intervention, and the integration, protection, and conservation of the archaeological remains with minimal physical impact, together with coherent landscape design strategies.

In order to ensure the protection of the archaeological remains and to formulate appropriate repair and conservation recommendations, a large-scale excavation campaign was planned, and the administrative process—particularly the necessary permits—was initiated in coordination with the Aksu District Governorship and the Isparta Museum Directorate. Studies related to the archaeological remains and the floor mosaic were conducted by the Isparta Museum Directorate concurrently with the preparation of the present project report. Furthermore, recognizing the critical importance of preserving the fauna and flora of the natural cave formation while enabling the active use of the designed environment, a comprehensive interior and exterior cave and landscape lighting project—one of the most essential components of the proposal—was prepared in

collaboration with relevant experts and institutions. The design process and technical specifications of this lighting scheme were documented and submitted as a separate technical report.

3.1.1. Upper-Scale Design Concept Decisions

Within the framework of contemporary conservation theory, particular care was taken to ensure that the design elements to be implemented are compatible with the natural and built environment, while simultaneously embodying the formal, material, and technological characteristics of the period in which they are introduced (Fig. 4).

Fig 4. Site Design of the Area

Integrated with the surrounding landscape, a bicycle path extends continuously for approximately 2 km from the Aksu district to the project area. In order to preserve the natural character and experiential quality of the environment, the parking area was deliberately located outside the core project zone. The parking facility has a capacity of 30 passenger vehicles and 5 buses.

To ensure the safety of cyclists along the bicycle path at the points of vehicular entry and exit, a dual-barrier system was implemented. When vehicles intending to enter the parking area stop in front of the barrier, or when the exit button is activated, a warning light on the bicycle path is triggered, temporarily granting right of way to vehicles and alerting cyclists to potential crossings (Fig. 5).

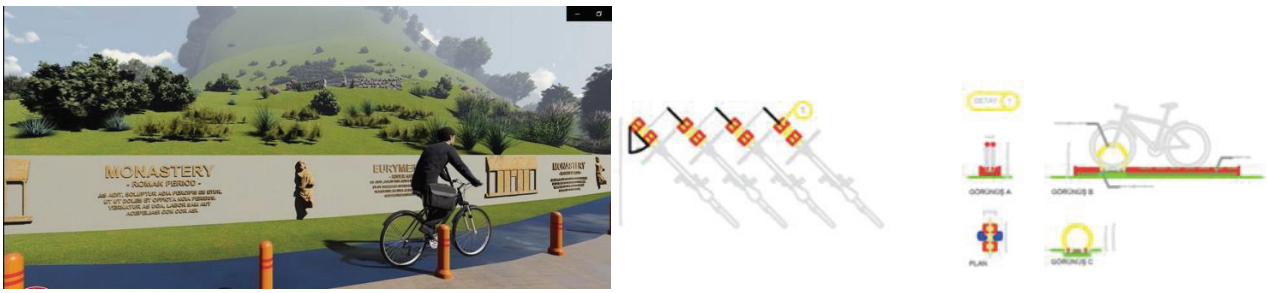

Fig. 5: Bicycle Path and Details of Parking Elements

In order to enable safe pedestrian crossing for visitors after parking their vehicles, designated pedestrian crossingswere incorporated along the roadway. From the parking area onward, the ground paving material was transitioned to stone block paving, reinforcing both durability and contextual compatibility. All pedestrian pathways within the site were designed with slopes compliant with accessibility standards, ensuring barrier-free access for individuals with disabilities.

The entrance, information, and wayfinding signage used throughout the site was designed in accordance with the specifications set forth in the *Directive on Entrance, Information, and Wayfinding Signage for Museums and Archaeological Sites*, which is applicable to areas designated under the site's new legal status as an "archaeological site (ören yeri)". The types, details, and quantities of these signage elements were proposed in compliance with the directive and are indicated on the site plan.

Following the entrance, information, and wayfinding signage, a single commercial unit is located along the walking and bicycle route. This unit was subdivided into three spatially equivalent sections, intended to accommodate functions such as the sale of local products, a museum shop, and related visitor-oriented uses.

Due to the terraced topography sloping toward the stream, ramps and stairways were introduced at various points across the site to accommodate changes in elevation. A cafeteria space was proposed to provide visitors with an area for rest and the consumption of light refreshments. On the façade oriented toward the cave, the building was designed with a more transparent surface, enhancing visual continuity with the surrounding landscape. Vertical circulation from the main interior space to the terrace, and from the terrace to the lower pedestrian pathway, is provided via stair access.

On the river-facing side of the existing restroom and security units, the addition of two terrace platforms was deemed appropriate, enabling this area to function as the outdoor seating space of the proposed restaurant. Adjacent to the cafeteria, a children's playground with rubberized flooring was incorporated. Located next to the playground are the existing restroom facilities and the guard booth, ensuring functional continuity within the site.

At the cave entrance area, a seating terrace was created through terracing along the stream edge. This intervention provides visitors entering or exiting the cave with both a resting area and an enhanced opportunity to observe and experience the surrounding environment. The upper portion of the cave entrance stairway was protected with a double-layer steel mesh system, and a protective canopy was introduced to mitigate potential hazards from falling stones (Fig. 6).

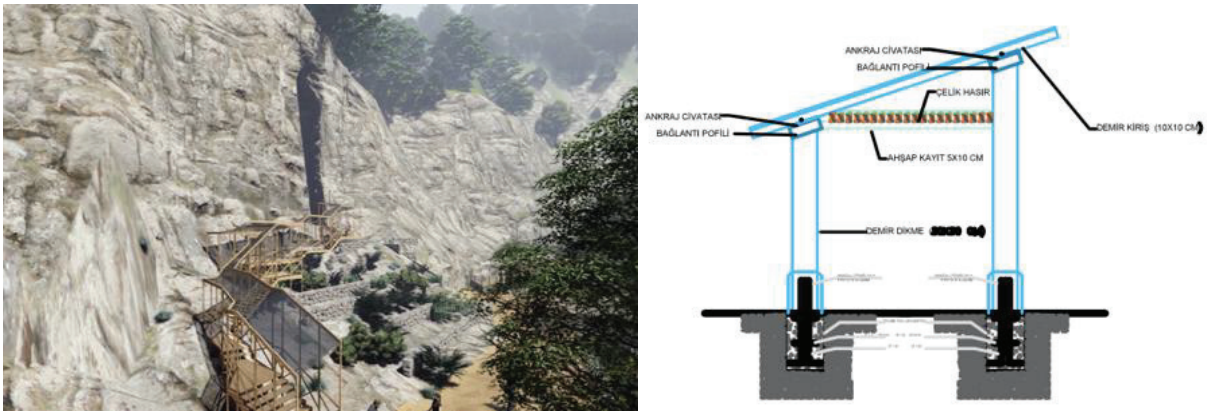

Fig. 6. Access Stairway to the Cave and Implementation Detail

In reflecting the established design concept in the architectural language—shaped by the religious function historically attributed to the cave formation and the surrounding archaeological area, as well as by the existing chromatic dominance of the natural environment—the architectural structures and

elements were predominantly designed using a palette of gray tones and black color scales, complemented by the selective use of wooden materials (Fig. 7).

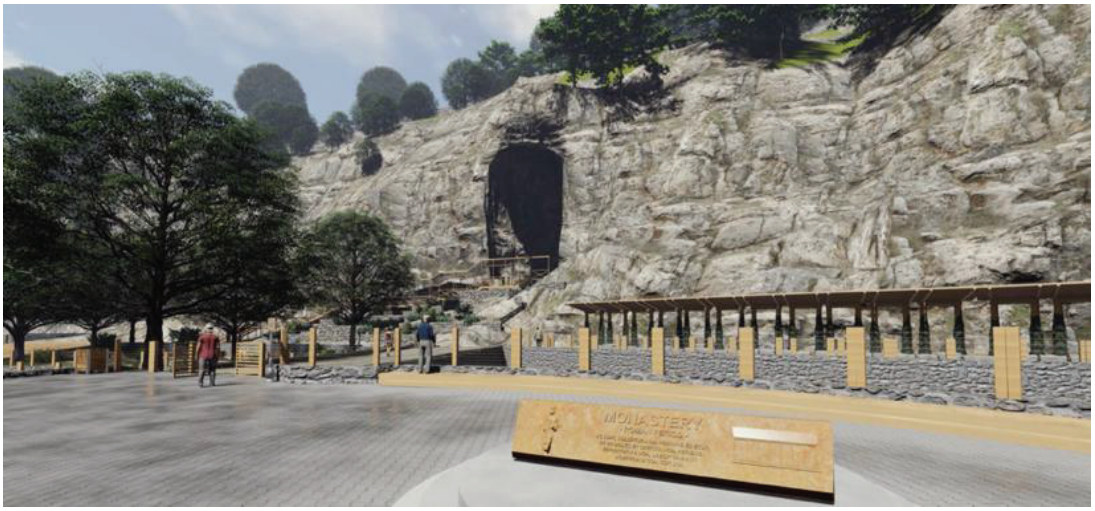

Fig 7: Cave Entrance and Pedestrian Area

A network of accessible routes was also developed with suitable gradients, ramps, and resting points, allowing universal access for visitors of all ages and mobility levels in accordance with inclusive design principles. Additionally, informational and orientation signage was proposed in line with the Museum and Archaeological Site Signage Directive, ensuring that visitors receive clear, educational, and aesthetically compatible guidance throughout the site without disrupting its visual harmony. The plan also included the integration of a visitor service zone, featuring a café-restaurant, a local product sales unit, and a small children's play area (Figure 8).

Fig 8: Design of café-restaurant and a children's play area

These facilities were designed using locally sourced, natural materials—such as wood, stone, and steel—and constructed with low-impact methods to blend seamlessly with the surrounding landscape while supporting local economic activity. Collectively, these interventions reflect the project's broader aim to harmonize visitor comfort, cultural education, and environmental stewardship.

It is observed that the Roman Bridge has not lost its functional capacity and remains in active use. An examination of early written sources indicates that the pagan cult worshipped the god Eurymedon (Köprüçay) at the site, and that during the Roman period, both a bridge and a church were added to

the area. The cave, which was used as a dungeon during the Roman period, derives its historical name from this function.

In its current state of active use, it was deemed necessary to reduce the structural load imposed on the bridge. Furthermore, due to the adverse impact of the applied travertine cladding on the perceptual integrity of the structure, it was planned that this material be removed with the required official permissions and that the original stone fabric be restored. Prior to the project intervention, the Roman Bridge functioned as a pedestrian crossing; however, its position along the primary access axis to the cave resulted in a diminished visual perception of the structure, thereby necessitating a reconfiguration of the access route to the cave.

Within this framework, the project proposes a newly defined circulation axis beginning with pedestrian guidance over the structure referred to as the "New Bridge," supported by informational and complementary design elements. Designed as a steel structural system, the New Bridge also serves as a viewing platform, offering users a comprehensive panoramic vantage point encompassing the Roman Bridge, the archaeological remains at the cave entrance, the river, and the cave entrance itself, thereby facilitating both visual observation and photographic documentation (Fig. 9).

Fig 9 : Roman Bridge and a new pedestrian bridge

Visitors admitted through a turnstile system from the proposed bridge (for which detailed design drawings and structural calculations have been prepared) will proceed along the interpretive information route, access the archaeological area, and subsequently enter the cave, while the return route is directed over the Roman Bridge. This configuration establishes a one-way pedestrian circulation loop, whereby the Historic Roman Bridge is used exclusively for return circulation rather than for bidirectional movement, effectively reducing its dynamic load by approximately half and, consequently, mitigating the risk of structural deterioration to a comparable extent. To reinforce this circulation strategy, a reverse-direction gate is proposed at the entrance side of the Roman Bridge to prevent visitor access in the inbound direction.

In order to convey the historical narrative of the site, the implementation of a contemporary interpretive design—potentially activated through thematic designations such as *"light path," "information path,"* or *"history path"*—is planned to ensure continuous information flow and effective site interpretation. While incorporating modern design elements, the project also emphasizes the use of natural materials. The overall design approach is characterized as minimal, refined,

functional, and concept-driven, with the circulation axis conceived in integration with ground paving and associated landscape elements.

Both the interpretive pathway and the bridge are finished with wooden deck flooring. Along the interpretive route, replica artifacts and informational displays related to the site are presented. As the circulation axis is necessarily positioned beneath steep rock formations, it is covered with a semi-open protective canopy designed to safeguard visitors, replica exhibits, and informational units from falling stones. This overhead structure is planned to be clad with steel mesh, ensuring both safety and visual permeability.

Fig. 10. Interpretive Pathway Providing Access to the Cave

It is proposed that a replica of the statue, originally known to have been located at the cave entrance and whose authentic original is currently housed in the Isparta Museum, be produced and reinstalled at its original location, as this intervention is expected to yield positive outcomes in terms of cultural tourism and visitor experience. Until new interventions and implementations are carried out within the archaeological area, it is recommended that the existing remains be made more visually legible, particularly during evening hours, through the application of an appropriate lighting strategy. Where feasible, this lighting approach is intended to reflect the historical periods represented at the site, thereby enhancing both interpretive clarity and experiential quality.

3.1.2. Interior Cave Design Plan

Zindan Cave may be evaluated as comprising three distinct spatial zones: the entrance area, the section that currently offers approximately 750 meters of accessible visitor circulation, and the terminal area of the axial route locally referred to as the “bath”, located at the end of the circulation axis.

Upon entering Zindan Cave, visitors are immediately encountered by a geometric floor mosaic, which demonstrates that the space functioned not merely as a natural cavity but as a sacred threshold intentionally shaped for ritual purposes during the Roman Imperial period. The mosaic transforms the cave entrance into a “threshold space”, symbolizing the transition from the profane to the sacred. At the western end of this space—whose boundaries are defined by the bedrock walls—the revealed floor mosaic depicts a female figure accompanied by dolphins and winged child figures, further reinforcing the ritual and symbolic significance of the area (Fig. 11).

Fig. 11. Eurymedon (River God) Floor Mosaic (Alp, 2013)

The first course of the walls defining the mosaic on its northern and western sides has been preserved, although portions of the mosaic were damaged prior to excavation, particularly during earlier walkway and drainage works (Alp, 2013).

The conservation of the floor mosaic at the cave entrance was carried out during a previous restoration phase. In order to protect the mosaic from potential stone fall originating from the cave ceiling, a protective covering was installed over the surface. As the risk of falling stones remains valid, a new protective canopy has again been proposed to safeguard the conserved surface, and the matter has been discussed in consultation with the relevant survey (rölöve) unit. The existing protective roof was reconstructed using more restrained architectural elements and improved workmanship, and the height of the upper covering was increased to ensure functional performance without negatively affecting visual perception. The use of simple steel cable elements allows the artifact to remain visually accessible at eye level, while maintaining the necessary level of protection.

Given that the primary viewing direction of the artifact is oriented toward the cave entrance, a raised landing/viewing platform was introduced immediately to the left of the entrance, accessed via steps. This element, positioned without anchoring to the ground and stabilized through its own weight and structural design, provides an elevated vantage point that enables visitors to clearly observe the mosaic.

Access to the second major spatial component of the cave, characterized by a predominantly linear and walkable zone, is provided through a cave opening at a depth of approximately 16.0 m. The circulation axis varies in width, measuring 6.00 m at its narrowest point and expanding to 9.00 m at its widest. Immediately in front of the entrance and along the continuation of this axis, several blocks of the original floor paving have been preserved in situ (Alp, 2013).

The replacement of the existing electrical installations within the cave, together with the introduction of necessary new arrangements as recommended by the relevant authorities, constitutes a significant component of the project. As a natural formation with distinctive biological, geological, and physical

characteristics, the cave was carefully examined on site to assess the impacts of previous interventions, leading to the formulation of new repair and design decisions.

The conceptual foundation of these decisions prioritizes minimal intervention and the improvement of existing adverse conditions. The primary objectives of the interventions are the use of materials and design solutions that are compatible with the cave's microclimatic conditions, safe, reversible, sustainable, and suitable for long-term use. Within this framework, expert reports identified that the previous electrical system—particularly the methods of mounting lighting fixtures onto cave surfaces, as well as the inappropriate lighting system and intensity levels—had caused damage to the cave interior. Consequently, it was decided that all existing electrical installations be completely removed.

The existing cast-in-place concrete walking path currently present on the cave floor was not removed, based on the assessment that dismantling it would cause damage comparable to, or greater than, its initial construction. Instead, it was decided to transform this element into a design advantage. Accordingly, a proposal was developed to install a metal substructure over the concrete surface, finished with wood-textured deck cladding. This approach serves a critical functional purpose within the project: the proposed platform is designed to accommodate architectural and technical components such as security cameras, service conduits, cabling, and lighting elements.

Considering that this natural formation is still developing and has been characterized by specialists as "young," the design anticipates the possibility that the cave may need to be temporarily closed to visitors at certain times. To allow the cave to fully revert to its natural ecological state during such closures, a specialized design approach was adopted. The platform is conceived as a modular system, with minimal contact with the cave floor, and is to be fabricated from corrosion-resistant materials. In the event that the platform needs to be removed in sections, this strategy ensures that the intervention leaves minimal residual impact on the cave environment.

4. CONCLUSION

The results of the Zindan Cave Environmental Revitalization Project reveal the successful integration of architectural, archaeological, and ecological design strategies within a sensitive heritage context. The project achieved a balanced approach that preserved the archaeological remains—such as the Roman Bridge, ancient mosaics, and church structures—while improving accessibility and visitor experience through modern yet reversible interventions. The introduction of a new pedestrian bridge and redesigned circulation routes effectively reduced pressure on the original Roman Bridge, ensuring its structural longevity. The interior interventions, including the elevated steel-deck walkway and controlled lighting system, provided safe and sustainable visitor access without disturbing the cave's natural formations or microclimate. In parallel, the external landscape design established a clear hierarchy between vehicular and pedestrian zones, enhanced with environmentally compatible materials and vegetation. These outcomes collectively demonstrate that conservation and tourism development can coexist through careful design and interdisciplinary collaboration. The project was ultimately approved by the Antalya Regional Board for the Protection of Cultural Heritage in February 2020, confirming its compliance with national conservation standards and its role as a replicable model for future heritage revitalization efforts across Turkey.

This initiative, developed by Süleyman Demirel University's Faculty of Architecture for Aksu District Governorshipunder the auspices of the Isparta Governorship, demonstrates how academic expertise can serve public institutions in safeguarding and revitalizing Turkey's natural and cultural assets.

Declaration of Generative AI Use:

Generative AI was used in a limited capacity during the writing process. Specifically, ChatGPT was utilized for grammar checking and improving sentence clarity.

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Chapter 6

ON CUSTOMIZABLE ARCHITECTURES FOR TEMPORARY DISASTER SHELTER

Ahmet Emre DİNÇER[1] , Necmettin SANCAK[2]

1 Corresponding Author, Assoc. Prof. Dr., Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Department of Architecture, aedincer@aybu.edu.tr, ORCID: 0000-0002-3439-3637.
2 Res. Asst., Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Department of Architecture, nsancak@aybu.edu.tr, ORCID: 0000-0003-3155-1641.

1. DESIGNING WITH DIGNITY: SHELTER BEYOND PHYSICAL PROTECTION

Throughout history, shelter has functioned as more than a physical barrier against environmental threats. It has also played a formative role in shaping social organization, reinforcing cultural identity, and supporting psychological well-being. For this reason, the quality of a living unit cannot be assessed solely through the durability of its structural components; it must also be understood in relation to how effectively it enables individuals and communities to experience belonging, maintain privacy, and sustain a sense of continuity in everyday life.

The emotions that a dwelling unit evokes in its users can be wiped out in an instant by natural disasters (earthquakes, floods, fires, etc.), depriving millions of living beings not only of their physical safety, but also of their everyday life practices and social relationships. In the aftermath of disasters, dwelling units that have been destroyed in a moment are replaced by temporary housing solutions that focus on basic criteria such as speed, cost and functionality, yet overlook users emotional needs related to cultural context, personalization and belonging. This approach causes temporary shelter units to remain inadequate in supporting disaster victims recovery processes after natural disasters, and to persist as monotonous spaces closed to user personalization and to changing needs.

In his 1969 book “House Form and Culture”, Rapoport explained the impact of user experience through the example of the Motilone natives living in the Amazon. This indigenous community lives in collective dwellings known as bohios, each accommodating 10–30 families. Formally, a bohios generally has a circular plan and is covered with reeds as a roofing material. Bohios, which have a conical geometry, feature a spatial setup in which the low rate of openings on the walls allows a limited amount of natural light to enter the interior. Looking at the interior layout, one can see private areas assigned to each family where hammocks are placed. It has been identified that hearths, which meet food and heating needs, are positioned at the centre of the structure and form boundaries between spaces. The spatial organization under consideration creates personalized private areas for different families within the same dwelling unit and strengthens the perception of privacy by limiting visual contact (Rapaport, 1969).

Over time, as a result of intercultural interaction, a series of alternative shelter typologies were proposed for the Motilone people, and studies were carried out on their spatial, cultural and environmental experience in these new structures (Rapaport, 1969). In the newly built shelters, the natural materials used in bohios, such as wood and reeds, were replaced with artificial materials such as metal roofing and reinforced concrete floors. While the indirect admission of natural light into the bohios created dim interiors, the new shelters produced bright interiors through large façades and artificial lighting. Ultimately, examinations showed that the indigenous community did not sufficiently embrace the modernized new shelters. Rapoport (1969) attributes this to the removal of interior partitions that ensured privacy in the spatial organization, which led to a reduction in specialized living areas, and to the alteration of familiar patterns in the cultural context. The inadequacy of centrally located cooking areas that defined spatial boundaries and the way artificial light illuminated the space in an unfamiliar manner increased the community's adaptation difficulties. The reinforced concrete floor used in the new dwelling units prevented the continuation of cultural practices by eliminating both the direct contact of the indigenous people with the soil and the use of furniture traditionally embedded in the ground. As a result, despite their visually and spatially modern designs, the new dwelling units could not respond to the spatial habits, social order and cultural continuity of the Motilone community (Rapaport, 1969).

The study focusing on the Motilone natives shows that, even in communities labeled as primitive, dwelling units cannot be reduced solely to environmental or material conditions and that spatial, social and cultural organization must be addressed as a whole. For a dwelling unit to be considered successful in spatial, social and cultural terms, it needs to have an organization that goes beyond structural permanence and modernity (Carmona, 2019). Achieving this requires preserving the dynamics through which users maintain their daily lives, privacy needs and social relationships.

One of the major factors that disrupts the order of spatial, cultural and social dynamics is natural disasters. Natural disasters break the continuity of communal life and increase the need for physical space after the event. In addition to the requirement for physical space, they also reshape social relationships and push disaster victims into a prolonged recovery process. The need for shelter, which is located at the first level in Maslow's hierarchy, not only provides physical protection but also serves as a basis for psychological and social continuity (McLeod, 2007). At this point, shelters to be designed specifically for disaster victims who need both physiological and psychological support after a natural disaster gain great importance in the context of reconstruction.

Although temporary shelters are initially designed to meet urgent physical needs, they can evolve into spaces that respond to personal, social and cultural needs associated with prolonged use during the rehabilitation process of disaster victims. The reason for this is that, depending on the scale of the natural disaster, administrative, economic, climatic and similar conditions can arise that force users to return to temporary shelter units and to use them for extended periods. In this respect, the study critically examines the transformation of post disaster shelters through theoretical paradigms, typological shifts and design strategies. Before introducing exemplary architectural cases that display flexibility, adaptability and cultural sensitivity in design, the text begins by addressing the prevailing approaches to post disaster shelter stages and typologies. The case studies discussed in the study have been analyzed using a comparative analysis method. The discussion framework is formed by how the emergency shelters used after natural disasters are influenced, in addition to their physical characteristics, by spatial, social, cultural and environmental factors that support the concept of belonging.

2. POST DISASTER SHELTER: PHASES, TYPOLOGIES AND HUMAN NEEDS

The process of sheltering after a natural disaster begins at the moment the disaster occurs and continues until safe, permanent and habitable dwellings are provided for the affected population. The intervention process in natural disasters typically consists of three stages: emergency relief, rehabilitation and reconstruction (Tosun & Maden, 2023). Throughout the process, disaster victims are obliged to reside in various shelter units depending on prevailing conditions and available resources. Bashawri and others (2014) classified post disaster shelters into seven different groups according to their characteristics: “emergency shelters, temporary shelters, temporary housing, transitional shelters, progressive shelters, core shelters (single room shelters) and permanent housing”.

Emergency shelters are used to provide basic shelter for people and to ensure their survival for one or several days. They do not support long term medical care or extensive meal preparation. Similarly, temporary shelters consist of tents or simple shelters used for several weeks, designed with time and cost efficiency in mind. In temporary housing, where short term use begins to shift, occupancy periods range from six months to three years. It typically includes rented accommodation or prefabricated units and is usually located in temporary areas suitable for post disaster use. With transitional shelters, short term occupancy begins to give way to more long term, habitable units. This

type of construction is typically built by the disaster victims themselves. Therefore, the shelters are designed to support user self management of the construction process and community participation. Progressive shelters, in turn, aim to create basic living spaces that can expand and be customized according to user needs. As one moves from temporary shelters toward permanent housing units and basic standards begin to be met, core (single room) shelters are typically one or two room dwelling units with solid foundations and sanitary and electrical infrastructure. At this point, permanent housing is created by reworking transitional shelters, progressive shelters and core shelters or by constructing new houses.

Considering the long term transformations of post disaster shelters over time, detailed planning of sheltering activities between temporary shelters and permanent housing becomes vital during the design process. When designing shelter units, one of the primary aims is to provide spaces that support basic daily activities such as sleeping, cooking, dressing, personal hygiene, storage, washing and drying (Cerrahoğlu & Maden, 2024). McLeod (2007) notes that once the basic needs and safety requirements specified in Maslow's hierarchy are met, prolonged displacement tends to encourage the pursuit of higher level psychological and self actualization needs. At the third level of Maslow's hierarchy, the need for belonging and emotional connection becomes increasingly important (McLeod, 2007). Therefore, architectural interventions that support spatial belonging, social interaction and emotional well being are among the essential requirements of these shelter designs.

The fundamental criteria of shelter design typically include durability, safety, privacy, reusability, portability, rapid assembly, easy storage, compactness, expandability and flexibility (Cerrahoğlu & Maden, 2024). In addition, technical requirements such as waterproofing, thermal insulation and ventilation are important parameters that need to be taken into account. Among the basic design criteria, privacy and flexibility play a critical role in strengthening individuals sense of belonging and supporting the development of social connections.

3. USERS, ADAPTATION AND CULTURAL CONTINUITY IN TEMPORARY HOUSING

Post disaster temporary shelter areas are expected to form holistic spatial systems that respond not only to the need for physical protection, but also to the social, cultural and environmental requirements of their users. However, research indicates that uniform and standardized physical solutions intended to meet shelter demands frequently fall short of accommodating the variety of users' spatial, cultural, and social behaviors (Şener & Altun, 2009; Ünal & Akın, 2017; Tarakçı & Kavut, 2025). The need to design temporary housing units with a higher degree of flexibility and multidimensional adaptability becomes evident when post-disaster shelter environments are observed over time. User-led interventions and informal adaptations are not exceptional responses; rather, they emerge as a nearly inevitable outcome of prolonged occupancy in standardized shelter units. This tendency reveals an underlying mismatch between predefined spatial configurations and the evolving requirements of daily life after a disaster.

A substantial body of research has documented these user-driven modifications. In their study conducted in the Kocaeli–Yeniköy district following the 1999 Marmara Earthquake, Şener and Altun (2009) reported that 81% of temporary shelter residents altered their living environments. Among these interventions, 30% were limited to outdoor spaces, 3% focused exclusively on interior spaces, and 48% involved changes to both interior and exterior areas, while 19% of respondents indicated that they made no modifications. The same survey also revealed that 57% of participants lived with four to five individuals, and 8% shared their shelters with eight to nine people. These findings suggest

that spatial insufficiencies do not remain confined to physical constraints, but instead trigger broader social and psychological challenges. Participants reported a wide range of problems, from separation of bathrooms and toilets to the need for additional rooms, lack of green and play areas, discomfort due to temperature fluctuations, requirements for environmental organization and the need for contextually sensitive housing production (Ünal & Akın, 2017). Similar conditions were observed after the earthquakes of 6 February 2023 in Kahramanmaraş and Hatay. In a study conducted with 105 residents living for more than a year in the Disaster and Emergency Management Authority (AFAD) container settlement in İskenderun, Hatay, major issues included lack of spatial organization, absence of expandable or adaptable living areas for large families and ergonomic problems caused by limited spatial mobility (Tarakçı & Kavut, 2025). Additional complaints involved thermal and acoustic issues arising from structural deficiencies, as well as sanitary inadequacies caused by poor infrastructure. It is possible to observe an increase in the number of research studies conducted on post disaster temporary shelter units. However, in the context of Turkish standards, the consistent findings of these studies, carried out roughly a decade apart, underline the persistence of previously identified spatial, environmental and cultural problems.

4. DESIGN RESPONSES: FLEXIBLE AND CULTURALLY SENSITIVE PROTOTYPES

In relation to the spatial, environmental and cultural problems observed in post disaster temporary shelter units, the literature contains numerous studies that aim to develop modular, flexible, customizable, expandable and adaptable shelters (Şener & Torus, 2009; Karaoğlan & Alaçam, 2018; Karaoğlan & Alaçam, 2019; Özden & Özden, 2023; Yetkin et al., 2024; Gökçe et al, 2025). In selecting the case studies examined within the scope of this study, examples that had either resulted in an actual production process or reached the prototype stage were chosen, taking into account their relationship with the aforementioned features. The main purpose of selecting examples that have been produced or prototyped is to evaluate, through the concept of spatial belonging, design solutions that are not only compatible with spatial and environmental requirements but also economic, feasible and directly integrable into the production process, in contrast to conceptual studies in the literature that have low implementation reality.

The analysis primarily focuses on formal configuration, spatial organization and their effects on human psychology and sociology, while also addressing production practices and contextual issues. The selected examples are compared with similar cases in the literature. In conducting the comparative analysis, the evaluation criteria that enhance the sense of spatial belonging are identified, based on previous studies in the literature, under the headings of spatial organization, sociology, cultural adaptation, building physics, environmental factors and material and technology (Şener & Altun, 2009; Tosun & Maden, 2023).

When examining shelter units, the belonging criteria considered under the Spatial Organization parameter are used to identify modular and flexible spaces that optimize user circulation, spatial hierarchy and continuity. Sociological criteria analyze the distinction between public and private areas, the intensity of user interaction and the perception of safety and privacy that arises from spatial arrangement. The unit's capacity to integrate everyday living practices, symbolic references and culture specific spatial patterns, as well as its potential for personalization, is evaluated under the Cultural Adaptation criteria. Building Physics measures the conformity of structural system strength and indoor comfort components (thermal transmittance, daylight, ventilation, etc.) to standards, while Environmental Factors address the adaptation of the structure to site conditions such as topography, ground conditions and drainage through geotechnical parameters. Finally, Material

and Technology evaluates localization strategies that include production efficiency, ease of assembly, standardization, logistical optimization and the use of local materials.

The implemented projects found in the existing literature and examined through the comparative analysis method are evaluated in chronological order and analyzed according to the parameters mentioned above that strengthen spatial belonging.

4.1. Hexacube

The Hexacube prototype, built between 1968 and 1975 by Georges Candilis and Anja Blonstedt in Port Leucate, demonstrated that domestic living experiences in plastic houses and tourist accommodation areas in France could be sustained and thus enable alternative ways of living. The structure was designed as an extension of an alternative architectural approach called the "Micro-Living Capsule", which emerged in the late 1960s as a reaction to the architectural style dominant in the post-World War II period (Gjakun, 2015). This approach aims to make interior spaces multifunctional, adaptable and flexible, thereby increasing long term spatial efficiency. Beyond the work of Candilis and Blonstedt, this approach is reflected in projects such as Warren Chalk's Capsule House (1964) and David Greene's Living Pod (1965), as well as in examples like Plug-in City (1964), where the entire structure is conceived as an urban scale system consisting of plug-in units for different functions.

Hexacube offers a high level of configurable spatial organization potential thanks to its cubic modules, which can be articulated together through hexagonal surfaces (each cubic unit has an edge length of approximately 2.5 m and a weight of 300 kg). In the configuration of the housing typology, two basic cube modules were developed based on functionality The system is composed of two main components (Figure 1). The first is a living unit that provides the essential domestic functions, and the second is a service unit that contains the kitchen, toilet-WC and storage areas. The service unit occupies a floor area equal to half of the standard cube. When this half-cube is paired with its symmetrical counterpart and the hexagonal openings are aligned, it generates fluid spatial sequences that can be adjusted to a wide range of use scenarios (Carbone, 2019). Because the structure is modular and can be clustered according to user density, it supports different balances of social interaction, privacy and safety. In addition, the half-scale independent form of the service unit reinforces social-spatial interfaces that respond to the diversity of user behaviors (Blain & Duport, 2022).

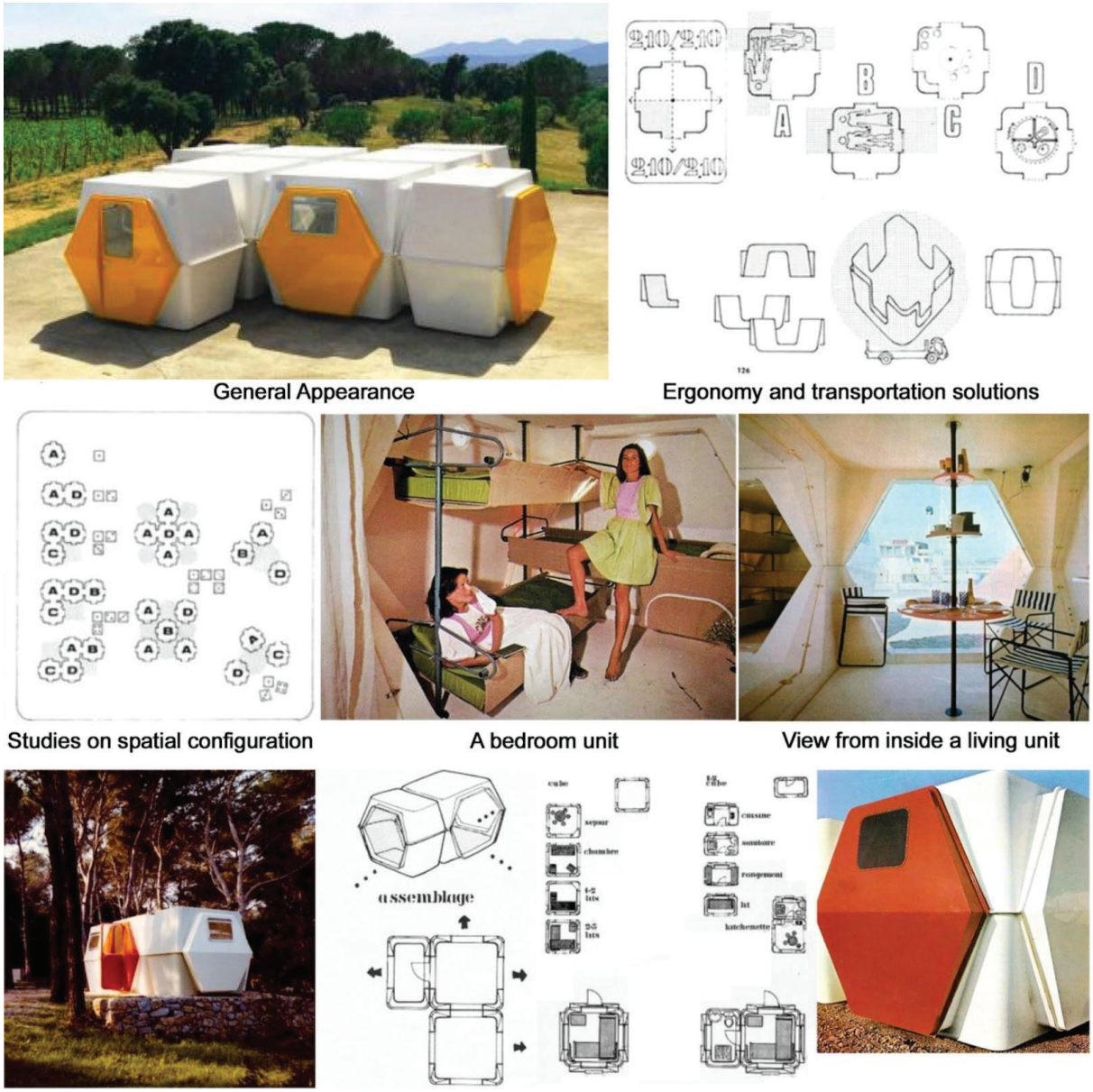

Figure 1. Technical details, façade images, and interior space appearances in the Hexacube Shelter model (Rojo, 2024).

Customization opportunities that enhance users' feeling of identity inside the area are made possible by the capacity to close openings in accordance with practical and aesthetic choices. Through its recognizable geometric language, the system allows the area to evolve into a culturally meaningful domain shaped by lived experience rather than fixed prescription. In this respect, the spatial configuration occupies an intermediate position between designer intent and user-driven adaptation, enabling continuous reinterpretation over time (Rojo, 2024). Unlike a static structural system, this module has an expandable infrastructure composed of plug-in and removable integrated elements. The resistance of polyester coated rigid foam shells to lateral loads, moisture and biological degradation, combined with the lightweight shell geometry, optimizes both structural integrity and comfort performance (Blain & Duport, 2022). The modular shell form, which makes limited contact with the ground, offers site adaptability that allows it to be placed on different topographies with minimal intervention and provides flexibility in settlement decisions. The transportable composite modules, designed as half cubes to facilitate handling and capable of being transferred by truck, trailer, railcar or helicopter, together with their demountable components that do not require a steel

frame, enhance logistical efficiency and industrial scale producibility, transforming the system into a standardized cellular settlement model (Carbone, 2019).

4.2. MobArch

MobArch is a post disaster modular settlement and temporary shelter design project in Istanbul in 2003, supported by İstanbul Teknik Üniversitesi, İstanbul Büyükşehir Belediyesi and the European Commission (Şener & Altun, 2009). In this project, sustainability principles such as preventing environmental pollution, selecting materials that do not contain harmful emissions and ensuring recyclability were followed.

The spatial organization of MobARCH creates a fluid pattern of use within the temporary shelter unit, separating private and common areas through a central semi open space. This spatial configuration allows the unit to be adapted both to individual living practices and to spatial and functional connections at the neighborhood scale (Şener & Altun, 2009). With the layout adopted in the structure, it becomes easier to establish a balance of social interaction, privacy and safety among users, while the limited typological variety identified in previous research is seen to partially circumscribe socio spatial variation (Karaoğlan & Alaçam, 2018). The fact that the semi open area can be customized by users makes it possible to reproduce culturally familiar references and strengthens the role of space as a carrier of identity.

From a material and building-physics perspective, indoor comfort emerges through the combined performance of the sandwich panel system, mineral wool insulation, and the inherent thermal properties of wood (Figure 2). Rather than functioning as isolated components, these elements operate as an integrated envelope that balances thermal efficiency with structural performance. The use of lightweight prefabricated components further supports this balance by enabling rapid assembly while maintaining functional efficiency on site.

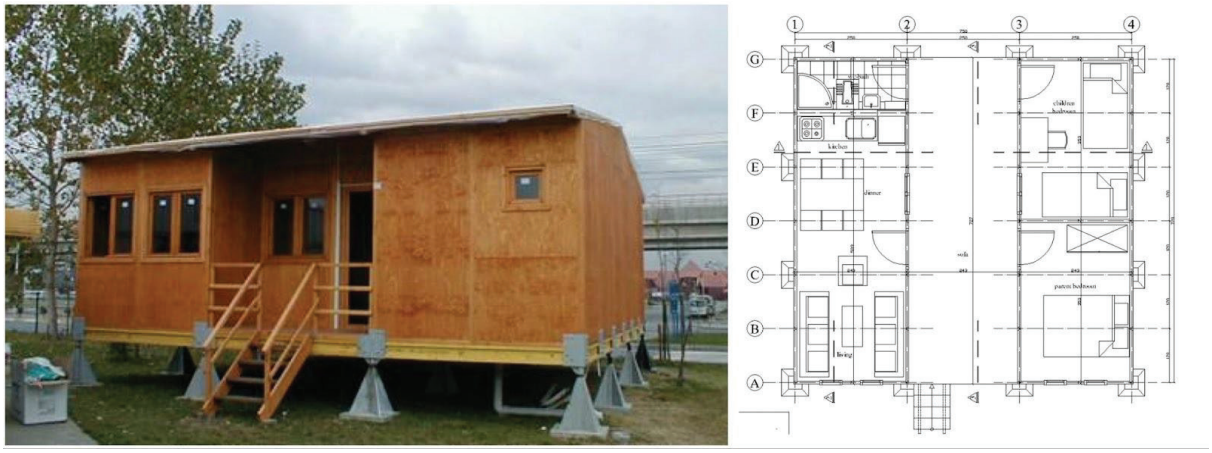

Figure 2. The MobArch prototype and its floor plan (Şener & Altun, 2009).

Prefabricated foundation systems play a critical role in minimizing ground disturbance and expanding installation flexibility across diverse terrain conditions. This approach supports adaptable settlement strategies by allowing structures to be positioned with minimal site intervention. At the material–technology scale, the use of wood as a recyclable, low-emission, and natural resource-based material responds to sustainability criteria while simultaneously enhancing production efficiency, portability, and speed of assembly within an integrated construction system.

4.3. Onagawa Container House

The town center of Onagawa experienced extensive destruction following the 2011 earthquake along the Pacific coast of Japan's Tohoku region and the subsequent tsunami. In the aftermath of the disaster, the Japanese government initiated efforts to diversify short-term housing solutions, prompting the exploration of alternative construction strategies. Within this context, Shigeru Ban proposed multi-storey housing units constructed from shipping containers. The adoption of vertical building typologies was not merely a design preference but a response to both tsunami risk and the scarcity of flat land resulting from the region's mountainous topography (Hikone & Tokubuchi, 2014). Beyond enabling rapid construction, this approach demonstrates a clear sensitivity to local terrain while also supporting economic sustainability (Figure 3).

Figure 3. Construction and interior space Images, site plan, and plan schemes of the Onagawa House (AV Monographs, 2017).

Ban's container-based housing scheme introduced a spatial configuration defined by staggered stacking. This arrangement separated living modules from sleeping and bathroom units, allowing the settlement to be reconfigured both vertically and horizontally over time. Such flexibility made it possible to articulate varying degrees of social and private space within a compact settlement structure (Hikone & Tokubuchi, 2014; AV Monographs, 2017). Through adaptable typologies capable of accommodating different household sizes, this construction logic established a balance between communal interaction and individual privacy, thereby contributing to community-based recovery processes and supporting the continuity of everyday life through an integrated infrastructural framework (Özden & Özden, 2023). In line with the design criteria, three housing types were

developed: units of 19 m² for one or two people, units of 29.7 m² for three to four people, and units of 39.6 m² for families of four or more. The “Plus Box” modules used as the container frame type offer a high potential for large spans, allowing a reinterpretation of the simple spatial layouts characteristic of Japanese architecture. In addition, this frame type has strengthened spatial familiarity and supported identity production by making it easier for users to transform their living spaces according to their personal routines, belongings and cultural habits (Yılmaz, 2021).

The cladding materials and exterior panels are made of fire resistant materials, and the rigid frame behavior of the containers allows acoustic performance, thermal protection and structural stability to be addressed together, enabling the units to provide safe living environments suitable for multi storey use (AV Monographs, 2017). The need for obligatory elevated siting imposed by the mountainous morphology of the region was addressed with minimal intervention in the topography thanks to the lightness and modular stackability of the containers, making it possible to carry out post disaster spatial resettlement in harmony with environmental requirements (Hikone & Tokubuchi, 2014). Even the existing connection capacity of standard containers, when combined with the demountable frame type modules, has enhanced economic sustainability and construction speed by enabling rapid production, easy transportability and industrial scalability. Overall, the system has formed a holistic temporary shelter model that unites logistical efficiency with structural logic.

4.4. CODEMOSCH

Pérez-Valcárcel et al. (2025) conducted a research project in Spain in 2020 titled “CODEMOSCH: Expandable and Modular Humanitarian Disaster Structures”, focusing on building solutions inspired by emergency shelters in developed countries. One of the main focal points of the project is temporary shelters and transitional housing. The prototype created within the scope of the project was installed on the A Zapateira Campus.

The CODEMOSCH prototype offers a reconfigurable solution at a level that can meet both temporary shelter and transitional housing needs in its spatial organization, through a structural logic that allows space to expand by means of a foldable accordion system and two different typologies (2.5 and 7.5 metres) (Figure 4). In the typologies considered, the dormitory oriented layout of Type I and the separation of sleeping and living areas by a W.C.-bathroom unit in Type II create zones that can be shaped according to user density. This zoning establishes an interior layout that controls levels of social interaction and boundaries of privacy between users under intense use of the emergency shelter space. In addition, furniture that can be transformed according to daytime and nighttime use, especially in the living area, generates a socio-spatial flexibility that accommodates the personalization behaviours of different user profiles. The separation of sleeping and living functions produces an interior organization that approximates culturally familiar spatial arrangements. The possibility of stacking the units up to three storeys, as in the Onagawa example, allows the reproduction of compact settlement models based on vertical densification and thus facilitates the relationship of the settlement with familiarity and patterns of use (Hikone & Tokubuchi, 2014; AV Monographs, 2017).

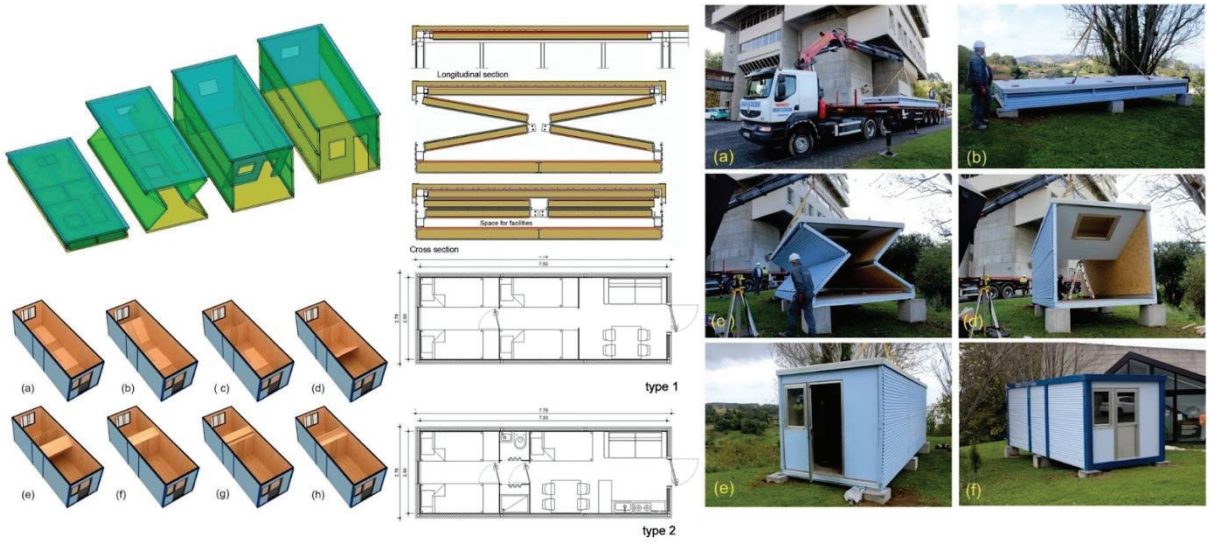

Figure 4. Two and three-dimensional technical drawings, installation steps of the prototype in the CODEMOSCH model (Pérez-Valcárcel et al., 2025).

The OSB floor panels, mineral wool insulation, PVC roof membranes and galvanized steel components that make up the structure integrate thermal performance, fire safety and structural strength within a single system. The fact that the load bearing system allows the foldable wall and roof planes to be assembled without requiring specialized expertise reveals a user-oriented construction strategy. The platform, designed to be adaptable to site conditions, develops a settlement strategy that can accommodate terrain slopes and irregular surfaces, enabling similar performance to be achieved on different topographies. At the material-technology scale, the modular frame supporting the opening and closing movement of the accordion system offers a design logic compatible with local production capacity. The use of OSB-based components, steel connections and mineral wool both rationalizes production costs and provides a set of components that can be adapted to various contexts. In this way, with its portability and modular configurations that can redefine space according to user needs, the system holistically responds to the multilayered spatial requirements extending from temporary shelter to transitional housing, in both technical and socio-cultural dimensions.

4.5. Ensamble House

Pérez-Valcárcel et al. (2024) examined the modular housing type produced by the Ensamble Company on the A Coruña University Campus in Spain in 2019 and, based on this evaluation of its potential, developed a new transitional container housing design.

The transitional shelter container model developed by Pérez-Valcárcel et al. (2024) on the basis of Ensamble Company's modular housing typology measures 2.70 × 7.70 m and, with its mezzanine level, offers a compact yet flexible spatial organization of 27.2 m². The separation of the bunk-bed sleeping units, mini kitchen and transformable living area on the ground floor from the mezzanine level, which functions as the main bedroom, has enabled circulation within the dwelling to be structured with a clear hierarchy. The possibility of expanding the basic capacity of six people up to eight, and, in configurations where two modules are combined, the creation of shared living-kitchen spaces in addition to two bedrooms each on both the ground and mezzanine levels, has allowed socio-spatial density to be adapted to different household types and has made it possible to

establish a social balance that supports both collective life and privacy zones among user groups (Figure 5).

The vertical separation provided by the mezzanine and the flexible character of the living area in everyday use have ensured compatibility with different cultural living practices, lending the space familiarity and personal patterns of use; this has enhanced the cultural adaptation capacity of the modelled unit and strengthened its character as a form of transitional housing.

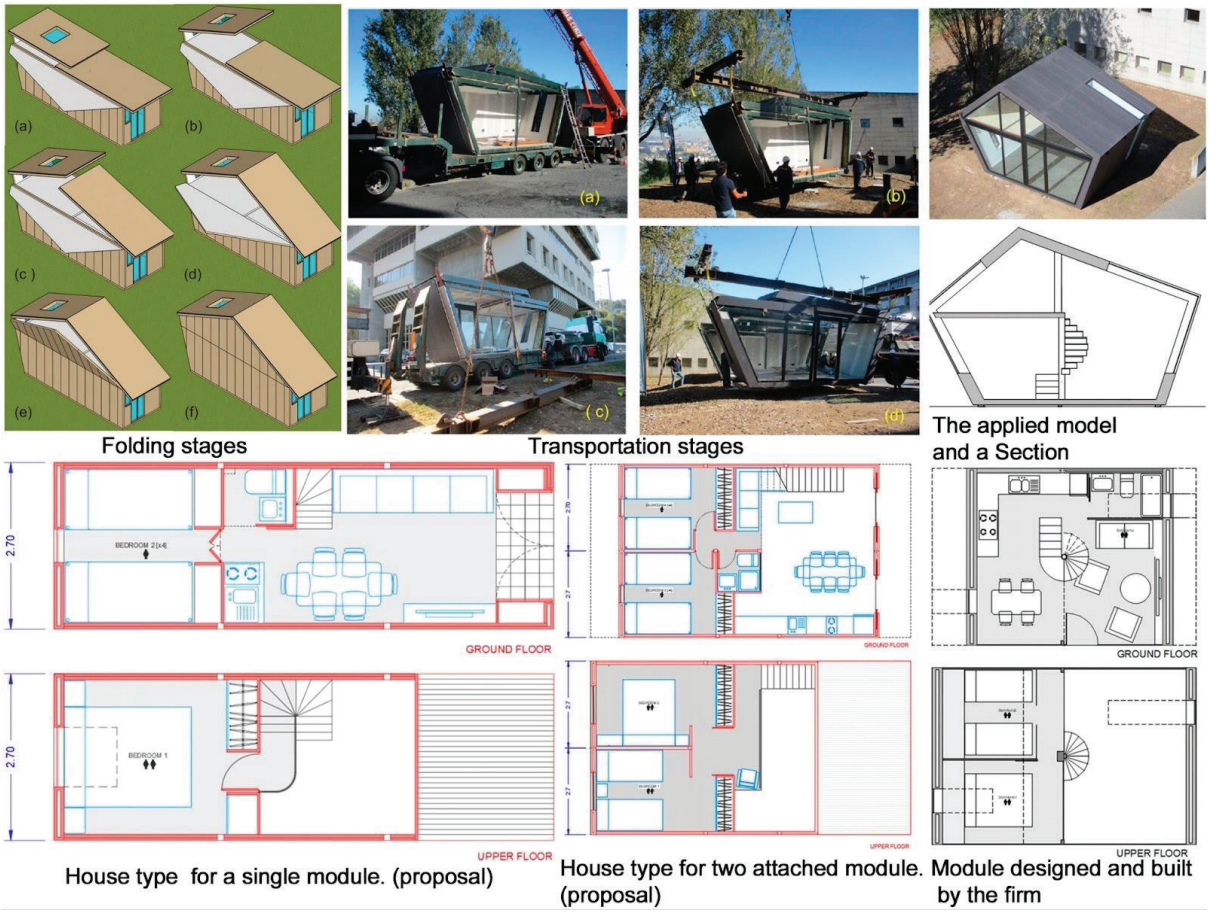

Figure 5. The images and technical drawings of the Emsamble prototype (Pérez-Valcárcel et al., 2024).

In the realized prototype, the absence of interior partitions and the on-site opening of the roof section to install the mezzanine components combined the structural system with a partially foldable logic, integrating thermal and structural performance with the on-site assembly process. From a climatological perspective, the gypsum board interior surfaces, cement based exterior claddings and OSB based floor-ceiling components demonstrate favourable resistance to climatic effects such as rain and wind. Optimizing the box height to 3.60 m in line with transport regulations has increased the logistical feasibility of the prototype under different geographical conditions and facilitated site access. In terms of material selection, the shift in the produced prototype from reflective aluminium panels reinforced with wood fibre and resin profiles, as proposed in the model, to cement based trapezoidal sheets shows that the design offers a technological framework that can be adapted to local production capacity, standards compliance and cost parameters.

4.6. Expandable House

Chu (2012) proposed, in 2012, a design in Japan in which a shelter model could expand through mobile and foldable systems as an alternative solution to the housing problems that emerged after the 2011 earthquake and tsunami disasters.

The proposed shelter model creates a foldable spatial organization in which a fixed central core works together with mobile volumes positioned on both sides, offering a spatial arrangement for post-disaster temporary shelter that can remain compact when needed and expand when required (Figure 6). Around the fixed module that contains service units such as the bathroom-WC and kitchen niche, the mobile parts that can be opened and closed by means of an accordion mechanism generate units that require minimal volume when in the closed position, while in the open position they transform into bedroom and living areas, defining a flexible interior volume ranging between 19–42 m². This open-close spatial sequence enables users to organize both their daily routines and their social interaction and privacy requirements according to changing spatial scenarios, thereby contributing to the establishment of psychosocial balance in the disaster context.

Figure 6. The container type developed Chu (2012).

The fact that the floor plane functions as a terrace when the enclosed volume is not in use increases socio-spatial diversity through semi public–semi private usage possibilities. The open–closed states of the mobile surfaces produce an experience aligned with the spatial rhythms of the concepts of “Ma” and “Mu” in Japanese culture and, by allowing voids to be perceived not as a lack but as a potential field, enable users to add a culturally familiar layer of meaning to the space (Ek, 2023). According to Ek (2023), the terrace plane under consideration and the movement of the panels allow the space to be reshaped through temporal continuities and pauses. Surfaces supported by

origami techniques and the contemporary interpretation of the scissor mechanism found in Mongolian yurts integrate with the movement principle of the load bearing system, supporting the structural logic of the foldable system, while the fixed module claddings composed of fabric covered thermal insulation panels, steel sheets, glass fibre and composite components optimize thermal behaviour, strength and protection against weather conditions.

Resolving the geometric gaps that occur when the foldable panels are compressed with PVC covers allows controlled natural light to enter the interior, creating a light–shadow experience that supports both energy performance and the psychological recovery process. As Lin (2021) notes, this variability in the amount of light reduces the sense of isolation associated with enclosed space for disaster victims and helps them establish a perceptual connection with the outside environment. Taken together, these design decisions reposition the system as a temporary shelter model capable of accommodating diverse site conditions while maintaining a high level of functional and cultural adaptability. Such an approach becomes particularly relevant in crisis contexts where rapid on-site assembly is required and spatial solutions must remain responsive to both practical constraints and lived experience.

5. DISCUSSION: SPATIAL BELONGING IN CUSTOMIZABLE SHELTERS

The design approaches of the shelter examples we have examined differ from one another. However, these examples share common features that support a diversity of models capable of adapting to conditions in potential disaster situations. Their positive differences also illustrate the breadth and flexibility of this potential.

In terms of spatial organization, Hexacube offers, in the horizontal direction, a higher range of possibilities for expansion in all directions compared to the other examples in terms of flexibility. Ensamble and Extendable shelters also partially allow temporal change within the dwelling both vertically and horizontally. All of the examples, in line with their functional characteristics, introduce distinctive spatial separations, particularly with respect to privacy. For instance, they show that the distinction between individual and social relations in such structures can sometimes be achieved through a mezzanine solution, sometimes through the creation of a sofa-like central hall, or through a linear layout with a fixed service core placed at the centre. When other criteria are taken into account, it is possible to say that solutions incorporating a linear hierarchical order are more common.

In the sociological context, the possibility of Hexacube growing in different directions and forming alternative configurations in line with the number of users or spatial needs is significant in that it allows variations in container city layouts. Through such configurations, the boundaries of open and semi open areas can be clearly defined and, under challenging conditions, the formation of different social solidarity interactions can be enabled. Although there is a problem of repetition in the urban layout, the semi open entrance courtyard proposal supports interaction with the external environment and the sense of togetherness. In Chu's Expandable House example, the foldable terrace feature is also noteworthy. By adding the notion of temporality, this project takes a step that considers psycho social relationships. Alongside these, as in the Onagawa example, considering multi storey settlement proposals in regions with high density (for instance, cities like Istanbul) or with difficult terrain conditions, and seeking differentiation in the vertical dimension as well, is valuable in terms of spatial organization capacity. At the same time, the existence of a floor limit points to the need to take into account psychological factors such as fear and safety that may arise after disasters like earthquakes.

From the perspective of cultural adaptation, the concept of space in all of the examples goes beyond a purely physical shelter. In other words, there are similarities with Norberg-Shulz's (1971) perspective, which defines space as a bearer of meaning and identity in spatial approaches. For example, the sofa and hayat solution in MobArch, in a sense, refers to the traditional Turkish house. In the Expandable house, the proposal for the use of enclosed and semi open spaces shows a similarity with the "moya"-"hisashi" (main space-transition space) relationship in traditional Japanese houses. In the Onagawa container, a Japanese minimalist approach is present in the interior layout and material selection, combined with a modern perspective (Yılmaz, 2021). In the CODEMOSCH example, the designers stated that the model was developed within the framework of European standards as a response to the problem of cultural adaptation. In contrast, Hexacube is much more general purpose compared to the others. However, it is still possible to say that its flexible modular character can be adapted to different cultural contexts.

When considered in terms of environmental factors, the way shelters make contact with the site on which they are placed is of primary importance for sustainability. The MobArch and Onagawa shelters are designed on reusable individual foundations. The approaches in the CODEMOSCH and Ensamble examples are similar, although concrete is proposed instead of steel. Intervention in the ground has been kept to a minimum. Hexacubes are placed directly on the ground, but their base area occupies a minimal footprint due to their limited size. These aspects indicate a certain degree of sensitivity. Furthermore, above all the Onagawa container example, as well as CODEMOSCH and Ensamble with its mezzanine solution, provide alternatives for disaster areas where physically suitable land is scarce.

From a climatic standpoint, material selection is also important. In terms of the materials used, Hexacube and the Expandable shelters differ from the others. These examples offer a suitable option for certain regions (warm and temperate climates), whereas the others address a broader geographic spectrum. In the remaining examples, the primary material is wood. As Wright (1928) also stated, wood offers positive contributions from psychological perspectives such as a sense of familiarity and spiritual comfort, and in the given examples it is combined with specific protective measures. Nevertheless, in such structures, fire safety and the need for regular maintenance to prevent moisture and biological deterioration remain important.

In terms of material selection and technology, transport emerges as a significant criterion. As indicated in the examples, the overall dimensions of the models (2.5*2.5 m, 7.5*7.20 m, 2.70*7.70 m) have been developed in line with the maximum width limits of transport vehicles. In all of the examples, dimensions have been envisaged that can be adapted to vehicle sizes. This situation creates a constraint or weak point for shelter examples that offer diverse parameters related to spatial belonging. From the perspective of an optimum solution, Ensamble and Expandable shelters draw attention as the examples requiring the least processing in terms of the assembly of components, while CODEMOSCH offers ease of both installation and transporting a larger number of units at once. However, thanks to the lightness of its materials, Hexacube demonstrates that many more components can be transported and that a greater number of units can be assembled with the support of fewer people. MobArch, in a more traditional sense, directs towards on-site construction, whereas Onagawa, through a hybrid approach, proposes both bringing together skeletal components on site and positioning ready-made shelter blocks together. In this regard, it is evident that foldable systems offer significant advantages, yet problems such as mechanical fatigue and leakage, and the associated needs for maintenance and repair, still remain open to further development.

In particular, the Onagawa, CODEMOSCH and Ensamble examples, similar to Habraken's (1972) open building concept, provide the possibility of freely reconfiguring subsystems. While these examples meet criteria such as rapid production, controlled access and orderly spatial hierarchy, they also hold the potential to foster the formation of social spaces that enable the re-establishment of everyday life. At the same time, since vertical circulation and walking platforms are required for multi storey examples, there is a need to develop new rational infrastructural solutions to counter increased costs and new risks related to accessibility.

6. CONCLUSION

This study examines post disaster temporary shelter solutions from the perspective of spatial belonging, which is one of the key problems encountered in practice. It reveals, through specific examples, the factors that enhance user experience and satisfaction under difficult conditions and the states and relational networks of the abstract and concrete architectural components associated with these factors. Although the number of examples presented is limited, there are certain generalizable common characteristics that influence this approach. Among these, it is possible to list design criteria such as modularity, the potential for reconfiguration according to conditions, spatial socialization, cultural familiarity, environmental integrity and materials considered from a socio psychological standpoint. Although their approaches or areas of focus differ from standard shelter solutions, all of the examples have, to varying degrees, offered users direct or indirect participation in spatial formation and the possibility of personal customization. Naturally, this has a positive effect on the formation of a sense of belonging.

It is evident that modular and foldable systems, due to their advantage of delivering a greater number of units to disaster areas in a short time, should not be limited solely to the emergency shelter phase but also be integrated into transitional housing processes. The transformability offered by movable elements increases the service life and flexibility of the shelter by accommodating users spatial needs as they change over time. As observed in most of the examples, the possibility of articulating modular units to one another enriches spatial diversity and offers broader design possibilities at the settlement scale. Materials with strong biophilic effects, such as wood, support user well-being by providing a natural sense of warmth; however, considering fire resistance and maintenance requirements, material choices need to be made in a balanced manner. Light coloured interior surfaces, fire resistant components and claddings that offer ease of maintenance, as in the examined examples, both enhance spatial spaciousness and ensure suitability for disaster conditions.

In addition, not only the individual design of shelters, but also their positioning within the settlement area, constitutes a design scale that directly affects social interaction and the need for open space. The balanced distribution of open, semi open and enclosed areas, the provision of visual, physical and psychological interaction with the external environment, and the avoidance of monotonous settlement layouts play a critical role in the formation of spatial belonging. As seen in the examined examples, the creation of interfaces that allow both individual and collective living accelerates the social recovery processes of disaster victims.

In conclusion, although existing studies provide a valuable starting point, more comprehensive research is needed to develop sustainable, user-centred and context-sensitive shelter solutions after disasters. It is of critical importance for future studies to be supported by data obtained from real field applications and for the relationship between design and user feedback to be transformed into a continuous cycle, so that temporary shelters can evolve into qualified living environments.

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Chapter 7

SCIENTIFIC TRENDS ON OAK (QUERCUS): A BIBLIOMETRIC APPROACH FROM NATURE TO DESIGN

Ayşenur BAYSAK[1]

1 Master's Student, Munzur University – ORCID ID: 0009-0009-3252-9009

INTRODUCTION

The oak genus (*Quercus*), comprising over 400 species, is one of the most significant woody plant groups, widely distributed across the temperate and subtropical zones of the Northern Hemisphere. These species hold great ecological, economic, and cultural value. Oaks are key species in temperate forests, playing a central role in maintaining biodiversity, carbon storage, and ecosystem stability (Cavender-Bares, 2019). Due to their rich biodiversity, contributions to soil fertility, and roles in the carbon cycle, oaks form the backbone of forest ecosystems. In particular, their deep root systems, erosion-preventing characteristics, and long lifespan make them foundational species that support the continuity of many ecosystems. *Quercus* species are not merely botanical entities; they function as ecosystem engineers, forming complex webs of life by hosting numerous species of insects, fungi, birds, and mammals.

From an ecological standpoint, oaks play a crucial role in regulating the carbon cycle in terrestrial ecosystems and in soil formation processes. According to Camponi et al. (2023), soil–plant interactions shape the physical, chemical, and biological properties of soil and control the dynamics of nutrient cycles through the turnover of soil organic matter. Through their root systems, they help maintain soil moisture balance, support microbial activity, and ensure the continuity of biological cycles. By shedding their leaves, they contribute to the formation of the humus layer, and the high tannin content in their leaves helps regulate the soil's pathogen balance. Therefore, *Quercus* species are seen not only as carbon sinks but also as sustainers of natural filtration and soil regeneration processes. Moreover, their photosynthetic resilience and physiological adaptations to drought grant them a special status among forest species resistant to climate change.

Oak forests are widely distributed across Europe, North America, Asia, and North Africa. According to Xiong et al. (2020), the *Quercus* genus possesses the highest number of species and the widest distribution range among oak species, occurring naturally across Asia, Europe, North America, and North Africa. This indicates that the *Quercus* genus represents ecological diversity across different continents. In Europe, countries such as Spain, France, Portugal, and Turkey are among the natural habitats of various oak species, while in North America, species such as *Quercus alba*, *Q. rubra*, and *Q. macrocarpa* stand out both ecologically and economically. In Asia, oak species play significant roles in both local ecosystems and traditional forest product industries.

Moreover, as Valbuena-Carabaña et al. (2005) noted, gene flow and hybridization are quite common among species within the *Quercus* genus, enhancing the evolutionary flexibility and adaptive capacity of oaks to environmental conditions. Similarly, McVay et al. (2017) emphasized that genetic exchange among oak species blurs species boundaries but reinforces ecological resilience. This high hybridization potential is one of the main factors that increase the genetic diversity and strengthen the ecological resilience of the *Quercus* genus.

From an evolutionary perspective, oaks have been a dominant component of terrestrial ecosystems since the Pliocene epoch. This long evolutionary history has enabled *Quercus* species to adapt strongly to climatic fluctuations, fire regimes, and soil changes. According to Wang et al. (2024), "*Quercus* is a keystone genus in the forests of the Northern Hemisphere; its broad distribution across diverse ecosystems and long evolutionary history make it an ideal model for studying the genomic foundations of ecological adaptation." Traits such as xerophytic leaf morphology, stomatal control, and defense/structural pathways associated with lignin in wood tissue are consistent with this molecular basis of adaptation. The authors report "expansions and tandem duplications in certain gene families contributing to the physical and chemical defense of plants" (e.g., cuticle biosynthesis and

oxidosqualene cyclase genes). Therefore, oak species are increasingly recognized in many countries today as resilient components of ecosystems in climate adaptation policies.

Turkey is one of the world's richest gene centers for the *Quercus* genus, with approximately 18 native oak species. According to studies conducted in the Marmara Region, about 26.34% of the country's forests are covered by oak woodlands (Şahin, 2014). These areas are of critical importance both ecologically and socioeconomically. Oak species in Turkey are distributed across a wide ecological range—from the high mountain ecosystems of Eastern Anatolia to the maquis formations of the Aegean and Mediterranean regions. In particular, the İspir oak is a unique species found in northeastern Anatolia, representing the ecological resilience of local ecosystems.

As emphasized in the *Oak Acorn Action Plan (2022–2026)* by the General Directorate of Forestry (2022), oak species are not only components of ecosystems but also socio-economic resources that support rural economies through timber production, firewood, tannin extraction, mushroom cultivation, and livestock activities. For this reason, oak forests form the foundation of both ecological and social resilience in many regions of Turkey.

Economically, oak species hold significant value in the furniture, flooring, wine barrel, cork, and biomaterials industries. "Oaks provide valuable raw materials for furniture, flooring, barrel making, firewood, as well as tannin and cork production from their bark" (Kremer & Hipp, 2020). Oak wood is one of the essential raw materials in the furniture industry due to its high durability, aesthetic texture, and workability. Oak bark is rich in tannins, which are used in leather processing, dye manufacturing, and plant-based extract products. Furthermore, "the cork industry produces a wide variety of by-products; these include biologically active compounds such as tannins, phenolic acids, and terpenoids, which are being explored in the cosmetics and pharmaceutical sectors" (Carriço et al., 2023). This demonstrates that *Quercus* has become a versatile resource, valued not only for traditional forestry products but also for innovative biotechnological applications.

Culturally, oak has held profound symbolic meanings throughout human history. In ancient Greece, the oak was known as the tree of Zeus and was central to sacred forests; in Roman culture, it symbolized strength and permanence as the plant used to craft victory wreaths. In Anatolian cultures, the oak was regarded as an ancestral symbol of nature—its roots signifying connection to the earth, its trunk representing strength, and its shade offering protection. According to Şeyda Büyükcan Sayılır (2021), "Tree cults are common motifs in cosmogonic, cosmological, and underworld myths, frequently appearing in the narratives of different civilizations as the 'World Tree' or 'Tree of Life'." This cultural legacy has turned the oak into more than just a biological entity—it has become a symbol of the continuity of human–nature relations.

Global environmental issues such as climate change, deforestation, and biodiversity loss have made the conservation of oak forests more important than ever. With their high biomass production and carbon storage capacity, oaks serve as crucial natural tools for mitigating the negative impacts of climate change. They also form the foundation of sustainable ecosystems through their roles in maintaining habitat diversity, stabilizing soil, and regulating the water cycle. As stated by Turan Sönmez and Burhan Gencal (2023) in their study on *Quercus cerris* (Turkey oak) stands, "oak species contribute to the ecosystem in a multifaceted way—not only through timber production but also through their fruits, leaves, and bark, which are utilized as animal feed." These features position oak forests at the heart of nature-based solutions.

The conservation of oak species in Turkey is not only an ecological responsibility but also a cultural and economic one. In recent years, increasing forest degradation, drought, and changes in land use have threatened the sustainability of oak forests. However, restoration projects carried out in various regions of Anatolia, local seed banking initiatives, and agroecological practices offer

promising steps toward the recovery of oak species. As stated in Sinan Yücedağ's (2024) study on the relationship between fruit yield and tree diameter in Turkey oak (*Quercus cerris* L.), "oak taxa in our country's forests cover an area of 6.8 million hectares and hold significant potential in terms of non-timber forest products." Especially, the propagation of local oak species and biomaterial-focused studies conducted around Tunceli, Elazığ, Aydın, and Balıkesir demonstrate that *Quercus* research in Turkey is developing both academically and practically.

Oaks are also an integral part of the cultural landscape. Many ancient settlements in Anatolia are surrounded by oak forests, which historically played a central role in human shelter, fuel, belief, and artistic practices. Therefore, oak is not merely an ecological entity but also a symbol carrying Anatolia's cultural memory. According to Leroy (2020), "oak trees have been associated with longevity, strength, fertility, and resilience, serving as symbols representing the continuity of life throughout cultural history." Similarly, Lazic (2021) emphasizes that oaks have been both a practical and symbolic part of human life since ancient times, noting that "acorn remains found in caves indicate that oaks were an important food source in early human settlements and also held a place in cultural life as a sacred element associated with deities." Today, in research on art, design, and environmental aesthetics, the oak motif is reinterpreted as a symbol of the symbiotic relationship between nature and humans.

This study aims to examine scientific publications on oak (*Quercus*) through a bibliometric approach, revealing the historical development, thematic trends, and international research networks in the field. Accordingly, 30,474 records obtained from a search conducted on October 5, 2025, in the Web of Science Core Collection database were analyzed. The findings indicate that *Quercus* research is gaining increasing importance not only in ecological dimensions but also in the contexts of climate change, sustainable material science, and environmental policy. Thus, oak is addressed as a central element of a multidimensional scientific approach extending from nature to design.

The significance of this research lies in being one of the first comprehensive studies to holistically analyze the scientific literature related to *Quercus* species. Until now, oak research has primarily focused on ecology, forestry, genetics, or botany, but the connections between these fields have not been systematically investigated. This study contributes to framing oak not only as a biological but also as an environmental, economic, and cultural entity by revealing interdisciplinary interactions. Moreover, the findings demonstrate the global trends of oak-related studies linked to sustainable development goals and provide a guiding framework for future research.

METHOD

In this study, a bibliometric analysis method was used to reveal the trends, research networks, and thematic focuses of scientific publications on oak (*Quercus*). Bibliometric analysis is a research approach that enables the quantitative evaluation of scientific production. This method allows for the systematic examination of the scientific structure, author relationships, institutional connections, and thematic orientations based on numerical data from studies published in a specific field.

The concept of bibliometrics was first introduced by Pritchard (1969) and is based on the statistical measurement of scientific knowledge. This approach made it possible to analyze scientific production not only qualitatively but also quantitatively. In later periods, citation analysis models developed by researchers such as Small (1973) and Garfield (1979) transformed the bibliometric method from mere publication counting into a multilayered structure that allows understanding of information flow, interaction intensity, and scientific communication.

Bibliometric analysis objectively reveals the general direction and structural relationships of scientific production, especially in cases where qualitative review is limited in extensive literature. This method statistically evaluates variables such as publication count, citation frequency, author collaboration, keyword co-occurrences, and geographic distribution. "Bibliometric analysis is a powerful and rigorous approach for exploring large volumes of scientific data and systematically uncovering the evolution, emerging topics, and interaction networks of a field" (Donthu et al., 2021). Thus, it provides comprehensive information about the development over time, focused themes, and level of international interaction in a specific research area.

The main reason for choosing the bibliometric method in this study is the multidisciplinary nature and global prevalence of *Quercus*-related research. Studies on oak species are conducted across various disciplines such as ecology, forestry, genetics, biotechnology, material science, and environmental policies. Analyzing this multidimensional structure with quantitative mapping methods rather than qualitative review objectively reveals the direction of scientific production. Additionally, "bibliometrix is an open-source tool designed for comprehensive science mapping analyses; it enables the holistic production of bibliometric outputs such as collaboration networks, co-citation, and keyword co-occurrence maps" (Aria & Cuccurullo, 2017). Bibliometric analysis is also an appropriate method to evaluate the international visibility, citation impact, and relationship with sustainable development themes of oak research.

The data for the study were obtained from the Web of Science (WoS) Core Collection database. The search was conducted on October 5, 2025, using the keyword "Quercus" in the "All Fields" category. Only publications from 1980 to 2025 were considered during the search, resulting in a total of 30,474 records. The dataset included articles, proceedings papers, review-type publications, and book chapters. Documents with low scientific contribution such as news notes, abstracts, forewords, conference invitation letters, and similar materials were excluded from the analysis.

Web of Science is widely preferred especially in bibliometric studies due to its reliability, index coverage, and citation integrity (Mongeon & Paul-Hus, 2016). The obtained data were classified based on variables such as year, author, country, institution, journal, publisher, language, document type, and citation count. During this classification process, WoS's built-in "Analyze Results" and "Create Citation Report" tools were utilized.

The data were then transferred to Microsoft Excel, where data cleaning procedures were carried out. In this phase, duplicate records were removed, and spelling variations in author names (for example, "Penuelas J." and "Peñuelas J.") were manually corrected. Data cleaning is a critical step for the accuracy of bibliometric analyses; "data normalization ensures the accuracy of co-authorship and co-citation networks by resolving inconsistencies in author and affiliation data" (Zupic & Čater, 2015).

The visual and relational analysis of the data was conducted using the built-in tools of the Web of Science system and the VOSviewer software. Visualization tools play an important role in the interpretation of bibliometric network structures. These tools enable "bibliometric mapping [that] allows visualization of scientific domains, revealing clusters and thematic structures within research fields" (van Eck & Waltman, 2010). The analysis results were evaluated under various categories including years, document types, countries, institutions, authors, journals, publishers, open access types, and sustainable development goals.

This approach allowed the examination of trends in the *Quercus* literature directly through the reliable statistical tools provided by Web of Science data, without relying on visual mapping software.

Thus, the study quantitatively revealed the scientific development, geographic distribution, and thematic focuses of the field using a simple yet highly accurate method.

During the data analysis process, the obtained records were evaluated through quantitative indicators. Each publication was classified based on variables such as year, type, language, country of origin, number of authors, publishing journal, affiliated institution, publisher, and total citation count. This classification comprehensively revealed the historical development, geographic distribution, productivity level, and scientific visibility of *Quercus*-related research. Similarly, in Umut Zan's (2012) study, collaborations and citation behaviors between scientific fields were compared. Additionally, the trend of increase in the number of publications over the years was evaluated to show periods when scientific interest was most intense. Citation analysis was carried out using the "Create Citation Report" tool of the Web of Science system. This tool calculated indicators such as total citation count, average citation rate, and h-index. Uçar and colleagues (2023), in their bibliometric analysis specifically on breastfeeding research in Turkey, addressed impact, collaboration, and author-level analyses similarly using WoS data sets. Since the WoS system allows detailed citation reports for a maximum of 10,000 records per session, citation analysis was conducted on selected sample subsets. Although this did not affect general trends, it created limitations in resolving detailed citation networks. In examinations at country, institution, and author levels, the most productive units were determined based on publication numbers and citation rates.

Thus, it was revealed at which international centers *Quercus* research is concentrated and which researchers have shaped the field. Similarly, analyses at the level of publishers and journals showed on which academic platforms studies on oak are more visible. Data regarding open access types were also examined separately. Classifying the studies as full open access, green access, hybrid, or closed access provided an important comparison regarding the shareability of scientific knowledge and access policies. This analysis made it possible to evaluate the extent to which *Quercus*-related research aligns with open science principles.

In addition, the relationship between *Quercus*-related publications and the United Nations Sustainable Development Goals (SDGs) was examined using the "Sustainable Development Goals" (SDG) module of the Web of Science system. Within this scope, each publication's connection with SDG labels was assessed, and which goals it was most strongly related to—especially Goal 15: Life on Land, Goal 13: Climate Action, and Goal 14: Life Below Water—was identified. The SDG module provides classification support to make the intersection of the literature with sustainability themes visible; similarly, bibliometric analyses in ecological architecture/eco-architecture have revealed sustainability-focused themes through scientific mapping techniques (Burkut & Dal, 2023). Thus, *Quercus* research was evaluated not only in ecological and forestry contexts but also within global environmental policy frameworks.

Among the limitations of the study is that the Web of Science database covers only indexed publications. This resulted in the exclusion of studies published especially in local journals or conducted on a national scale from the analysis. Also, some scientific outputs not included in the WoS database (e.g., graduate theses or institutional reports) could not be evaluated within this scope. On the other hand, bibliometric studies conducted with WoS data have been shown in various fields to be suitable for compiling and summarizing publication types, citation metrics, and network representations with software support (Dal, Burkut, & Karataş, 2023).

In conclusion, this methodological approach objectively allowed the examination of the *Quercus* literature across time, country, institution, and publication type dimensions. The bibliometric method, in this regard, reveals not only the quantitative distribution of publications but also the journals and platforms where the field is visible, dominant themes, and collaboration patterns in an

integrated manner; applications in different disciplines such as cultural-art management have also shown that software-based bibliometric analyses are effective in mapping journal/theme visibility (Tekin, Burkut, & Dal, 2024).

FINDINGS AND DISCUSSION

When examining the distribution of the 30,474 records obtained under the keyword "Quercus" in the WoS database according to document types, it is observed that the highest proportion is in the article type (n=28,351) (Table 1). This situation indicates that scientific production on oak (*Quercus*) is largely shaped through original research published in academic journals. The dominance of article-type publications reveals that oak research is systematically conducted in disciplines such as ecology, forestry, and environmental sciences, and thus the field possesses an institutionalized scientific production line.

Among the documents other than articles, conference papers (n=1,617) constitute a significant second group. This situation shows that *Quercus* research is frequently shared at academic meetings and congresses, particularly addressing interdisciplinary discussions on forestry, botany, and environmental sustainability themes. The presence of conference papers at this rate points to the dynamic and developing nature of the field.

At lower rates are review articles (n=690) and book chapters (n=180). These publication types indicate that research on oak is evaluated not only at an applied level but also within a theoretical framework. Especially, the existence of review studies contributes to the synthesis of the knowledge base on oak species and the holistic analysis of research trends.

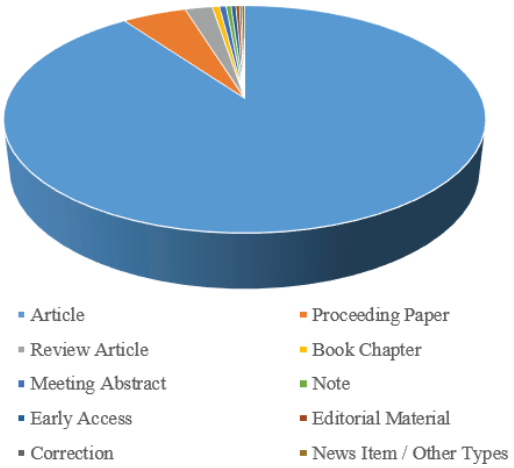
Other document types such as conference abstracts (n=167), notes (n=129), and early access articles (n=117) have relatively small shares but indicate that the field maintains its currency and continuity. Editorials (n=93) and corrections (n=58) point to ongoing methodological discussions and scientific transparency in oak research.

Overall, it is observed that the vast majority of studies on *Quercus* are produced in the form of peer-reviewed journal articles and conference presentations. This picture demonstrates that research on oak has deepened at both theoretical and applied levels and that the field has gained interdisciplinary maturity. Similarly, bibliometric examinations conducted in different scientific fields have also shown that article-type publications are decisive in scientific production, reflecting the institutionalization level of fields (Mongeon & Paul-Hus, 2016). "Most studies in the Web of Science are published as original articles, which constitute the core structure of scientific communication." (Mongeon & Paul-Hus, 2016). Thus, the findings obtained confirm that *Quercus* research similarly has a mature and continuous publication structure.

Table 1. Distribution of Publications on Quercus by Document Type

Document Type	Record Count
Article	28351
Proceeding Paper	1617
Review Article	690

Document Type	Record Count
Book Chapter	180
Meeting Abstract	167
Note	129
Early Access	117
Editorial Material	93
Correction	58
News Item / Other Types	72



When examining the annual distribution of the 30,474 records obtained with the keyword "Quercus" in the WoS database, it is observed that scientific production on oak shows a marked increasing trend especially after the 2000s. When early period records (1980–2004) are examined, it is understood that annual production was quite limited during this period and studies were mostly restricted to taxonomic descriptions and ecological observation reports. This indicates that *Quercus* research was initially approached within a descriptive scientific framework, but starting from the 2000s, it began to be associated with modern ecology, environmental management, and sustainable material sciences.

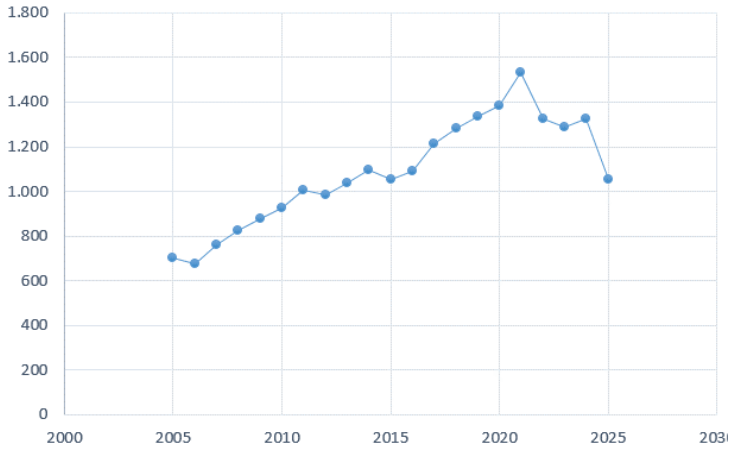
When the period 2005–2025 is examined, a continuous increasing trend in the number of publications on oak is observed (Table 2). Production gained momentum from the early 2010s and reached its highest level after 2020. The year 2021 was the year with the highest production within the period, with 1,533 publications. As of 2024, 1,324 publications have been recorded, and although 2025 data are not yet complete, it has already reached 1,055 publications. These data show that *Quercus* research has consistently intensified over the last five years and scientific interest has been sustained.

Overall, the increase between 2005 and 2025 reveals that oak research has gained interdisciplinary visibility not only in ecological and biological contexts but also in areas such as climate change, carbon cycling, forest management, and material science. In this regard, the *Quercus* literature has become an important scientific axis in discussions of ecological sustainability.

Table 2. Annual Distribution of Publications on Quercus (2005–2025)

Year	Count
2025	1.055
2024	1.324
2023	1.289
2022	1.327
2021	1.533
2020	1.385
2019	1.334
2018	1.282
2017	1.213
2016	1.093
2015	1.052

Year	Count
2014	1.097
2013	1.036
2012	986
2011	1.008
2010	925
2009	878
2008	824
2007	759
2006	676
2005	702



When examining the language distribution of publications obtained with the keyword "Quercus" in the WoS database, it is observed that the highest output is in English (n=29,178) (Table 3). This clearly indicates that oak (*Quercus*) research is largely produced within international academic networks and that English is the dominant language of scientific communication. The high proportion of English publications shows that studies on oak are addressed not only in local ecological contexts but also in global environmental and sustainability discussions.

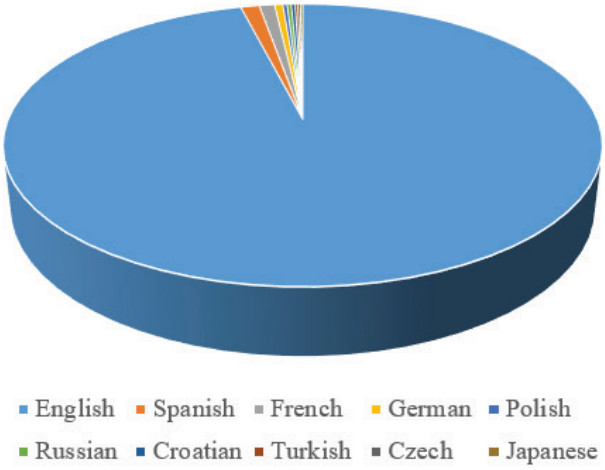
Among the prominent languages other than English are Spanish (n=364), French (n=301), German (n=159), and Polish (n=83). The production in these languages reflects the long-standing research tradition of European countries on oak ecosystems. Particularly, the presence of publications originating from Spain, France, and Germany highlights the importance of *Quercus* species in Mediterranean and Central European ecosystems in terms of biodiversity and climate resilience.

Russian (n=81) and Croatian (n=76) publications indicate the continuation of local ecological research in the Central and Eastern European region. The relatively low number of Turkish publications (n=54) reveals that most studies on oak in Turkey are published in English, while publications at the national level remain limited.

Overall, the dominant position of English in oak research demonstrates that the field is conducted within a global research network and that scientific interaction is shaped at an international scale. Production in other languages points to the presence of regional ecological studies and local biodiversity research.

Table 3. Distribution of Quercus Publications by Language (Top 10 Languages)

Language	Record Count
English	29178
Spanish	364
French	301
German	159
Polish	83
Russian	81
Croatian	76
Turkish	54
Czech	49
Japanese	47



When examining the distribution of publications obtained with the keyword "Quercus" by country in the WoS database, it is observed that the highest output in oak-related research is produced by the United States (n=7,776) (Table 4). The U.S. is followed by Spain (n=4,497) and the People's Republic of China (n=2,565). This distribution indicates that *Quercus* research is concentrated in both North American as well as Mediterranean and East Asian ecosystems.

In Europe, France (n=2,373), Germany (n=2,117), and Italy (n=1,999) make significant scientific contributions to oak research. A large portion of the studies conducted in these countries focus on forest ecosystem adaptation to climate change, soil biodiversity, and carbon cycling. In countries such as Japan (n=1,392) and Portugal (n=1,267), research primarily concentrates on the genetic diversity and conservation strategies of local *Quercus* species.

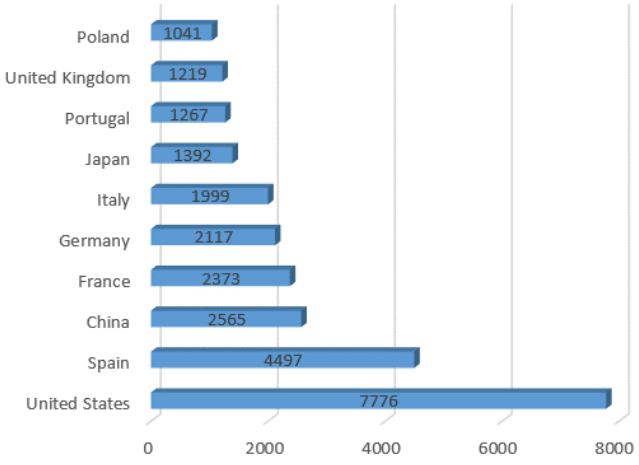
The United Kingdom (n=1,219) and Poland (n=1,041) also play active roles in interdisciplinary projects as part of the European research network. Publications from these countries are related to various fields such as ecological modeling, forest biometrics, and material science.

Turkey appears under two separate entries in the database as "Turkey" and "Türkiye," with a total of 858 publications. This number shows that Turkey holds an active position in global *Quercus* research. Considering the ecological diversity and regional importance of oak species in Turkey, it is anticipated that this productivity will continue to increase in the future.

Overall, oak research demonstrates a broad geographic distribution globally, with a strong scientific interaction network established among countries in America, Europe, and Asia.

Table 4. Distribution of Quercus Publications by Country (Top 10 Countries)

Country	Record Count
United States	7776
Spain	4497
China	2565
France	2373
Germany	2117
Italy	1999
Japan	1392
Portugal	1267
United Kingdom	1219
Poland	1041



Data obtained from the WoS database under the keyword "Quercus" indicate that oak research is concentrated around interdisciplinary studies conducted over many years by a specific group of authors. Most of the prominent names on the list of the most productive authors are internationally influential researchers in the fields of ecology, forestry, botany, and environmental sciences (Table 5).

At the top of the list is Peñuelas J. (n=206), who stands out with studies on ecosystem dynamics, plant physiology, and ecological responses to climate change. Pereira H. (n=145) and Kremer A. (n=132) are important representatives of the field, focusing especially on the genetic diversity and wood properties of *Quercus* species.

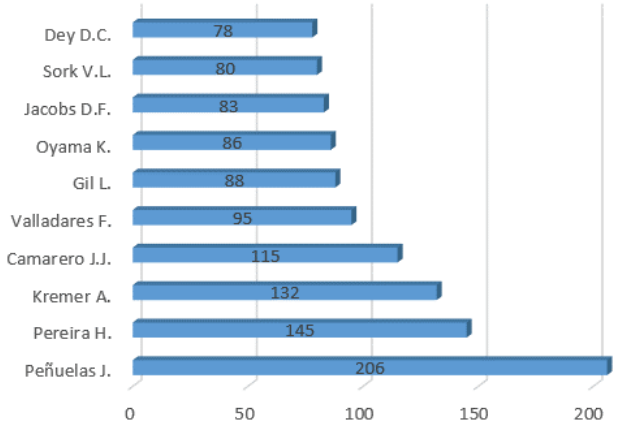
Researchers such as Camarero J.J. (n=115), Valladares F. (n=95), and Gil L. (n=88) are prominent for their field studies on oak ecosystems in Spain and the Mediterranean basin, providing significant contributions on climate stress, drought tolerance, and biodiversity.

Oyama K. (n=86) and Sork V.L. (n=80) have conducted globally influential research on gene flow, population structure, and genetic adaptation processes of oak species. Jacobs D.F. (n=83) and Dey D.C. (n=78) are known for their work on forest restoration and *Quercus* species regeneration in North America.

Overall, it is observed that the majority of productive authors in the *Quercus* literature are of European and North American origin, and the research covers both applied forestry and ecological modeling dimensions. This picture demonstrates that oak research develops around individual areas of expertise while forming an interactive academic network on a global scale.

Table 5. Top 10 Most Productive Authors in Quercus Publications

Author	Record Count
Peñuelas J.	206
Pereira H.	145
Kremer A.	132
Camarero J.J.	115
Valladares F.	95
Gil L.	88
Oyama K.	86
Jacobs D.F.	83
Sork V.L.	80
Dey D.C.	78



The data obtained from the WoS database under the keyword "Quercus" indicate that the institutions publishing the most research in the field of oak studies are predominantly based in North America and Europe. The leading institutions in terms of publication numbers are research centers and universities focused on ecology, forestry, and environmental sciences (Table 6).

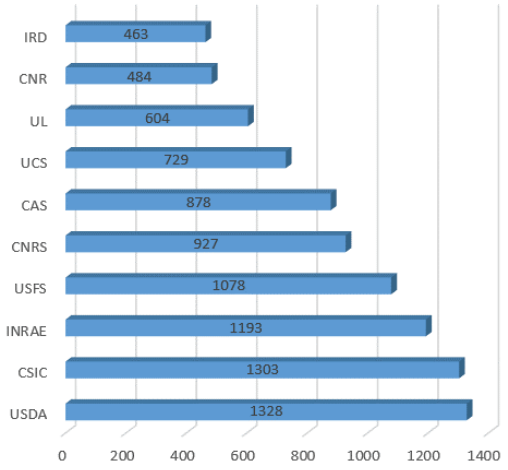
At the top of the list is the United States Department of Agriculture (USDA) with 1,328 publications. It is followed by the Spain-based Consejo Superior de Investigaciones Científicas (CSIC) with 1,303 publications. INRAE (France), United States Forest Service (USA), and Centre National de la Recherche Scientifique (CNRS, France) rank third, fourth, and fifth, respectively.

Among the top ten institutions are also the Chinese Academy of Sciences (China), University of California System (USA), Universidade de Lisboa (Portugal), Consiglio Nazionale delle Ricerche (Italy), and Institut de Recherche pour le Développement (France).

This distribution reveals that the scientific output on *Quercus* species is carried out by a strong network of institutions on an international scale, with a particular concentration along the European and North American axes.

Table 6. Top 10 Most Productive Institutions in Quercus Publications

Institution Name	Count
United States Depart. of Agr. (USDA)	1328
Consejo Sup. de Invest. Cient.(CSIC)	1303
INRAE	1193
United States Forest Service	1078
Centre Nat.l de la Rech. Scien. (CNRS)	927
Chinese Academy of Sciences	878
University of California System	729
Universidade de Lisboa	604
Consiglio Nazionale delle Ric. (CNR)	484
Ins. de Rech. pour le Dévelop. (IRD)	463



When examining the distribution of the 30,486 records obtained from the Web of Science database under the keyword “oak,” it is observed that the majority of studies are concentrated primarily in the fields of forestry, plant sciences, and ecology (Table 7). This indicates that research on oak species mainly focuses on ecological processes, forest ecosystems, and plant diversity.

The field with the highest number of publications is forestry, ranking first with a total of 8,918 studies. This finding reveals that oak species hold an important place in global forest ecosystems and are therefore frequently studied within the contexts of forest biology, regeneration dynamics, sustainable forestry policies, and ecosystem management.

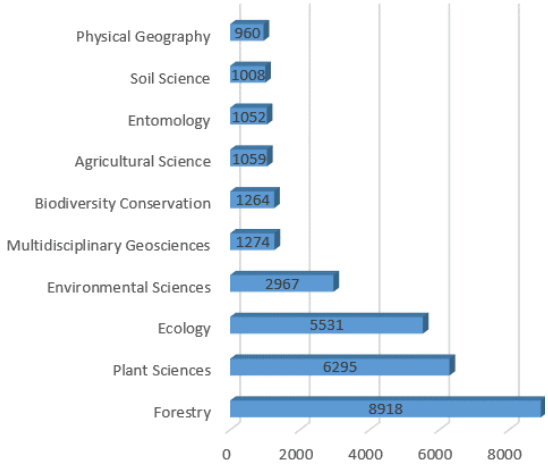
The second most represented field is plant sciences, encompassing 6,295 publications. This area focuses on fundamental biological topics such as the morphological characteristics, physiological processes, photosynthetic activities, and adaptation mechanisms of oak species to environmental conditions. The third-ranked field is ecology, with 5,531 studies, which mostly investigate interspecies relationships of oaks, habitat characteristics, responses to climate change, and their roles within ecosystems.

Environmental sciences rank fourth with 2,967 publications. These studies address the impacts of oak species on soil, water, and air quality, their carbon storage capacities, and relationships with ecosystem services. They are followed by multidisciplinary geosciences with 1,274 publications and biodiversity conservation with 1,264 publications.

Additionally, there are 1,059 publications in agricultural sciences, 1,052 in entomology, 1,008 in soil science, and 960 in physical geography. These data demonstrate that oak research is approached not only from biological perspectives but also with environmental, geographical, agricultural, and ecosystem-based approaches. Studies conducted across various disciplines highlight the multifaceted role of oak species within ecosystems and show that the research areas cover a wide spectrum.

Table 7. Distribution of Oak (Quercus) Publications by Research Field

Research Field	Count
Forestry	8918
Plant Sciences	6295
Ecology	5531
Environmental Sciences	2967
Multidisciplinary Geosciences	1274
Biodiversity Conservation	1264
Agricultural Science	1059
Entomology	1052
Soil Science	1008
Physical Geography	960



An examination of the five most cited studies among the 30,474 publications in the Web of Science database reveals that oak research is closely linked to studies focusing on the understanding of ecological processes and climate change (Table 8). These publications not only explain species distributions and physiological adaptation mechanisms within forest ecosystems but also address how plant functional traits interact with environmental changes within a theoretical framework.

In this context, the study published by Hetherington and Woodward (2003) marked a significant turning point in understanding ecophysiological processes by explaining the role of stomatal dynamics in plants in sensing and responding to environmental changes. The research by Valladares et al. (2014) focused on the relationship between phenotypic plasticity and local adaptation capacities of species, offering a new perspective on modeling the impacts of climate change.

Phylogeographic analyses conducted by Taberlet et al. (1998) examined postglacial colonization routes in Europe, guiding studies on genetic diversity and species migration. Similarly, Dyderski et al. (2018) modeled the threat levels of climate change on the distribution ranges of forest species, while Funk et al. (2017) demonstrated that plant functional traits are among the most important indicators for understanding ecological processes.

Overall, these five highly cited publications have pioneered an interdisciplinary approach in oak ecology and forest research, providing theoretical and methodological foundations for studies conducted in physiological ecology, climate science, and biodiversity conservation.

Table 8. Top Five Most Cited Publications on Quercus According to the Web of Science Database

Author(s) and Year	Title of the Publication	Journal / Source	Document Type	Citation Count
Funk, J.L.; Larson, J.E.; Wright, J. (2017)	*Revisiting the Holy Grail: Using plant functional traits to understand ecological processes*	Biological Reviews	Article	648
Hetherington, A.M.; Woodward, F.I. (2003)	*The role of stomata in sensing and driving environmental change*	Nature	Article	1779
Dyderski, M.K.; Paz, S.; Jagodzinski, A.M. (2018)	*How much does climate change threaten European forest tree species distributions?*	Global Change Biology	Article	726

Valladares, F.; Matesanz, S.; Zavala, M.A. (2014)	*The effects of phenotypic plasticity and local adaptation on forecasts of species range shifts under climate change*	Ecology Letters	Article	846
Taberlet, P.; Fumagalli, L.; Cosson, J.F. (1998)	*Comparative phylogeography and postglacial colonization routes in Europe*	Molecular Ecology	Article	2513

In this study, due to the broad scope of the 30,474 records retrieved from the WoS database, the "Citation Report" tool could not be utilized. The Web of Science system limits this type of analysis to a maximum of 10,000 records. Therefore, instead of directly reporting citation trends, graphs illustrating the number of publications by year were used. This approach aims to quantitatively reflect the developmental trend of the field while preserving the integrity of the data.

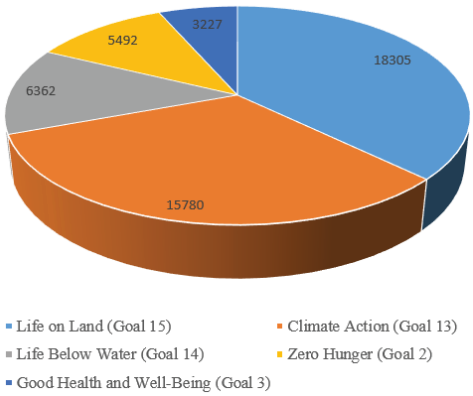
According to the Web of Science database analysis, the relationship between Quercus-themed studies and the United Nations Sustainable Development Goals (SDGs) is detailed in Table 9. The data reveal that the majority of research is concentrated under the categories of "Life on Land" (Goal 15) and "Climate Action" (Goal 13). This finding highlights the key role of oak ecosystems in terrestrial biodiversity conservation, carbon storage capacity, and climate adaptation processes. Particularly, studies under Goal 15 emphasize the ecological importance of oak species in the sustainable management of forest ecosystems, prevention of soil erosion, reduction of habitat fragmentation, and mitigation of biodiversity loss. Similarly, research categorized under "Climate Action" evaluates oaks in terms of their high carbon sequestration potential and resilience against climate change scenarios, positioning oak forests as natural solutions that could contribute to carbon neutrality goals.

Moreover, connections established with goals such as "Life Below Water" (Goal 14), "Zero Hunger" (Goal 2), and "Good Health and Well-being" (Goal 3) indicate that oak ecosystems extend beyond terrestrial systems, indirectly influencing water cycles, microclimate regulation, food production, and local quality of life. The regulatory effects of oak species on soil and water relationships demonstrate the need to consider environmental, economic, and social dimensions together within the sustainability of ecosystem services.

Overall, the distribution presented in Table 9 shows that scientific research on oaks is directly linked not only to ecological processes but also to sustainable development, climate policies, and environmental planning approaches. This outcome reflects that oak ecosystems are increasingly addressed within a multidisciplinary framework in the scientific literature, becoming reference points in fields such as nature-based solutions, climate adaptation, and environmental ethics.

Table 9. Distribution of Sustainable Development Goals According to the Web of Science Database

Sustainable Development Goal (SDG)	Count
Life on Land (Goal 15)	18305
Climate Action (Goal 13)	15780
Life Below Water (Goal 14)	6362
Zero Hunger (Goal 2)	5492
Good Health and Well-Being (Goal 3)	3227



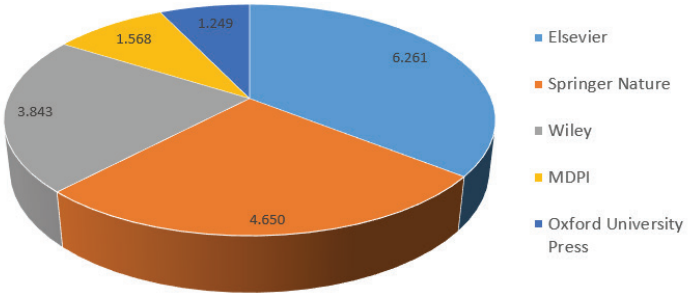
An examination of the publisher distribution of Quercus-themed publications in the Web of Science database reveals that scientific output is largely concentrated around a few international publishers, as shown in Table 10. The data indicate that research in this field is primarily published in journals belonging to well-established publishers such as Elsevier, Springer Nature, and Wiley. Journals under Elsevier stand out with high-impact studies in ecology, forestry, and environmental sciences, focusing on themes like the sustainability of oak ecosystems, climate change adaptation, and ecological restoration. Springer Nature contributes interdisciplinary research particularly in forest ecology, plant biology, and ecophysiology.

Wiley, with its diverse range of journals covering natural sciences and environmental engineering, enhances the variety of the literature, while MDPI's open access policy facilitates broader academic reach for oak-related research. Oxford University Press offers distinguished publications focusing on environmental planning, biodiversity management, and forest ecosystem themes, providing valuable contributions to the field.

Overall, the distribution of publishers demonstrates that oak research is not confined to a specific region but gains global visibility through international publishing platforms. This situation strengthens the interdisciplinary nature of studies on Quercus species and illustrates the integration of scientific publishing with the concept of sustainable ecosystem understanding.

Table 10. Distribution of Oak (Quercus) Publications by Publisher

Publisher	Record Count
Elsevier	6261
Springer Nature	4650
Wiley	3843
MDPI	1568
Oxford University Press	1249



An analysis of the access types of Quercus-themed publications in the Web of Science database reveals that open access practices are quite widespread, as shown in Table 11. A significant portion of the total 30,474 publications falls under open access, indicating that research findings have become more broadly accessible to the scientific community and the public.

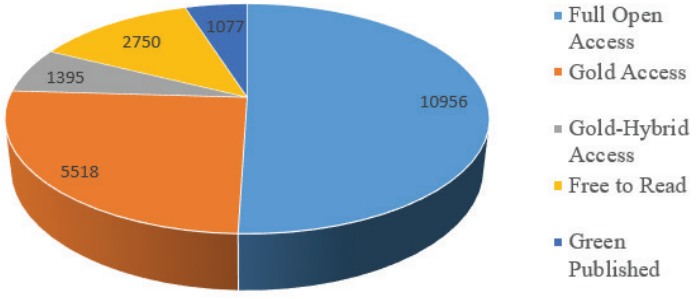
Among the types of open access, the highest share belongs to the gold access model. In this model, articles are typically published openly on journal websites in exchange for article processing

charges paid by the authors. This approach particularly enables researchers working in fields such as environmental science, ecology, and forestry to share their findings transparently. The gold-hybrid access model, which combines subscription and open access systems, serves as an important balancing mechanism during the transition period.

Publications categorized as free to read provide free access to readers but generally include copyright restrictions. The green published and green accepted models refer to instances where authors make their articles available in their own archives or institutional repositories. These systems especially facilitate access to knowledge for researchers in developing countries, thereby contributing to the broader dissemination of scientific production.

Table 11. Distribution of Oak (Quercus) Publications by Access Type

Access Type	Record Count
Full Open Access	10956
Gold Access	5518
Gold-Hybrid Access	1395
Free to Read	2750
Green Published	1077



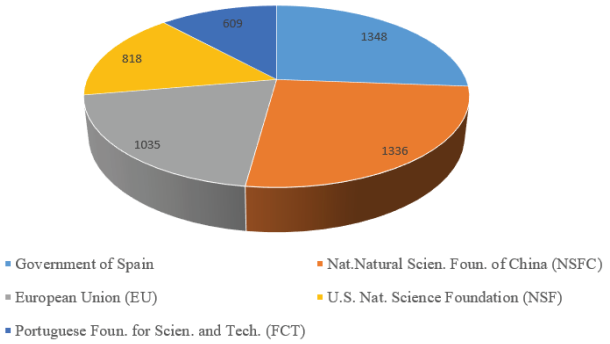
An examination of the funding agencies supporting Quercus-themed publications in the Web of Science database reveals, as shown in Table 12, that the majority of the studies are financed by national and international public research institutions. This indicates the strategic importance of research on oak ecosystems in terms of environmental sustainability, forest management, and combating climate change.

The highest funding contributor is identified as the Government of Spain, which particularly supports projects focused on Mediterranean ecosystems, drought tolerance, and the adaptation of Quercus species. Studies funded by the National Natural Science Foundation of China (NSFC) concentrate on genetic diversity, carbon cycling, and plant physiological adaptation. Projects supported under European Union (EU) funds are generally carried out through “Horizon” programs, enhancing inter-country collaboration.

The United States National Science Foundation (NSF) provides resources for research focusing on ecosystem services, carbon storage, and forest dynamics. The Foundation for Science and Technology (FCT) of Portugal, ranked fifth, supports projects aimed at the conservation of biodiversity and sustainable management of oak forests in the Mediterranean basin. This overview clearly demonstrates that oak research holds not only ecological but also economic and political significance at an international level.

Table 12. Distribution of Oak (Quercus) Publications by Funding Agency

Funding Agency	Count
Government of Spain	1348
National Natural Science Foundation of China (NSFC)	1336
European Union (EU)	1035
U.S. National Science Foundation (NSF)	818
Portuguese Foundation for Science and Technology (FCT)	609



An examination of the citation indexes in which Quercus-related publications are included within the Web of Science database reveals, as shown in Table 13, that the vast majority of studies fall under the Science Citation Index Expanded (SCI-Expanded). This indicates that oak research is predominantly concentrated in fields such as natural sciences, ecology, forestry, and environmental sciences.

However, a significant number of publications are also indexed in the Conference Proceedings Citation Index – Science (CPCI-S). This suggests that topics such as oak ecosystems and sustainable forest management are being discussed not only in academic journals but also at international conferences and symposia.

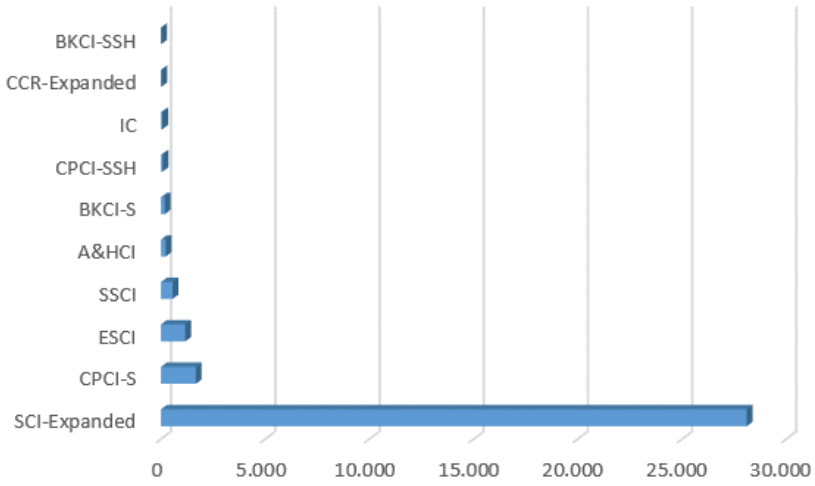
Publications indexed in the Emerging Sources Citation Index (ESCI) demonstrate that the topic is gaining increased visibility in newly developing sub-disciplines and open-access journals.

Moreover, the presence of publications in the Social Sciences Citation Index (SSCI) and the Arts & Humanities Citation Index (A&HCI) indicates that research on oaks also encompasses social, cultural, and artistic dimensions. In addition, a limited number of publications indexed in the Book Citation Index – Science and Social Sciences & Humanities (BKCI-S, BKCI-SSH) and the Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) show that the concept of Quercus is beginning to be addressed in interdisciplinary book chapters and collected conference papers.

This diversity highlights the fact that oak research forms a multidimensional field of interaction that spans ecology, culture, sociology, and the arts.

Table 13. Distribution of Oak (Quercus) Publications by Web of Science Citation Index

Citation Index	Count
SCI-Expanded	28.099
CPCI-S	1.669
ESCI	1.164
SSCI	557
A&HCI	221
BKCI-S	178
CPCI-SSH	80
IC	67
CCR-Expanded	16
BKCI-SSH	7



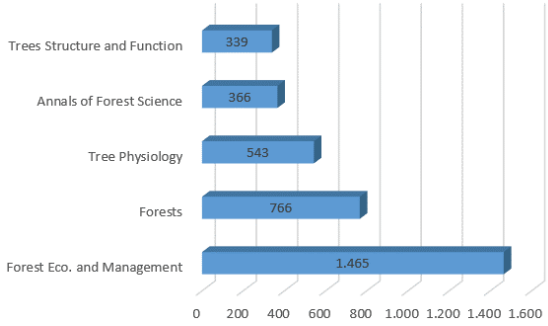
When the distribution of oak (Quercus)-themed publications in the Web of Science database is examined by journals, as shown in Table 14, it is observed that a significant portion of the research is concentrated in scientific journals focused on forestry, ecology, and plant physiology. The fact that the highest number of publications appears in the journal *Forest Ecology and Management* indicates that oak species hold considerable importance in the international literature in terms of sustainable forest ecosystem management, modeling of ecological processes, and understanding interspecies interactions. The studies published in this journal generally focus on topics such as carbon cycling in forest ecosystems, fire regimes, soil productivity, and adaptation strategies of oak species.

This is followed by the journals *Forests*, *Tree Physiology*, *Annals of Forest Science*, and *Trees – Structure and Function*. The journal *Forests*, with its open access policy, delivers ecological, genetic, and applied research on oak ecosystems to a wider academic audience; *Tree Physiology* hosts studies that examine the physiological responses of oak species, including photosynthetic performance, water balance, and stress tolerance in detail. In *Annals of Forest Science* and *Trees – Structure and Function*, research predominantly focuses on the morphological traits, biomechanical structures, and responses of oak trees to environmental changes.

These findings reveal that studies on oak species are not limited to ecological observations but are addressed through a multidisciplinary approach encompassing forest management, plant physiology, genetic diversity, and climate change. Moreover, the high number of studies published in these journals indicates the growing international awareness of both the ecological and economic value of Quercus species and underscores the increasing scientific interest in the sustainability of oak ecosystems.

Table 14. Distribution of Oak (Quercus) Publications by Journal

Journal Title	Count
Forest Ecology and Management	1.465
Forests	766
Tree Physiology	543
Annals of Forest Science	366
Trees Structure and Function	339



DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This study aims to reveal scientific trends, interdisciplinary connections, and thematic concentrations related to oak species through a comprehensive bibliometric analysis conducted in the Web of Science (WoS) Core Collection using the keyword “Quercus.” Based on the 30,474 records retrieved on October 5, 2025, the findings indicate that oak research forms a broad knowledge network bridging ecology, forestry, environmental science, and biotechnology. The results not only present quantitative trends but also uncover the historical transformation of the global research structure and the place of *Quercus* species within the framework of sustainable development.

The annual publication trend shows that *Quercus* research remained limited during the 1980s but entered a steady upward trajectory beginning in the early 2000s. This acceleration is particularly associated with the growing scientific awareness around ecosystem services, carbon management, climate resilience, and forest management policies after 2010. The increase observed after 2020 has been further reinforced by the widespread adoption of open-access policies, the development of remote data-sharing networks, and the impact of interdisciplinary research programs such as Horizon Europe and COST Actions. This pattern suggests that oak species are no longer considered merely regional ecological assets but are now seen as strategic components of global environmental policy.

The analysis by document type reveals that articles constitute the backbone of the literature (n=28,351). This indicates that oak-related studies are largely based on original, data-driven experimental and model-based research. The presence of conference papers reflects the topic’s prevalence in international academic discourse, while the increase in review articles suggests a growing effort to synthesize accumulated knowledge in the field. This trend shows that *Quercus* ecosystems have matured into a well-established research domain, advancing from empirical observations toward theoretical development.

The parallel increase in annual citation counts demonstrates that the field is growing not only in volume but also in impact. The noticeable rise in citations after 2018 aligns with contemporary scientific demands regarding carbon storage, soil microbiology, biodiversity management, and climate adaptation. In this regard, oak research can be considered a scientific reflection of the global environmental crisis.

An analysis of country-level contributions highlights the clear dominance of the United States, Spain, and China. The leadership of the U.S. is linked to its long-standing work in forest ecology and climate modeling; Spain's prominence reflects a research tradition focused on the ecological resilience of Mediterranean oak species; and China’s rapid rise stems from its major investments in biotechnology and genomic studies over the past decade. Türkiye, on the other hand, shows a regional upward trend. Phytochemical analyses conducted particularly in the Eastern Anatolia and Aegean regions have revealed the biomaterial potential of local oak species. This suggests that Türkiye has the potential to develop oak research not only ecologically but also industrially and culturally.

In the institutional analysis, USDA Forest Service, CSIC, and INRAE stand out. These institutions, with their multi-centered research structures, enable comparative studies of the physiological traits, genetic diversity, and carbon dynamics of *Quercus* species across different climate zones. The collaborative efforts of these Europe- and North America-based institutions contribute to the assessment of forest ecosystems as globally interconnected systems. In Türkiye, the joint studies conducted by the General Directorate of Forestry, TÜBİTAK, and various universities have the potential to serve as a regional extension of this international network.

Peñuelas J., Pereira H., Kremer A., Gracia C., Bréda N., and Aranda I. are among the most prominent authors in the analysis. The common ground among these researchers lies in their

pioneering work on ecophysiology, climate sensitivity, carbon, and water balance. When examining the network maps, it becomes evident that these authors have established strong collaborations with institutions in different countries, indicating that oak research has developed into a global network structure.

This international structure observed at the country and author level is also mirrored in publishers and journals. The most frequently publishing journals include Forest Ecology and Management, Forests, Tree Physiology, Annals of Forest Science, and Trees Structure and Function. The common feature of these journals is their direct focus on forest ecology, plant physiology, and climate relationships. In addition, the increasing preference for open-access journals (such as Forests and Sustainability) shows that Quercus studies are becoming more democratically accessible in academic terms.

In terms of publishers, Elsevier, Springer Nature, and Wiley stand out clearly. These publishers' environmentally and sustainability-oriented publication policies enhance the international visibility of studies related to oaks. MDPI's open-access model has shown a noticeable increase especially in the past five years, thereby allowing oak research to reach a wider academic audience. The contribution of established publishers such as Oxford University Press is important in terms of academic quality and continuity in the field.

In terms of access types, it has been found that more than one-third of the publications are open access. The high rate of full open access (Gold Access) indicates a significant transformation in ecological research regarding social impact and knowledge sharing. The rise in green and hybrid access models is helping to reduce inequalities in access to information, especially in developing countries. This trend reflects the "open science" movement, which promotes directing ecological knowledge toward public benefit rather than commercialization.

Among the funding organizations are the Government of Spain, the National Natural Science Foundation of China (NSFC), the European Union, the United States National Science Foundation (NSF), and the Portuguese Foundation for Science and Technology (FCT). This funding structure shows that oak research is conducted not only academically but also through policy-based support. A significant part of EU funding is provided under programs such as "Horizon" and "LIFE," linking Quercus ecosystems to carbon neutrality goals.

Analysis of Web of Science citation indexes shows the dominance of the Science Citation Index Expanded (SCI-Expanded), although SSCI, A&HCI, ESCI, and CPCI indexes have also been including an increasing number of publications. This indicates that oak research is expanding its impact area from natural sciences to social sciences. Especially the studies included in A&HCI and SSCI indexes reveal that the oak is not only a biological species but also a part of cultural landscapes, artistic narratives, and environmental ethical thought.

The analysis of the Sustainable Development Goals (SDGs) shows that oak-related publications are most closely associated with Goal 15 (Life on Land), Goal 13 (Climate Action), and Goal 14 (Life Below Water). This distribution confirms that the carbon sink capacity, habitat provisioning, and influence on the water cycle of oak species are scientifically prioritized. This SDG-oriented approach demonstrates that oak research is being conducted not only as a scientific endeavor but also within an ethical and political framework of responsibility.

Findings related to the most-cited publications show that works defining the theoretical foundations of Quercus literature stand out. In particular, studies such as Bréda et al. (2006), Kremer et al. (2010), and Peñuelas et al. (2008) have focused on oak ecosystem responses to climate change, genetic adaptation processes, and physiological tolerance limits. These studies are considered major references shaping the theoretical framework of today's Quercus literature. In addition, pioneering

studies conducted by Abrams (1992) and Valladares et al. (2004) have developed new conceptual approaches to ecophysiological topics such as water stress, shade tolerance, and photosynthetic adaptations in oaks. These findings have revealed that oak species show high plasticity in response to both climatic and environmental variables, guiding subsequent research.

A common feature of these highly cited studies is their treatment of the oak not merely as a forest tree but as a biological indicator of climatic variability. This approach has become a critical reference point in recent years for understanding the role of oaks in carbon storage capacity, ecosystem services, and ecological restoration processes. Therefore, these most-cited publications have integrated the ecological, genetic, and environmental dimensions of Quercus research, providing a scientific foundation for sustainable forest management and climate policies today.

When the overall results of this study are evaluated, it becomes clear that Quercus research possesses both intra-disciplinary depth and interdisciplinary breadth. Oak has become a key model organism for ecosystem resilience, carbon cycling, and biodiversity conservation. In the context of Turkey, it is observed that local oak species (e.g., Quercus ispirii) represent a unique research area that can be associated with biomaterials, insulation technologies, and art-design applications.

In conclusion, oak (Quercus) research presents a multi-layered body of knowledge that contributes scientifically, culturally, and economically in areas such as nature-based solutions, sustainable design, ecological restoration, and climate adaptation. Future research should include comparative analysis of WoS data with other databases such as Scopus and Dimensions; investigation of Turkey’s oak species in their local ecological, socio-cultural, and economic contexts; and integration of oak’s biomaterial potential into sustainable production processes. In this respect, Quercus has become not just a forest tree but a symbol representing the continuity of nature, ecological awareness, and a vision for a sustainable future.

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Chapter 8

AN ANALYSIS OF RECENT TOKİ MASS HOUSING PROJECTS IN THE CONTEXT OF FACADE AND IDENTITY

Ahmet Fazıl BAYRAKCI[1], Emine YILDIZ KUYRUKÇU[2]

1 Research Assistant, Aksaray University Faculty of Architecture and Design
Orcid ID: 0000-0002-3256-5677
2 Associate Professor, Konya Technical University Faculty of Architecture and Design
Orcid ID: 0000-0002-5794-3507

Introduction

Since the 19th century, when globalization began to accelerate, the blurring of spatial and cultural boundaries has brought about a marked tendency toward homogenization in the aesthetic and spatial productions of societies. In Turkey, the growing rural-to-urban migration that intensified from the 1960s onward, together with the rising demand for housing, reshaped housing policies around speed, cost efficiency, and repetitive standardized typologies. This, in turn, led to the dominance of standardization in mass housing projects produced by TOKİ. Within this context, traditional architectural elements-such as bay windows (cumba), timber console brakets (eliböğründe), wooden beams (hatıl), and projections—appear widely in the facades of recent TOKİ housing projects as superficial, postmodern, and largely non-functional imitations (Yıldız Kuyrukçu, 2018). Rather than establishing a relationship with the authentic constructive logic of local architecture, these elements are reduced to decorative motifs appended merely to the visible surface of the building. As a result, the spatial, structural, and cultural layers embedded in traditional domestic architecture are transformed into a mere aesthetic shell on TOKİ facades, creating a disconnect between the characteristic values that constitute the genius loci and the architectural production itself.

For this study, the facades of fifteen TOKİ housing projects from different regions were examined through a formal analysis method, and the local and historical architectural elements appropriated in the designs were identified. The findings indicate that although the examined TOKİ projects are located in distinct regions with diverse local characteristics, they tend to replicate similar traditional Turkish house facade typologies, largely detached from the spirit of place. Moreover, local materials, climatic data, topography, and vernacular construction culture are not sufficiently reflected in the design decisions.

The study emphasizes that the facade design strategies of TOKİ housing do not contribute to strengthening local architectural identity; instead, they attach themselves to a postmodern, representational pseudo-traditionalism. This approach negatively affects both urban aesthetics and the sense of social belonging. Ultimately, for urban identity and sustainability, housing facades must incorporate not only superficial formal references but also the materiality, climatic adaptations, construction techniques, spatial organization, and cultural codes that define vernacular architecture.

With modernization, these local values have been pushed into the background, leading to the spread of a “universalist” architectural language and the neglect of local identity. Postmodern architecture-which emerged in the 1980s as a reaction to modern architecture, modern planning, and the International Style-opposed the abstract, uniform, anonymous, and purely functional aesthetic of modernism. The concept of postmodernism, first introduced in fields such as philosophy, sociology, and literature in the 1960s, found its place in architecture in the 1970s. Although postmodernism became widespread and influential in the early 1980s, it began to lose its prominence towards the end of the decade due to increasing criticism (Güzer, 1996).

Unlike modernism-with its ambition to produce holistic and universal architectural values and its rejection of historical forms-postmodernism adopted a fragmented character, treating historical and local architectures as a repertoire of forms. Elements drawn from Ancient Greek, Roman, Medieval, Romantic, and Neoclassical eras, as well as modernism itself and local cultures, were blended through techniques such as pastiche and collage, producing eclectic styles. Based on the idea that art and

architecture consist of repetitions, structures emerged that were eclectic, disjointed, derivative, ruleless, chaotic, and dreamlike-where forms detached from their original contexts were used arbitrarily. In this postmodern era of reproduced reality, architecture became a “simulation” (Yıldız Kuyrukçu & Ünal, 2021).

After the 1960s, new political, social, cultural, and economic conditions led to multifaceted explorations in architecture in Turkey. Due to economic and technical constraints, global postmodern trends reached Turkey only after the 1980s. During this period, a style characterized by extensive use of historical forms emerged. While elements of Turkish culture were employed on the one hand, architectural features borrowed from foreign cultures were also incorporated. In residential buildings constructed during this period-shaped by postmodern paradigms-contradictions between form and meaning became evident (Yıldız Kuyrukçu & Çınar, 2023). Postmodern architecture, emerging as a reaction to modernism’s functional and abstract aesthetic, adopted an eclectic and often ostentatious design approach that combined historical references, popular culture, and local elements. Within this context, notions such as kitsch, eclecticism, neoclassicism, and orientalism are distinctly observable in Turkey’s public and private housing projects (Yıldız Kuyrukçu, 2018).

This study aims to interpret the notions of placelessness and identitylessness through the facade designs of mass housing projects constructed by TOKİ in the early 21st century and to conduct a formal analysis of these structures. To this end, fifteen TOKİ housing projects from various regions were selected, and their facades were analyzed to determine the historical and vernacular architectural elements they imitate.

Standardization Problem in TOKİ Mass Housing Facades

The phenomenon of mass housing in Turkey began to gain prominence in the 1950s, when urbanization dynamics started to change rapidly. During this period, the dissolution of rural life based on agricultural production and the intense migration from rural areas to major cities created a significant housing shortage. Unplanned urbanization, insufficient infrastructure, and the widespread emergence of informal settlements made state intervention in housing production inevitable. In this context, the need for mass housing became a critical planning issue in terms of both the right to adequate shelter and the orderly development of cities.

Although housing cooperatives were supported throughout the 1960s and 1970s, this approach remained insufficient to meet large-scale housing demand. As urban populations continued to increase rapidly, the necessity arose for the state to assume a more institutional role in housing production. Accordingly, the Housing Development Administration of Türkiye (TOKİ), established in 1984, became a key actor in shaping modern mass housing policies in the country (TOKİ, 2025). TOKİ’s founding purpose was to meet the housing needs of low- and middle-income groups, create healthy and planned settlement areas, ensure stability in the housing market, and establish a systematic framework for housing production. Operating on a relatively limited scale from the late 1980s to the early 2000s, TOKİ expanded its production capacity significantly in the 2000s through legal reforms and new financing models (Karasu & Gültekin, 2012).

In the post-2000 period, TOKİ became the largest housing producer in Türkiye, engaging in a wide range of activities including social housing projects, urban transformation initiatives, satellite city developments, and post-disaster reconstruction efforts. During this period, hundreds of mass housing

estates were built in various geographical regions across the country, and speed, cost efficiency, and standardized typology projects became the principal determinants of the production process (Herdem, 2021).

However, this planning approach has also brought several problems. The repetition of similar block typologies in different cities—each with distinct climatic and cultural contexts—has led to criticism regarding identity loss, spatial monotony, and incompatibility with local settings. Although certain facade elements belonging to traditional Turkish domestic architecture have been employed in some projects, these features have generally remained superficial and decorative, failing to establish a holistic relationship with local architectural contexts (Gür, 2012).

Kuban (2000) and Tanyeli (2004) highlight the identity crisis experienced in the modernization of Turkish architecture, noting that the weakening of ties with local values has produced "cities detached from their place." This rupture observed in mass housing environments not only weakens formal architectural identity but also undermines socio-cultural belonging. Conversely, Bozdoğan (2001) argues that although modern architecture in Turkey has been shaped by Western influences, it can be reinterpreted through local perspectives. In this respect, reconstructing local identity in contemporary mass housing facades should be regarded as both an aesthetic and a social responsibility (Gül & Meşhur, 2023).

Today, mass housing production remains a significant tool of housing policy in Türkiye; however, concepts such as spatial identity, sustainability, preservation of local architectural values, social integration, and quality of life are becoming increasingly central to discussions on mass housing. Therefore, it is evident that mass housing should be approached not merely through a quantitative production perspective but through design strategies that are place-responsive, user-centered, and capable of reinforcing urban identity.

Material and Method

The housing production process in Türkiye has been reshaped, particularly since the 2000s, through large-scale projects implemented by the state. In this period, the Housing Development Administration of Türkiye (TOKİ) assumed a central role not only in addressing the housing deficit but also in increasing housing production for low- and middle-income groups within the framework of the social state concept. TOKİ's practices have led not only to a quantitative increase in the number of housing units but also to profound transformations in the morphological structure, spatial identity, and social fabric of cities.

In recent years, mass housing projects have proliferated rapidly, particularly on the peripheries of major metropolitan areas; however, the architectural qualities of these developments, their relationship with the environmental context, and their impact on place identity have increasingly become subjects of debate. Facade designs characterized by repetition and detached from local architectural language and cultural references have contributed to the homogenization of urban identity and the weakening of a sense of belonging. This condition has triggered not only a transformation of the physical environment but also changes in social lifestyles (Çelik, 2018; Yurtseven & Oğuz, 2023).

Therefore, analyzing the facades of mass housing projects constructed by TOKİ in recent years within the context of place and identity is of great significance for understanding Türkiye's contemporary housing policies and guiding future design approaches. This analysis reveals the necessity of a qualitative transformation in housing production in terms of both architectural aesthetics and socio-cultural sustainability.

For this study, TOKİ housing units constructed after the 2000s were selected deliberately from different geographical regions of Türkiye. The aim was to clearly demonstrate the extent of homogenization observed among regions that possess distinct local cultural and architectural values.

Figure 1: Schematic locations of the examined housing complex examples

In Table 1, the facades of TOKİ housing units constructed in Türkiye after the year 2000 were analyzed through a formal analysis method, and the local and historical architectural elements that were imitated were identified. In selecting the 15 TOKİ mass housing projects examined in the study, attention was given to ensuring that they were built after 2000 and located in different regions of the country. A comprehensive literature review was conducted for the selected housing units, visual documentation was collected, and architectural historians were consulted regarding the facade characteristics. Based on these evaluations, the local architectural elements imitated on the facades - such as bay windows (cumba), timber console brackets (eliböğründe), wooden beams (ahşap hatıl), stacked stone walls (yığma taş duvar), baghdadi white plaster (bağdadi sıva), timber lathing over a frame (karkas üzeri ahşap çıtalama), and window openings- as well as historical architectural components including eyvans, arches and crown gate (taç kapı), were identified (Table 1).

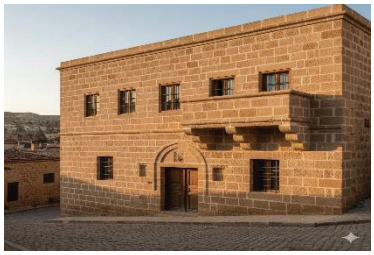
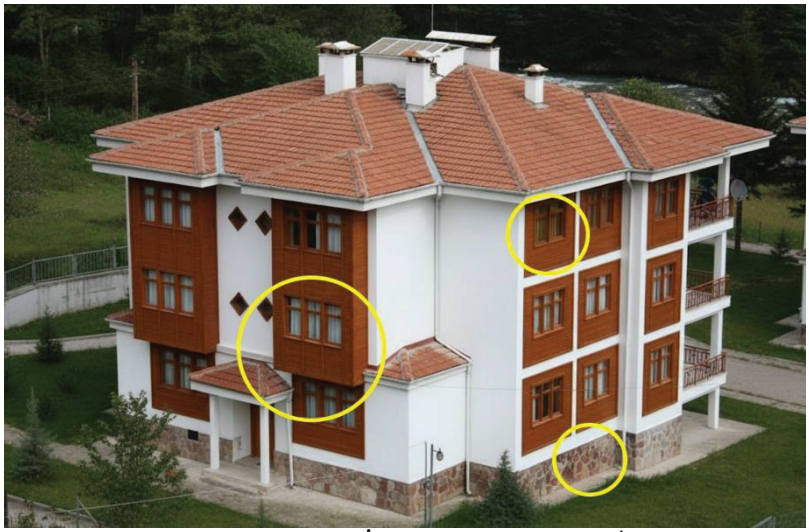
Table 1: TOKİ buildings constructed in our country in recent years and the building elements that were replicated

	TOKİ Project Image	Replicated Structural Elements
Bolu/Mudurnu	 **Figure 1:Bolu/Mudurnu TOKİ Building Facade** *(TOKİ, 2025)*	 **Traditional Turkish House Facade** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame** • **Window openings**
Bursa/Yunuseli	 **Figure 3:Bursa/Yunuseli TOKİ Building Facade** *(TOKİ, 2025)*	 **Turkish House with Arched Window** • **Stacked stone wall** • **Timber console bracket** • **Wooden beams** • **Arched Window**  **Seljuk Period Crown Gate Example** • **Crown gate (Seljuk Period)**
İzmir/Çeşme	 **Figure 4:İzmir/Çeşme TOKİ Building Facade** *(TOKİ, 2025)*	 **Bay Window in a Turkish Home** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Window openings**

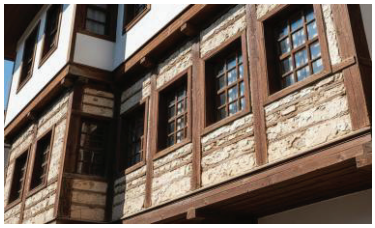
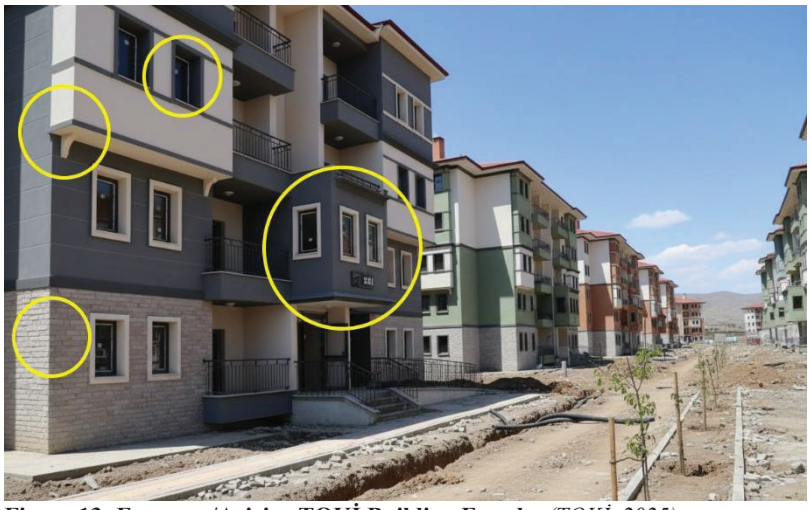
Continuation of Table 1...

Karabük/ Belen Mahallesi	 **Figure 5:Karabük/ Belen Mahallesi TOKİ Building Facade** *(TOKİ, 2025)*	 **Wooden Beams in a Turkish Home** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame**
Kastamonu/İhsangazi	 **Figure 6:Kastamonu/İhsangazi TOKİ Building Facade** *(TOKİ, 2025)*	 **Turkish House with Consoles and Stacked Stone Walls** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Window openings**
Kırklareli/Lüleburgaz	 **Figure 7:Kırklareli/Lüleburgaz TOKİ Building Facade** *(TOKİ, 2025)*	 **Detail of the Turkish Home's Timber Console Bracket** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame**

Continuation of Table 1...

Mardin/Merkez	 **Figure 8:Mardin/Merkez TOKİ Building Facade** *(TOKİ, 2025)*	 **A view of Traditional Mardin Houses from the Courtyard** • **Iwan** • **Stone balustrades** • **Arched pediments** • **Local stone texture**
Nevşehir/Avanos	 **Figure 9: Nevşehir/Avanos TOKİ Building Facade** *(TOKİ, 2025)*	 **Masonry Structure Built with Cut Stone (Traditional Nevşehir Houses)** • **Local stone texture**  **Crown Gate Example** • **Crown gate (Seljuk Period)**
Rize/Çamlıhemşin	 **Figure 10: Rize/Çamlıhemşin TOKİ Building Facade** *(TOKİ, 2025)*	 **Wood Frame System in Turkish Homes** • **Bay window** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame**

Continuation of Table 1...

Antalya/Akseki	 **Figure 11: Antalya/Akseki TOKİ Building Facade** *(TOKİ, 2025)*	 **Bay Window in a Turkish Home** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Baghdadi white plaster** • **Wooden lathing over frame**  **Crown Gate Example** • **Crown gate (Seljuk Period)**
Artvin/Yusufeli	 **Figure 12: Artvin/Yusufeli TOKİ Building Facade** *(TOKİ, 2025)*	 **Traditional Turkish House Facade** • **Bay window** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame** • **Window openings**
Erzurum/Aziziye	 **Figure 13: Erzurum/Aziziye TOKİ Building Facade** *(TOKİ, 2025)*	 **Bay Windows and Timber Console Brackets in Turkish Homes** • **Bay window** • **Timber console bracket** • **Wooden beams** • **Stacked stone wall** • **Window openings**

Continuation of Table 1...

Konya/Ereğli	 **Figure 14: Konya/Ereğli TOKİ Building Facade** *(TOKİ, 2025)*	 **Bay Windows and Stacked Stone Walls in Turkish Homes** • **Bay window** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame**
Uşak/Karahallı	 **Figure 15: Uşak/Karahallı TOKİ Building Facade** *(TOKİ, 2025)*	 **Bay Windows and Timber console brackets in Turkish Homes** • **Bay window** • **Timber console bracket** • **Stacked stone wall** • **Baghdadi white plaster** • **Window openings**  **Crown Gate Example** • **Crown gate (Seljuk Period)**
Ankara/Nallıhan	 **Figure 16: Ankara/Nallıhan TOKİ Building Facade** *(TOKİ, 2025)*	 **Wood Frame System in Turkish Homes** • **Bay window** • **Wooden beams** • **Stacked stone wall** • **Baghdadi white plaster** • **Wooden lathing over frame**

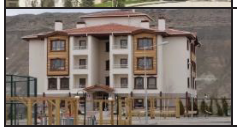
Evaluation

The façade is the surface that most directly expresses the identity of a building and its relationship with its surroundings. When the facades of TOKİ housing units constructed in various regions of Türkiye in recent years are examined using a formal analysis method, it becomes evident that these independently produced structures largely share a common design language. In these buildings, it is observed that, in an effort to establish a connection with the past, multiple stylistic and architectural elements are used simultaneously; moreover, the characteristic façade components of the *Traditional Turkish House* are often employed superficially as decorative features detached from their original functions (Table 2).

Table 2: TOKİ structures examined within the scope of the study and the structural elements they reference

TOKİ Buildings	Seljuk Period	Local Architecture	Traditional Turkish House
			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame, Window openings**
	**Crown gate**		**Stacked stone wall, Timber console bracket, Wooden beams, Arched Window**
			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Baghdadi white plaster, Window openings**
			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame**
			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Baghdadi white plaster, Window openings**
			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame**
		**Iwan, Stone balustrades, Arched pediments, Local stone texture**	
	**Crown gate**	**Local stone texture**	
			**Bay window, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame**
	**Crown gate**		**Bay window, Timber console bracket, Wooden beams, Baghdadi white plaster, Wooden lathing over frame**
			**Bay window, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame, Window openings**

Continuation of Table 2...

			**Bay window, Timber console bracket, Wooden beams, Stacked stone wall, Window openings**
			**Bay window, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame**
	**Crown gate**		**Bay window, Timber console bracket, Stacked stone wall, Baghdadi white plaster, Window openings**
			**Bay window, Wooden beams, Stacked stone wall, Baghdadi white plaster, Wooden lathing over frame**

The detachment of traditional façade elements from their spatial, climatic, and cultural functions and their transformation into mere decorative components diminishes the representational power of architectural identity and leads to the anonymization of buildings. Authentic architectural components such as bay windows (*cumba*), console brackets (*eliböğründe*), timber ties (*hatıl*), and eaves, which historically carried structural, climatic, and spatial roles, are reduced to superficial ornamentation on contemporary facades. Structural timber elements that once ensured earthquake resistance, eaves that provided protection from rain and sunlight, or projections integral to load-bearing systems are used in TOKİ facades merely to create a two-dimensional shell effect. Consequently, these architectural components acquire the quality of "material imitation," losing their authenticity. Particularly, the imitation of wood on reinforced concrete structures through painted bands, polyurethane coatings, or precast elements weakens both aesthetic sincerity and the cultural representational value of the material.

The scale and proportional character of the traditional Turkish house is also incompatible with the multi-story TOKİ blocks. In historical urban fabric, housing typologies seldom exceed two or three stories and maintain a direct relationship with the human scale. In contrast, applying elements such as projections, moldings, faux wooden posts, or oversized eaves to blocks rising 8 to 12 stories disrupts compositional unity in terms of scale and proportion. As a result, façade elements become disproportionate, functionless surface embellishments within the building mass. This mismatch not only produces an aesthetically inconsistent appearance but also generates an artificial sense of historicism that diverges from the essence of traditional architecture.

Furthermore, the application of these formal additions in identical ways across different climatic regions poses a significant issue. In traditional architecture, projections, shading eaves, or local stone materials serve specific climatic purposes; however, in TOKİ projects, such elements are incorporated as a standardized package independent of climatic data. This leads to the exclusion of contextual parameters that shape architectural identity, resulting in buildings that present a visual language incompatible with their surroundings. Ultimately, these artificial historical references weaken the unique character of urban identity and reduce architectural heritage to a superficial representation within collective housing areas.

Thus, the imitative approach observed in TOKİ housing neither contributes meaningfully to the preservation of traditional architectural forms nor provides a qualified alternative for contemporary housing production. The essence of traditional domestic architecture lies not solely in its formal components but in its construction techniques, material authenticity, climatic adaptability, and spatial logic. Therefore, creating a genuinely local architectural identity in mass housing design requires adapting the underlying principles of traditional architecture to contemporary conditions rather than relying on superficial form replication. Only through such an approach will it be possible to produce meaningful housing environments that respect cultural heritage and reinforce users' sense of belonging.

Conclusion and Recommendations

The phenomenon of globalization, which began to exert significant influence in the nineteenth century, has—together with rapidly advancing technological developments—substantially diminished the distinctiveness of spatial and temporal boundaries. As these boundaries have become increasingly blurred, societies have engaged in more intensive interaction, leading to varying degrees of cultural homogenization. This notion of "homogenization" signals a multifaceted transformation that can be evaluated across social, economic, cultural, architectural, physical, natural, and geographical dimensions.

Rural-to-urban migration, a major social dynamic that reinforces homogenization and simultaneously reflects the broader impacts of globalization, has played a decisive role in shaping Turkey's urban landscape. The accelerated rural–urban migration beginning in the 1960s triggered profound shifts in the country's urbanization patterns. Turkey's status as a developing country during this period directly affected the physical formation of its cities, causing socially informed, physically sustainable, and context-sensitive planning approaches to fall into the background.

In recent years, the rapidly evolving processes of urban transformation and mass housing production in Turkey reveal how shifts in architectural paradigms—from modernism to postmodernism and subsequently to globalization-driven tendencies—have been reflected in spatial configurations and façade design. While modernism aimed to generate an integrated and coherent urban identity, this approach gradually gave way to fragmented, pluralistic, and increasingly identityless architectural environments. This transformation has affected not only the physical formation of cities but also the experiential and symbolic dimensions of urban life, fundamentally altering the relationship between users and their built environment.

Analyses conducted within the scope of this study demonstrate that façade designs in recent TOKİ mass housing projects increasingly embody the postmodern pursuit of surface-level formal diversity, moving away from modernism's principles of simplicity, functionality, and unity. However, this formal diversity often fails to integrate with local culture, climate, materials, and geographic features, resulting instead in a homogenized visual language characterized by a superficial "Traditional Turkish House imitation."

In this context, adopting design approaches that preserve the *genius loci* and establish contextual coherence with the surrounding environment becomes essential in mass housing façade design. Façade configurations must be informed by climatic data, material culture, historical context, and socio-cultural structures. Only then can urban space function not merely as a physical container for

habitation but as a meaningful place that embodies identity, produces cultural value, and fosters a sense of belonging.

Ultimately, the reconsideration of Turkish mass housing facades through the lens of place and identity is imperative for ensuring that future cities develop in ways that are contextually grounded, identity-rich, authentic, and sustainable. This perspective reinforces the understanding that architecture is not merely a technical practice of constructing buildings but a discipline responsible for preserving cultural continuity and collective memory. In this regard, standardized approaches focused solely on quantitative housing production demonstrably undermine the cultural continuity of cities in the long term. Integrating local architectural knowledge into the early stages of design will contribute to the formation of urban identity and strengthen users' attachment to place. Moreover, policies that respect regional differences, encourage climate-responsive design, and promote the use of local materials will constitute the foundation for enhancing the quality of mass housing environments. Adopting such an approach in future planning and design processes will not only elevate the quality of the physical environment but also ensure the sustainable preservation of distinctive urban identities. Based on the research and analyses conducted, the following recommendations are presented:

• In all stages of mass housing projects—from site selection to façade design—local data should be utilized, and architectural design decisions should be directly informed by these contextual inputs.

• Use of local materials, climate-responsive façade solutions, and region-specific design decisions should be actively encouraged.

• Traditional architectural elements should not be employed merely as superficial decoration but should be integrated within a coherent contextual and functional framework.

• Regional architectural guidelines should be prepared for TOKİ and other mass housing producers, and instead of relying on standardization, design principles tailored to the identity of each region should be established.

• The early design phases of housing projects should incorporate local experts, architects, urban planners, and sociologists, ensuring a multidisciplinary collaborative process.

• Instead of uniform block arrangements, diverse spatial scenarios that allow for different configurations and mixed-use layouts should be developed in mass housing areas.

• Participatory design methods that consider users' expectations and needs should be employed throughout façade design processes.

• In design decisions, global trends should be secondary to solutions that support local living culture and spatial practices.

• Collaborative research projects with universities and research institutions should be encouraged to examine housing facades in terms of identity, sustainability, and energy efficiency.

• Instead of short-term cost advantages, long-term gains related to identity and sustainability should be prioritized in façade design.

• In new projects, the proportions and rhythms of the Traditional Turkish House façade should be reinterpreted within context as a generative component of architectural heritage.

• Following the completion of projects, regular assessments of user satisfaction and identity perception should be conducted, and the findings should be integrated into future project development processes.

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Chapter 9

DETERMINING USER OPINIONS OF URBAN AGRICULTURE POTENTIAL IN PARKS: THE CASE OF KONYAALTI, ANTALYA

RİFAT OLGUN [1]

1 Assoc.Prof.Dr., Akdeniz University, Vocational School of Serik G-S. Süral, Landscape and Ornamental Plant Cultivation Program, rifatolgun@akdeniz.edu.tr, ORCID: 0000-0002-5396-057X.

1. INTRODUCTION

Increasing urbanization on a global scale has led to various problems, such as the gradual loss of natural areas, disruption of ecological balance, and deterioration of food systems (Olgun & Karakuş, 2024; Olgun et al., 2024). According to United Nations data, more than 55% of the world's population currently lives in cities, and this percentage is expected to continue to increase (UN, 2018; Durukan et al., 2025). It is thought that the rate of urban population growth will be higher in developing countries such as Türkiye (City Farmer, 2011; FAO-FCIT, 2011; Kutsal & Polatoğlu, 2023). This rapid transformation is leading to changes in the spatial structures of cities, not only as areas for work, housing, and economic activity, but also as areas that encompass natural spaces. The urbanization process leads to a decrease in productive agricultural land and forest areas, an increase in air and water pollution, microclimatic changes, and the emergence of various socio-economic constraints (Orsini et al., 2013; Ranagalage et al., 2020; Olgun et al., 2025). Therefore, it is necessary to develop comprehensive planning strategies that target transforming cities into spaces that offer social, cultural, and healthy living environments (Erdoğan et al., 2016; Elmas, 2022). Urban green spaces are among the fundamental components of cities due to the ecosystem services they provide and the opportunities for social use they offer (Selim et al., 2023; Olgun et al., 2024). In addition, the planning of spaces that can contribute to ensuring food security for the growing and densifying population is an important issue that needs to be reconsidered by decision-makers and planners (Morgan & Sonnino, 2010; FAO, 2025; Tabrez, 2025).

Urban agriculture is one of the prominent strategies in the planning of sustainable cities. Urban agriculture is defined as a holistic system that encompasses plant and animal production activities carried out within cities or on their peripheries, including production, processing, and distribution processes (Artmann & Sartison, 2018; Türker & Anaç, 2022; Mwetulundila & Indongo, 2025). In addition to contributing to safe food production, urban agriculture offers significant gains in terms of environmental sustainability, social integrity, and economic benefits (Lovell, 2010; Ackerman et al., 2014). It also provides various ecosystem services such as reducing the urban heat island effect, carbon sequestration, stormwater management, and increasing urban biodiversity (Artmann & Sartison, 2018; Mwetulundila & Indongo, 2025). It is noted that urban agriculture practices are particularly effective in regulating the microclimate in areas with dense urban settlements (Artmann & Sartison, 2018; Yaman & Yenigül, 2022; USDA, 2025). At the social and individual scale, various studies have demonstrated that urban agriculture practices promote physical activity, reduce individual stress levels, support mental well-being, and increase interaction with nature (Yaman & Yenigül, 2022; Soga et al., 2017).

Urban agriculture practices can be spatially integrated into areas such as parks, public open spaces, vacant lots, residential gardens, and rooftops and terraces (Orsini et al., 2013; Taylor & Lovell, 2014). Among these areas, urban parks are considered important spaces for implementing urban agriculture in a multifunctional manner due to their large areas, high accessibility, and intensive public use (Yaman & Yenigül, 2022). Urban agriculture practices in parks can offer production, education, and environmental awareness, alongside recreational functions.

The integration of urban agriculture into park areas is not merely a process limited to spatial suitability or ecological capacity. Users' perceptions, expectations, willingness to participate, and potential concerns are among the decisive factors for the success and sustainability of such applications (Nadal et al., 2018). Planning and design approaches that do not take user opinions into account face difficulties in gaining social acceptance in public spaces and ensuring long-term sustainability. While the topic of urban agriculture in Türkiye has increasingly come to the fore in academic and practical areas in recent years, it is observed that a great deal of the existing studies focus on conceptual discussions, spatial suitability analyses, or policy recommendations, while user-based empirical studies remain limited (Yurday et al., 2024; Türker & Akten, 2023). It is particularly

noteworthy that there is a lack of studies addressing urban agriculture at the scale of urban parks from the user's perspective.

Antalya, located in the Mediterranean climate zone, has favorable climatic conditions for agricultural activities throughout the year. The spaciousness and intensive use of parks in the city indicate that these areas have significant potential for urban agriculture practices. The study aims to evaluate the potential for urban agriculture in parks based on user opinions, using the example of the 23 April National Sovereignty Park located in the Konyaaltı district of Antalya province. In the study, park users' usage habits, existing agricultural activities, perceptions and attitudes towards urban agriculture, and preferences for different urban agriculture scenarios developed at the park scale were analyzed. It is expected that this study will contribute to the landscape planning and urban design literature by presenting a user-based approach to the integration of urban agriculture into public open areas.

2. MATERIALS AND METHODS

2.1. Study Area

Antalya is located in the Mediterranean region in southern Türkiye and is one of the country's leading tourism and agricultural cities. With its Mediterranean climate prevailing throughout the year, long coastline, and intensive urban development, Antalya offers significant potential for the sustainable use of urban open green spaces. The park determined as the study area is located in the Konyaaltı district, west of Antalya city center. Konyaaltı, one of the five central districts, is bordered by the Mediterranean Sea to the south and the Beydağları Mountains, the western extension of the Taurus Mountains, to the north. The district, which has a coastline approximately 7.5 km long, encompasses both coastal areas and mountainous and forested ecosystems. Important natural and structural components within the district boundaries, such as the Olimpos–Beydağları Coastal National Park, Boğaçay Stream, Antalya Port, and Akdeniz University's main campus, enhance Konyaaltı's ecological, recreational, and socio-cultural importance. The district has a total area of approximately 546 km² (Manavoğlu & Ortaçeşme, 2007; Erdoğan et al., 2011; Dipova, 2016; Olgun, 2020) (Figure 1).

The 23 April National Sovereignty Park is an urban park area located within the boundaries of the Konyaaltı district and surrounded by a dense urban pattern. Due to its location, the park serves as an area that offers both active and passive recreational activities between residential areas, transportation axes, and public uses. The 23 April National Sovereignty Park, with its existing vegetation, pedestrian circulation networks, and open green spaces, makes a significant contribution to the urban ecosystem services of the region. The park's existing green space quality, user diversity, and accessible location provide opportunities for testing different urban agriculture scenarios.

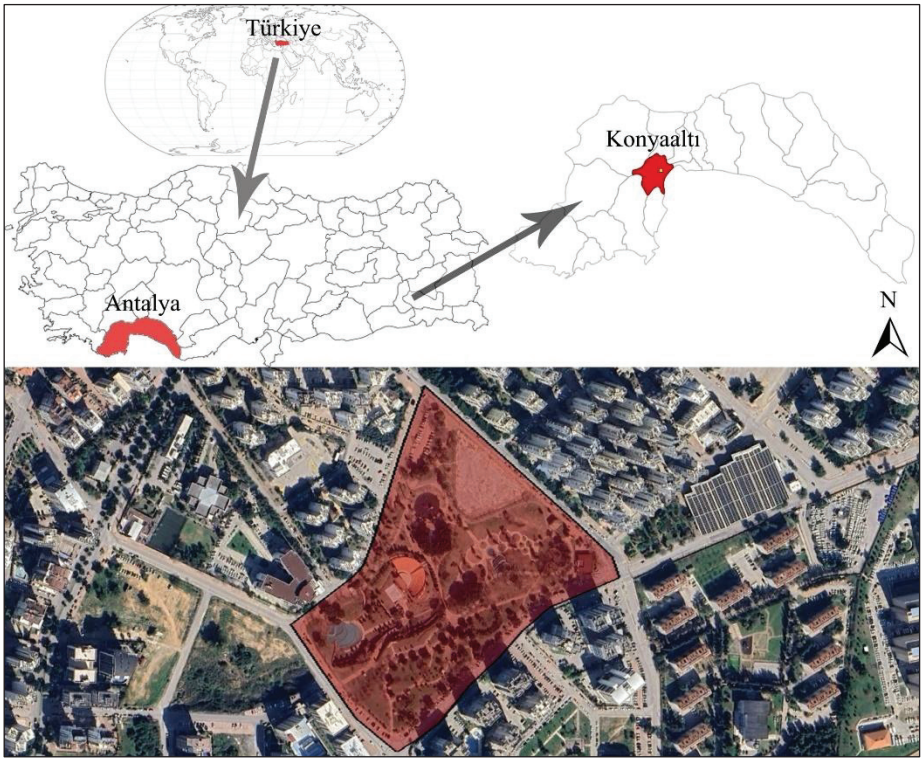

Figure 1. Map of the study area boundary of Konyaaltı, Antalya

2.2. Method

The study, which aims to evaluate the urban agriculture potential of parks based on user opinions, was conducted in three stages. In the first stage, the national and international literature related to the study topic was reviewed, and projects, articles, books, and thesis studies on the topics of urban areas, open green spaces, urban green spaces, parks, and urban agriculture were examined. In the second stage, a survey form consisting of four sections and 37 questions was prepared to evaluate user opinions. The first section of the survey form contained questions about participants' park usage habits, the second section about their current agricultural activities, the third section about their opinions on urban agriculture and their level of participation in proposals, and the final section contained questions to evaluate the socio-demographic structure of the participants. In addition, five different spatial scenarios for urban agriculture activities within the park boundaries were developed and visualized using Adobe Photoshop software. In the images produced, alternative plans were created by considering different types of agricultural uses, such as greenhouse areas, orchards, and open field plant cultivation plots, both separately and together. During the development of the scenarios, the area's existing green pattern, pedestrian circulation network, recreational uses, and environmental context were taken into consideration.

In this context, face-to-face and online surveys were conducted with 310 park users who had previously used the study area on different days and times of the week. The surveys were conducted on a voluntary basis, and simple random sampling was used for sample selection. In the final stage of the study, the data obtained from the surveys were digitized using SPSS software, and descriptive statistical analyses were performed. The analysis results obtained were evaluated together with field observations to assess the potential for urban agriculture in the parks.

3. FINDINGS

3.1. Socio-Demographic Structure of Participants

The study conducted at 23 April National Sovereignty Park in Konyaaltı district consists of 57.1% women and 42.9% men. When the age distribution of participants is examined, 14.2% of them are aged 18-30, 34.8% are aged 31-50, 31.9% are aged 51-65, and 19.1% are aged 65 and above. In terms of educational level, 15.2% of participants have primary education, 23.9% have high school education, 25.4% have associate's degrees, 31.6% have bachelor's degrees, and 3.9% have postgraduate degrees. When examining the professional status of participants, 11.3% of them are students, 39.7% are employed in any profession, 6.1% are unemployed, 29.7% are retired, and 13.2% are housewives. In terms of housing type, 34.2% of the participants reside in an apartment, 15.8% in a detached house, 48.1% in an apartment within a housing complex, and 1.9% in shantytown-type housing.

3.2. Park Usage Habits of Participants

The majority of participants (98.1%) stated that they regularly use the parks in the Konyaaltı district. When examining the frequency of park use, it was found that 44.2% of participants use the parks once a week, 27.1% use them once a month, and 21.0% use them almost every day. A significant portion of park users visit parks with their families (39.7%) or friends (36.8%). The purpose of visiting the parks was stated as relaxing and resting by 39.7% of the participants. In addition to this purpose, the use of parks is diversified with various activities such as exercising (running and walking), social meetings, playing with children, having a picnic, walking pets, reading books, passing the time, and being together with other individuals. When the time of park use was evaluated, it was determined that 56.3% of participants visit parks on weekends, 32.4% visit both weekdays and weekends, and 11.3% visit only on weekdays. The majority of participants (53.7%) use parks in spring and summer, especially between 4:00 p.m. and 8:00 p.m. In terms of time spent in the park, 46.3% of participants spend an average of 1–3 hours in the park, while 30.7% spend 3-5 hours.

3.3. Current Agricultural Practices of Participants

It was determined that 34.2% of participants have a residential garden, while 23.9% currently engage in some form of agricultural activity at their residence. Of the participants engaged in agricultural activities, 47.3% carry out these activities in their residential gardens, 22.9% on their balconies, 17.6% on their terraces, and 12.2% on the roofs of their residences. When the types of products grown were examined, it was found that 39.2% of participants grow vegetables, 25.7% grow fruit, 18.9% grow ornamental plants, and 16.2% grow medicinal and aromatic plants.

When evaluating participants' purposes for engaging in agricultural production in their residences, the most important reason was found to be obtaining healthier products (54.1%). This was followed by hobby-based production (24.3%), the need for physical activity (12.2%), and contributing to the budget (9.4%). On the other hand, the majority (78.4%) of participants who did not engage in any plant and/or animal production in their residences explained this situation by citing insufficient or no space suitable for growing products.

3.4. Opinions of Participants Regarding Urban Agriculture

While 52.3% of participants stated that they knew about urban agriculture, 25.1% stated that they knew about it partially, and 22.6% stated that they had never heard of the term urban agriculture before. Participants indicated parks (39.7%), vacant lots (25.5%), residential gardens (21.9%), public open spaces within the city (11.3%), and rooftops/terraces (1.6%) as the most suitable areas for urban

agriculture activities. However, the majority of participants (89.2%) stated that they would like to see agricultural areas in the parks in their neighborhood. When examining opinions on the types of agricultural activities that can be carried out in urban areas, it is seen that 48.7% of participants find vegetable cultivation more suitable, while 38.4% find fruit cultivation more suitable. Other participants stated that medicinal and aromatic plants, ornamental plants, and grain types can also be cultivated within the scope of urban agriculture.

When urban agricultural activities are carried out in parks, 86.1% of participants stated that they would like to actively participate in these activities. Moreover, 82.6% of participants indicated that it is important for urban agricultural areas to be located within a 0–0.5 km walking distance. Regarding the amount of time that could be spent in these areas, 42.7% of participants stated that they could spend 0–2 hours, 30.9% stated that they could spend 2–4 hours, while the remaining participants stated that they could spend more than 4 hours. 58.3% of participants believe that urban agriculture areas in parks should be 2000–5000 m² in size. Furthermore, 76.4% of participants stated that these areas should be the responsibility of municipalities, while 14.4% said they should be the responsibility of the Provincial Directorate of Agriculture and Forestry, and 9.2% said they should be the responsibility of the private sector.

The urban agriculture scenarios developed for the 23 April National Sovereignty Park in Konyaaltı district aim to spatially integrate different production types while preserving the park's existing recreational character and green texture continuity. In this context, the visuals prepared depict agricultural areas designed with different production types, such as greenhouse structures, orchards, and open field plant cultivation plots. While greenhouse areas representing controlled production are highlighted in some scenarios, community-based production areas are proposed in some arrangements through semi-natural garden textures created with fruit trees or modular plot systems. Furthermore, hybrid planning approaches that combine these uses have been adopted in some designs, increasing both production diversity and spatial flexibility. In all scenarios, agricultural areas are positioned in harmony with the park's pedestrian circulation, existing tree cover, and recreational areas. Participants were asked to rate the images related to these scenarios. Accordingly, 46.8% of participants preferred Photo 2, 21.3% preferred Photo 5, 18.1% preferred Photo 1, 8.4% preferred Photo 4, and 5.4% preferred Photo 3. Photo 2, which received the highest score, reflects a hybrid agricultural production approach, presenting fruit orchards, modular plant beds, and greenhouse areas suitable for protected cultivation in this scenario (Figure 2).

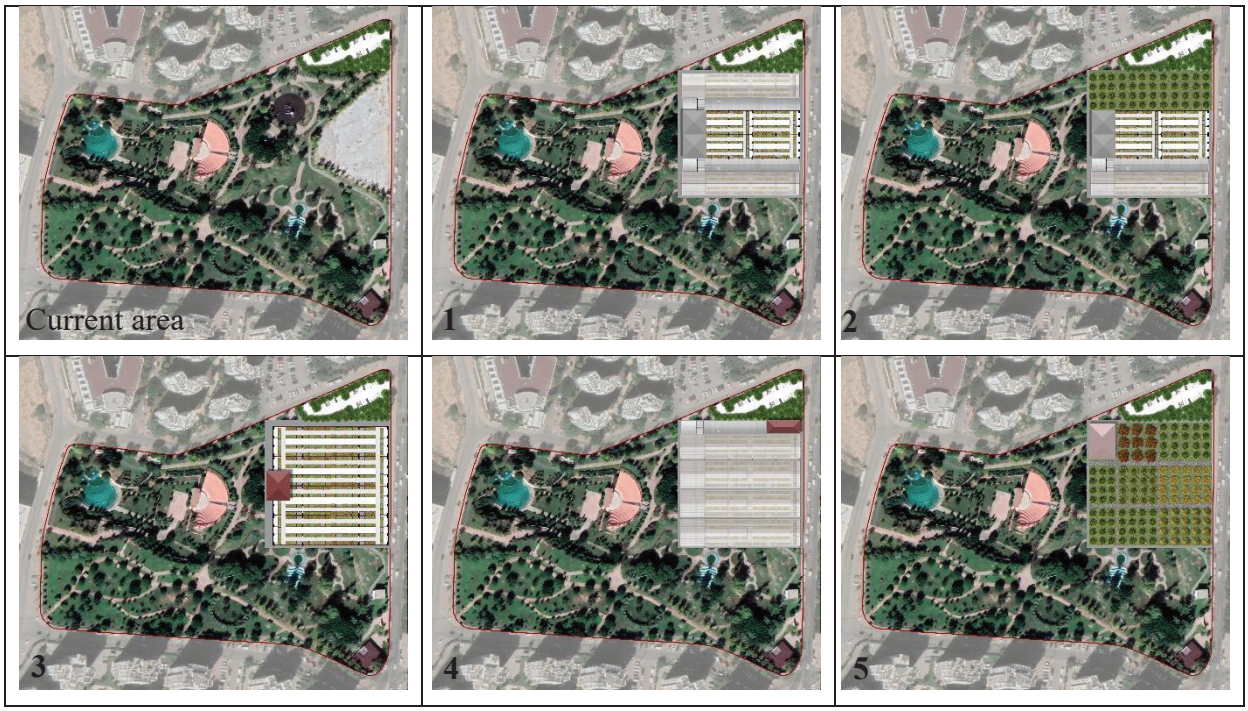

Figure 2. Proposed urban agriculture scenarios within the study area.

To evaluate participants' opinions on urban agriculture, 25 proposals were presented using a 5-point Likert scale. Participants showed a high level of agreement with the statements “contributes to reducing individual stress” ($\bar{X}$: 4.70), “provides opportunities for physical activity” ($\bar{X}$: 4.63), and “increases people's interest in agriculture” ($\bar{X}$: 4.58) (Table 1).

Table 1. Participants' level of agreement with statements regarding urban agriculture.

Proposal	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	$\bar{X}$	sd
	%	%	%	%	%		
Contributes to the urban ecosystem	1.0	4.2	20.6	41.3	32.9	4.01	0.890
Contributes to the social structure of the urban	0.6	12.9	3.9	16.5	66.1	4.35	1.076
Contributes to the urban economy	1.9	8.1	8.4	21.3	60.3	4.30	1.048
Contributes to the health of individuals living in urban areas	1.0	5.2	11.6	31.3	51.0	4.26	0.924
Urban agriculture improves the urban climate	3.9	11.6	9.0	45.8	29.7	3.86	1.088
Urban agriculture promotes social integrity	0.6	8.7	12.3	50.6	27.7	3.96	0.899
It increases social interaction among people.	1.3	6.8	3.2	39.4	49.4	4.29	0.913
Urban agriculture improves individuals' quality of life.	0.6	4.8	7.4	40.3	46.8	4.28	0.848
Urban agriculture is beneficial in providing aid to the poor.	1.6	4.8	11.6	41.9	40.0	4.14	0.916
It offers a recreational activity.	1.0	10.3	7.1	30.6	51.0	4.20	1.021
It benefits the local food supply.	3.9	8.7	11.0	51.6	24.8	3.85	1.017
It provides local job opportunities.	15.5	31.0	9.4	21.0	23.2	3.05	1.439
Provides access to fresh food	1.9	4.8	6.8	19.4	67.1	4.45	0.953
Contributes to reducing individual stress	0.0	3.2	1.9	16.8	78.1	**4.70**	0.667

Provides opportunities for physical activity	0.0	0.6	2.9	29.7	66.8	**4.63**	0.576
Provides psychological benefits	8.4	16.1	15.2	41.0	19.4	3.47	1.211
Provides opportunities to learn about agricultural activities	0.0	5.8	7.7	33.5	52.9	4.34	0.854
Increases people's interest in agriculture	0.3	2.6	1.0	31.3	64.8	**4.58**	0.677
Increases knowledge and skills related to agriculture	1.9	5.5	6.1	39.4	47.1	4.24	0.932
Provides green space for the area	4.5	19.7	8.4	42.6	24.8	3.64	1.182
Facilitates urban-rural integration	1.6	6.5	3.9	58.7	29.4	4.08	0.855
Promotes inter-generational cultural integration	1.3	5.5	14.5	52.6	26.1	3.97	0.862
Increases urban biodiversity	1.6	6.8	5.5	51.6	34.5	4.11	0.896
Mitigates the urban heat island effect	0.6	6.5	9.4	46.5	37.1	4.13	0.875
Reduces vandalism in parks	0.6	6.8	5.5	46.1	41.0	4.20	0.869

Additionally, participants are presented with 8 statements using a 5-point likert scale to assess negative user opinions regarding potential issues arising from urban agriculture. Participants mostly agree with the statement that urban agriculture pollutes the soil due to excessive use of chemicals and fertilizers. This statement is followed by the statements “it causes a decrease in water resources” and “it pollutes groundwater.” (Table 2).

Table 2. Participants' level of agreement with statements regarding urban agriculture.

Proposal	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**X̄**	**sd**
	%	%	%	%	%		
Increases the amount of waste produced in the park	41.9	31.9	6.8	15.8	3.5	2.07	1.199
Destroys the natural beauty of the park and its surroundings	49.7	34.2	3.5	11.9	0.6	1.80	1.015
Increases air pollution	33.5	47.4	8.4	10.0	0.6	1.97	0.938
Pollutes groundwater	31.0	49.7	3.2	10.3	5.8	**2.10**	1.127

Pollutes the soil due to excessive use of chemicals and fertilizers	7.1	34.2	11.0	35.5	12.3	**3.12**	1.209
Leads to a decrease in water resources	6.8	44.5	4.5	30.0	14.2	**3.00**	1.261
Increases the risk of soil erosion	34.8	46.1	10.6	7.4	1.0	1.94	0.915
Reduces the use of park areas	57.4	32.6	3.5	5.5	1.0	1.60	0.871

4. DISCUSSION AND CONCLUSION

Today, urban agriculture accounts for between 15% and 20% of the global food supply. This percentage is insufficient to meet the food needs of city residents. Studies show that 30% of urban land would need to be converted to agricultural land to meet the food demand in cities. In this context, urban agriculture is expected to support existing food sources (USDA, 2025). This study, conducted on the example of 23 April National Sovereignty Park in the Konyaaltı district of Antalya, contributes significantly to the literature by examining the suitability of parks in cities for urban agriculture based on user opinions. The findings reveal that the integration of urban agriculture into park areas is not limited to environmental and spatial dimensions; it also provides meaningful contributions to social interaction and individual health.

The findings of the study show that the majority of park users regularly use parks and spend long periods of time in these areas. This situation reveals that parks play an important role in individuals' daily lives. The positive effects of parks on physical and psychological well-being are frequently emphasized in the literature (Sturm & Cohen, 2014; Soga et al., 2017). The findings of this study also show that parks can be re-examined not only as passive recreation areas but also as productive spaces that encourage active participation by users. The fact that 23.9% of participants are currently engaged in agricultural activities in their own residences, while many individuals are unable to continue these activities due to insufficient space, clearly demonstrates the necessity of addressing urban agriculture at the park scale. This situation aligns with the views emphasized by Orsini et al. (2013) and Taylor and Lovell (2014) that urban agriculture must move beyond the spatial limitations of the residential scale and into public spaces.

When perceptions and attitudes towards urban agriculture are evaluated, it is seen that the majority of participants adopt urban agriculture as a positive practice and want such activities to take place in neighborhood parks. In particular, the high level of agreement with the statements “it contributes to reducing individual stress,” “it provides opportunities for physical activity,” and “it increases people's interest in agriculture” reveals that users strongly perceive the social and psychological dimensions of urban agriculture. These findings are consistent with previous studies showing that urban agriculture and gardening activities contribute to individuals' mental well-being (Soga et al., 2017; Gunapala et al., 2025).

The participants' generally high level of agreement with statements regarding environmental contributions indicates that urban agriculture has created significant awareness in the context of ecosystem services. Findings on improving the urban climate, reducing the urban heat island effect, and increasing biodiversity are consistent with the environmental benefits of urban agriculture identified by Artmann and Sartison (2018) and Pradhan et al. (2023). This shows that participants view urban agriculture not only as a recreational element, but also as a planning tool with ecological functions. Moreover, findings regarding the potential negative impacts of urban agriculture also reveal noteworthy results. Participants' emphasis on risks of soil and water pollution associated with

chemical fertilizer and pesticide use highlights the importance of oversight, education, and sustainable production techniques in the planning and management processes of urban agriculture practices. These findings indicate that urban agriculture can pose environmental risks when not properly managed.

The study results reveal that park users do not view urban agriculture as an activity limited solely to food production; rather, they evaluate it through its multidimensional contributions, such as social interaction, physical activity, psychological well-being, and environmental awareness. The fact that the majority of users want to participate in urban agriculture activities in parks and demand that these areas be within walking distance clearly demonstrates the importance of planning urban agriculture at the neighborhood level. It is a noteworthy finding that the hybrid production approach is preferred more by participants among the different urban agriculture area scenarios developed for the study area. This approach, which combines orchards, modular plant beds, and greenhouse areas, reveals that participants have adopted balanced solutions in terms of both visual landscape quality and production diversity.

Overall, this study demonstrates that urban agriculture practices in city parks should be considered not only based on physical spatial suitability but also in line with user expectations and preferences. Urban agriculture areas with high user participation, accessibility, medium scale, and managed by public authorities will be more sustainable and socially acceptable practices within park systems. This approach, based on user opinions, is expected to significantly guide future urban agriculture and park planning studies. In future studies, it is recommended to conduct comparative analyses across different cities and park types, examine long-term user behavior, and carry out comprehensive assessments supported by ecological indicators.

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Chapter 10

MT. NEMRUD: THE SPATIAL MANIFESTATION OF HEIDEGGER'S FOURFOLD

Zeynel Dündar[1]

1 PhD at Artvin Çoruh University, Faculty of Art and Design, Department of Interior Architecture and Environmental Design, Arhavi, Turkey, https://orcid.org/0000-0002-0762-3361

Introduction

Located in southeastern Asia Minor, the Kingdom of Commagene served as a crucial geopolitical buffer between the Seleucid Empire to the west and the Parthian Empire to the east during a period of Roman expansion eastward into territories controlled by Hellenistic states—a region bounded by the upper branches of the Euphrates River on one side and the Taurus Mountains on the other (Facella, 2006). Ruling from 70–38 BCE, King Antiochus I. not only navigated the political challenges of this turbulent era but also initiated a project of cultural and religious synthesis that would shape the kingdom's identity. His mixed heritage—descended from both the Orontid Armenian and Seleucid dynasties—proved decisive in his politics and religious vision (Versluys, 2017). The concrete expression of this vision is the monument he erected on Mount Nemrud (2150 m), the kingdom's highest peak. Here, as seen in Figure 1, he raised an artificial stone mound (tumulus) approximately 50 meters high and placed colossal statues, 8–9 meters tall, on terraces at the mountain's shoulder, depicting himself alongside the gods (Sanders, 1996).

Figure 1. The tumulus and colossal statues Terrace of Mt. Nemrut. Nuri Bilge Ceylan (photo). From Kommagene-Nemrut Management Plan, by N. Şahin Güçhan (Ed.), 2017, METU & Ministry of Culture and Tourism.

Traditional archaeological and art-historical discourse has almost invariably read this site as the monumental burial complex of Antiochus I, evidence of his giant statues and self-deification efforts. This reading reduces the site to a passive carrier of the historical figure and discourse of power it represents, ultimately framing it as an "archaeological object" to be preserved and displayed (e.g., Waldmann, 1973; for a contrasting view, see Smith, 1988). However, this approach subordinates the ontological quality of the place—the question of *how it exists* and *how it is experienced*—to the historical and iconographic question of *what it is*. Consequently, the monument remains a frozen representation of the past, and its transformative, existential power on today's visitor is overlooked.

In this study, we propose to move beyond this reductive paradigm of spatial representation. Our aim is to reread Mount Nemrud not merely as a *monument*, but as a *dwelling*—more precisely, as a *gathering place* where the fundamental principles of being come together and manifest. To ground this claim, we adopt a phenomenological approach that treats the structure and place as directly experienced phenomena. Phenomenology shifts the focus from the absolute essence of an object to its appearance in consciousness (the phenomenon) and, thus, to the qualities of directly experienced space (Merleau-Ponty, 2012). In an architectural context, this means seeking to understand the existential, sensory, and temporal relationship a structure establishes with the body, rather than its mere physical and visual data (Pallasmaa, 2024).

However, the primary theoretical foundation of this work will be the thought of Martin Heidegger, who moved phenomenology beyond a mere philosophy of consciousness to the plane of the question of being (ontology). For Heidegger, the primordial mode of human existence is not simply being present in the world but *dwelling* within it. Dwelling, beyond being a technical act of construction, is a meaningful making room for the world, protecting and caring for it (Heidegger, 1971a). In this study, Heidegger's concept of the *Geviert* (the Fourfold) will be used as the fundamental structure embodying this 'place-making' act. For Heidegger, this fourfold—*Earth* (Erde), *Sky* (Himmel), *Mortals* (Sterbliche), and *Divinities* (Göttliche)—exists in a dynamic relationship. A place becomes a genuine "dwelling" only when it gathers these four dimensions together and allows for the relationship between them—that is, when it "assembles" them (Heidegger, 1971a).

Proceeding from this basis, subjecting Mount Nemrud to a Heideggerian reading through the lens of the *Geviert* offers the possibility of reconceptualizing it not as a king's personal monument, but as a ritualistic gathering place that summons, holds together, and draws the visitor into a dialogue with these four existential principles. The mountain itself, the tumulus, the relationship of the terraces with the sky, the positioning of the statues, and the inaccessibility of the burial chamber can all be read as concrete sites of manifestation for this fourfold. This reading will be further enriched by the concept of the "spirit of place" (*genius loci*), developed by Christian Norberg-Schulz under influence of Heidegger. For Norberg-Schulz, *genius loci* is the inseparable unity of a place's material qualities (topography, light, material) and the existential meaning that unfolds there. Nemrud's *genius loci* arises not merely from its statues, but from the geographical singularity of the mountain, its isolated peak, the behavior of wind and light—in short, from the wholeness forged here between the natural and the cultural.

This approach appears to address a notable gap in the existing literature on the subject. Studies on Nemrud have focused predominantly on epigraphic analysis (e.g., Crowther & Facella, 2003),

sculptural iconography and stylistic criteria (e.g., Hoepfner, 1983), and historical chronology and political context (Facella, 2006, pp. 169-174). Recently, scholars such as Versluys (2017) have re-evaluated the monument within the context of identity construction and cultural representation. However, a systematic theoretical study that centres on the phenomenological and existential experience of the place—treating it not as a temporal "monument" but as an ongoing manifestation of "dwelling" and a field of dialogue for the *Geviert*—is still lacking. This study aims to fill that gap and to build an interdisciplinary bridge between architectural theory, phenomenology, and cultural heritage studies.

1. Theoretical Ground: Dwelling and the Fourfold

The concept of "dwelling" (*wohnen*), central to Martin Heidegger's later thought, transforms it from a mere act of sheltering into the fundamental and integral mode of human existence (*Dasein*) in the world. In his text "Building, Dwelling, Thinking" (1951), Heidegger challenges the modern tendency to reduce place to a housing problem—that is, to an object of technical and economic necessity (Heidegger, 1971a). For him, dwelling constitutes a radical break from the dominion of the technological framework that views the world as a standing reserve and transforms it into a resource open to exploitation. On the contrary, dwelling is a mode of relationship that "safeguards" and nurtures the world, stripping away the technological veil that obscures its essence and releasing beings into their own truth. This is a protective-releasing attitude, which Heidegger indicates with the phrase "to save the Earth" (Heidegger, 1971a, p. 148).

On this ontological ground, building is not a means or a result of dwelling, but rather the very manner of its realization. Delving into the roots of language, Heidegger shows that the words "*bauen*" (to build) and "*wohnen*" (to dwell) share the same ontological ground. From this, he advances his famous proposition: "We do not dwell because we have built, but we build because we dwell…" (Heidegger, 1971a, p. 146). Therefore, genuine building is not merely erecting a structure, but making room for a place that enables dwelling. This act of "making room" goes beyond delimiting a physical void; it is a gathering of a meaningful whole, thereby instituting a place (*Ort*).

1.1. Gathering as the Fourfold

For Heidegger, this gathering which makes dwelling possible is the coming together of four fundamental principles or dimensions that constitute the structural element of the world. This fourfold is not a fixed table of categories, but a dynamic network of relations intrinsic to one another:

Earth is the material ground that supports, bears, and nourishes, yet at the same time constantly withdraws itself, is inexhaustible and ultimately ungraspable. It tends to be a mystery that both gives and conceals itself. In the Heideggerian sense, the "clearing" (Lichtung) emerges only through and

in opposition to this self-concealment. Sky, as the counterpart and complement to Earth, is the realm of the sun, the moon, the stars, the seasons, and the weather. Embodying the rhythm, cyclicality, and measure of time, Sky is a domain of constant change and dynamic flux, filled with "fury and mercy," in contrast to Earth's solidity. Mortals are not merely beings with a biological end, but humans capable of thinking death *as death* and of anticipatorily accepting it as their ownmost possibility of being. This radical awareness of death is the source of their endeavor to establish a meaningful relationship with the world, to make it a "dwelling." Finally, the Divinities are not traditional, personified gods, but a dimension that points to the divine, the miraculous, and transcendent meaning. As beings that show themselves and yet conceal themselves, that "withdraw," the presence of the Divinities appears not as an absolute availability, but as a call or a sign from afar.

These four elements are not independent of one another; on the contrary, they reflect each other in a constant and dynamic "mirror-play." Each gains its own essence by mirroring and relating to the others. Something (for instance, a well, a bridge, or a temple) becomes a genuine "thing" and thus a "place" only when it gathers this fourfold within and around itself, when it mediates this reciprocal play among them (Heidegger, 1971a, p. 152). A bridge is not merely an engineering product connecting two banks; it creates a place by gathering the flow of the river (Earth), the climate of the sky, the journey of mortals, and perhaps the call to devotion from the divinities.

2. Reading Mt. Nemrud through the Fourfold

This chapter aims to move the monument beyond the traditional category of "monument-tomb" and show how it becomes an ongoing existential event. Each subsection will focus on one element of the fourfold, yet it will address that element within the context of its inevitable relationship to the other three; for in the Heideggerian fourfold, no element can exist alone. The integrity and power of the experience at Nemrud arise precisely from this reciprocal interplay and tension. This reading liberates the place from archaeology's objectifying gaze and allows us to conceive of it anew as a phenomenon as experienced.

2.1. Earth: The Resisting and Concealing Ground

As indicated earlier in the theoretical framework, Earth, which Heidegger defines as "self-concealing and self-revealing," manifests at Nemrud not merely as a ground or material, but as a constitutive and active subject of the place. Here, Earth presents a two-layered resistance and mystery: first, the geological and topographic presence of the mountain itself; second, as shown in

Figure 2, the construct of the tumulus, articulated by human hand upon this presence and radically following its logic.

Mt. Nemrud's 2150-meter summit is a steep-sloped, climatically harsh outcrop of the Taurus range, formed of hard limestone and basalt strata. This place does not offer permanent residence to humans; on the contrary, it places them in the position of a guest—temporary, exposed, and directly confronted with nature's raw forces (wind, cold, sudden fog). The mountain itself is in a constant

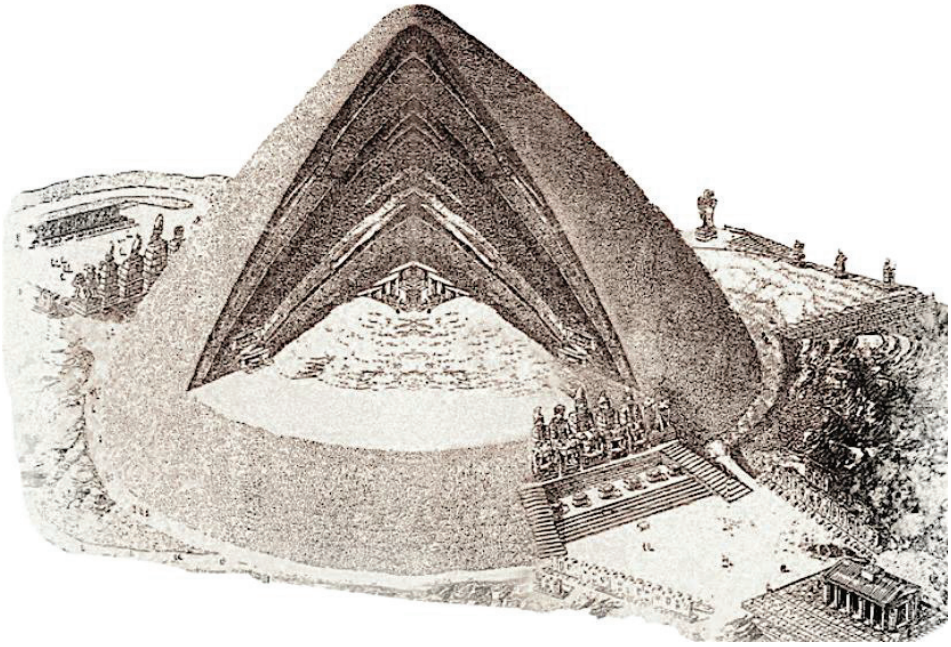

Figure 2. This hypothetical reconstruction of the burial mound on Mt. Nemrud indicates the presumed location of the tomb of King Antiochus I. Source: Adapted from The eighth wonder of the ancient world may have an untouched tomb by Á. C. Pérez Aguayo, August 15, 2024, National Geographic (https://www.nationalgeographic.com/history/article/mount-nemrut-dag-wonder-of-the-ancient-world). Accessed September 9, 2025.

state of self-withdrawal: its strata, origin, and exact geological composition remain an enigma and a secret to all who are there. What Heidegger refers to as "the heaviness of stone" is precisely this kind of resistant presence (Heidegger, 1971b). The ascent to the summit becomes a physical struggle against this resistance, sensitizing the visitor to Earth's autonomous existence, which is not subject to human will.

The tumulus, a human intervention shown in Figure 2, carries this natural Earth-logic into architecture, bringing it to its culmination. This artificial mound, approximately 50 meters high, 150 meters in diameter, and composed of 30,000 cubic meters of crushed stone, inverts the basic principle of traditional tomb architecture (hypogeum or rock-cut tomb) (Sanders, 1996). Whereas a classical tomb opens a void (Grabkammer) in the earth to conceal the dead and defines this void with architecture, the tumulus at Nemrud operates on a logic of fill and mass. The burial chamber assumed to be at its center is not marked by any external sign or accessible entrance. Although archaeological

soundings have shown the structure to be artificial, its central chamber has remained unreachable, its contents and precise location preserved in unknowingness (e.g., Doerner & Goell, 1963).

This radical concealment transforms the tumulus from a simple architectural object into a Heideggerian manifestation of Earth. The tumulus derives its monumentality not from what it conceals (the king's body, treasures) but from the act of concealment itself. It stands as a secret; it is trodden upon but not penetrated, a self-occluding clearing Antiochus's choice can be interpreted as entrusting death not to simple display or representation, but to the mystery and inaccessibility that are Earth's most fundamental qualities, thereby turning it into an ontological mystery. This is not a lavish display of power but an acknowledgment that power is ultimately subject to Earth's resistance and secrecy. In this state, the tumulus, though man-made, exhibits an Earthly character "revealing nothing, closing in upon itself" (Heidegger, 1971b, p. 172), much like a natural hill. Therefore, the Earth at Nemrud is not merely a context or a ground but, in both its natural and cultural forms, a realm of being with its own inherent laws—resistant, concealing, and definitive of the place's meaning.

2.2. Sky: The Spatialization of Cosmic Time

Viewed through the Heideggerian framework, Sky at Mount Nemrud is not merely a physical dome, but the embodied form of time's rhythms and measure. Here, Sky ceases to be a merely observed phenomenon and becomes an active, constitutive principle, woven into the architectural fabric of the place and shaping it. Architecture does not settle for a merely visual relationship with Sky; rather, it exists to invoke, capture, and eternalize Sky's ancient order within the permanence of stone.

The most evident and concrete manifestation of this dialogue is the absolute astronomical orientation of the East and West Terraces. These terraces are not arbitrary vantage points but fixed cosmic theatres, consciously subjected to the sun's annual and diurnal movements (Sanders, 1996). While the East Terrace is conceived as the stage for sunrise—the recommencement of time and life—the West Terrace functions as the place of sunset, the ancient reminder of completion and mortality. This precise alignment directly joints the architecture to the eternal cycle of celestial bodies, making the human-made place an inseparable part of a universal rhythm. Heidegger's definition of "dwelling" as a "place-making" act gains concrete form here: Antiochus's architects built a place that makes room for, that grants a place to, the rhythm of the Sky. This is not an effort to control the sky, but a conscious surrender and homage to its superior order.

The most sophisticated and symbolic expression of this surrender is undoubtedly the famous Celestial Lion Horoscope relief on the West Terrace. As seen in Figure 3, the combination of stars and a moon on it is thought to mark July 62 BCE, interpreted as the date of Antiochus's coronation (Goell, 1996; Jacobs, 2016). What is recorded here is not merely a date; more radically, it is the spatialization of time itself, carved into stone. In Heideggerian terms, the transient, fluid, and abstract time of "Sky" is fixed upon the concrete, permanent material of "Earth." The horoscope captures a moment—perhaps the inaugural moment of the sacred kingdom—and transforms it into an immutable component of the architecture. Thus, flowing cosmic time takes on the form of "something that stands" (ein Stehendes) on this stone tablet, becoming a spatial entity.

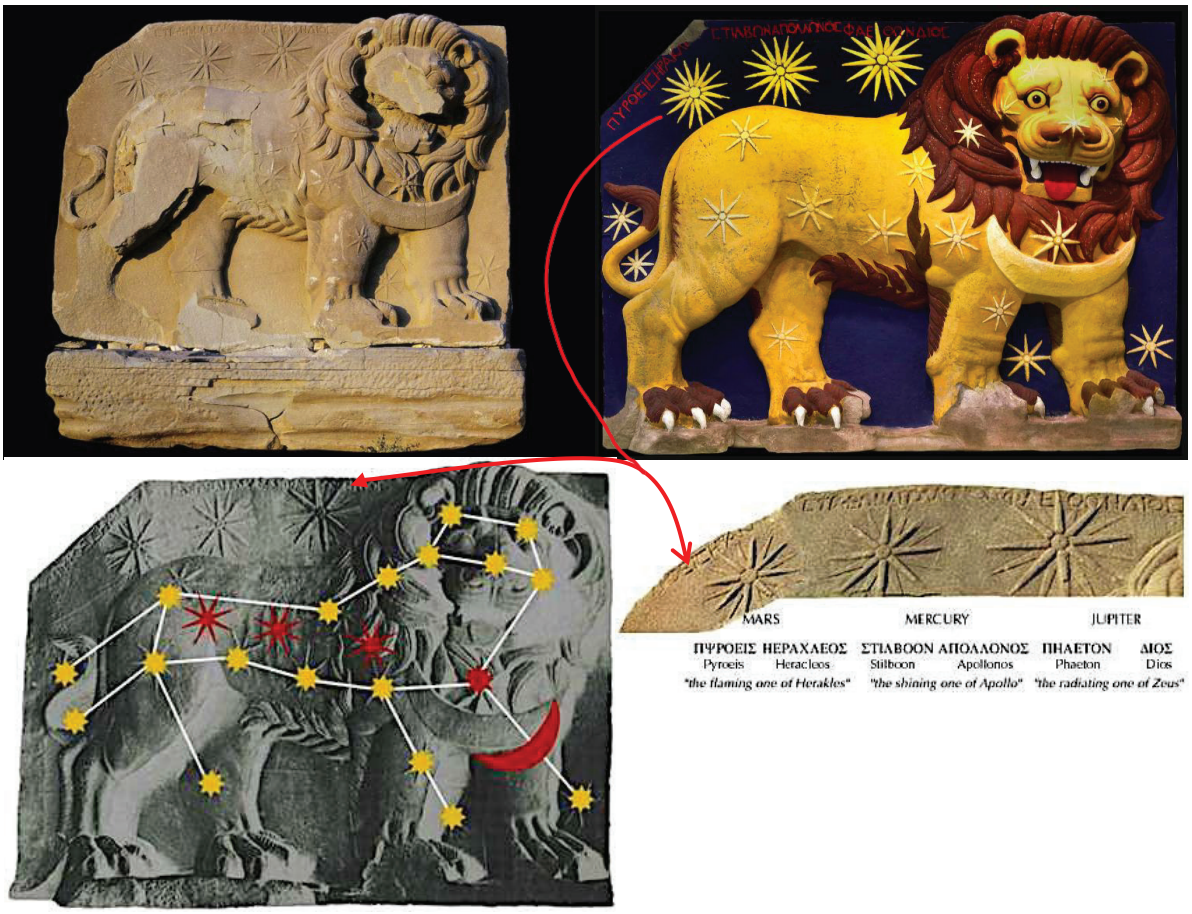

Figure 3. The Celestial Lion Horoscope: A Stone Sky at Mount Nemrud. The best-preserved relief at Mount Nemrud depicts a striding lion adorned with celestial symbols. Nineteen eight-pointed stars across its body correspond to the constellation Leo. A crescent moon, possibly representing a chest ornament, sits below the royal star Regulus. Three sixteen-pointed "stars" above its back are identified as the planets Mars, Mercury, and Jupiter. This precise arrangement is believed to be a horoscope, commemorating a specific event. While some scholars argue it marks a planetary conjunction on July 14, 109 BCE—possibly for the coronation of King Mithridates I—others suggest dates related to his son, Antiochus I, or the foundation of the sanctuary itself. Sources (Top): Detail of the Lion Horoscope, August 15, 2024, National Geographic (https://www.nationalgeographic.com/history/article/mount-nemrut-dag-wonder-of-the-ancient-world). Accessed September 9, 2025. | (Bottom): Diagram and analysis of the horoscope. From Lion Horoscope, International Nemrud Foundation (http://nemrud.nl/index.php/tourist-information/lion-horoscope/). Accessed September 9, 2025.

The presence of Sky at Nemrud is felt not only through these architectural alignments or astral symbols but also through the atmospheric conditions experienced directly and powerfully by the

body. The altitude exceeding two thousand meters places the visitor as if on the threshold of the sky. At this height, one often feels not “below” the clouds but “within” or “above” them. The severe diurnal temperature shifts, the suddenly descending veil of fog, the nearly constant fierce wind, and the immense sea of stars observable on a clear night are the concrete bodily effects of the sky-events (fury and mercy) described by Heidegger. As underscored by a UNESCO report, extreme seasonal and daily temperature variations, freeze-thaw cycles, and wind constitute one of the greatest threats to the site’s physical integrity, while simultaneously shaping its character and challenging nature (UNESCO, n.d.). These conditions transform the place from a static sculpture museum into a constantly changing, dynamic environment that engages the senses. As previously noted, Norberg-Schulz’s concept of genius loci comes into play here: Nemrud’s *spirit of place* is largely determined by the unique quality of light, the transparency of the air, and the behavior of the atmosphere created by this high altitude (Norberg-Schulz, 1980). Observing how the horizontal light at sunrise and sunset dramatizes the expressions on the statues’ faces and the folds of their garments is testament to the power of a transient atmospheric event to intensify and transform the meaning of the place.

In a place conceived this way, Sky becomes an absolute order, a measure, and ultimately a source of transcendence for mortal humans. King Antiochus I’s placement of himself at the very centre of this cosmic order—alongside the divine figures—can be read as a manifestation of the desire to relate his mortal kingdom to an eternal and everlasting order, thereby giving meaning to his transience within a grander context. His meticulous regulation of posthumous rituals in the Nomos inscriptions (Waldmann, 1973) also reflects this wish to harmonize with and become part of the cosmic order. For the modern visitor, the situation is no different: at the summit, the sense of smallness and transience on a human scale felt before the boundless horizon and sky leads directly to existential questioning. The ultimate function of Sky here is not to crush humans, but to make them conscious of their position, their limits, and their mortality. Heidegger’s “mortals” are defined precisely by this consciousness: beings who can comprehend death as death and exist with this knowledge (Heidegger, 1971a). Nemrud’s Sky is a powerful instrument that triggers, awakens this fundamental comprehension.

In conclusion, at Mount Nemrud, Sky is not a decorative backdrop or a passive spectacle. It is the constitutive principle of the place, the spatial counterpart of time, and the awakener of mortal consciousness. Architecture exists to capture this principle, to enter into dialogue with it, and to make it last. Through this dialogue, Nemrud brings together the transient (time) with the permanent (architecture), the mortal (humans) with the order of the divine and eternal (cosmic law), thereby manifesting the celestial dimension of the Heideggerian Fourfold with clarity and power.

2.3. Mortals: The Awareness and Transcendence of Finitude

In Fourfold, Mortals are not merely beings with a biological end, but beings capable of thinking death as death, of anticipatorily accepting this ultimate possibility as a fundamental condition of their existence, and of shaping their actions with this awareness. This radical consciousness of finitude is the driving force behind their endeavor to dwell in the world. At Mount Nemrud, this existential condition is concretized on two parallel planes: in the design by its founder, King Antiochus I, and in the experience of today's visitor. By bringing these two mortal layers together, the place becomes not a simple denial or tragedy of finitude, but the stage for a conscious confrontation and attempt at transcendence.

The point at which King Antiochus I most intensely represents this awareness is the extreme meticulousness with which he planned his death and what would follow. In the sacred law inscriptions known as the *Nomos,* he regulated in the finest detail the rituals to be performed after his own death, the sacrifices to be offered, even the garments the priests were to wear. This regulation is not a claim to immortality, but rather an indicator of his radical awareness of his own mortality and his will to give meaning to and gain control over this inevitability on his own terms (Waldmann, 1973). Placing his own statue next to the gods on the East and West Terraces is the architectural expression of this effort at meaning-making. This act can be read not so much as self-deification, but as a desire to transcend his mortal being by situating it on the same spatial and symbolic plane as divinity and cosmic order, thereby dissolving his finitude within a larger, permanent context. In this way, Antiochus sought to integrate his individual death into the eternal time of the universe and divine order. His project is a hierothesion—a sacred placement—that goes beyond a tomb, a place where mortality is addressed as an ontological problem and transformed into a dialogue through architecture.

However, the experience of mortality at Nemrud is not exclusive to its founding king. The place is also constructed to compel a similar existential confrontation in the modern visitor. Everyone who reaches the summit is confronted with their own scale and transience by the physical conditions of the place (see Figure 4). The mountain's solitary peak, the boundless horizon, the overwhelming vastness of the sky, and the superhuman scale of the colossal statues make visitors feel their own bodily smallness and mortality. In Heidegger's terms, here the *world* expands, but at the same time, one acutely perceives the limits of one's own *being-in-the-world*. The harsh transitions of day and season, the suddenly descending fog, the sharp wind, and the physical discomfort remind one of the body's vulnerabilities and transient guesthood. This experience brings to the surface, at a bodily and sensory level, the awareness of mortality that remains mostly concealed in the daily life of the modern world. The visitor, not as a permanent inhabitant but as a temporary guest, becomes aware of their own mortal nature. In this context, Schulz's concept of genius loci gains a new dimension: the spirit

of place creates not only an aesthetic pleasure but also a melancholic yet illuminating atmosphere that brings humans into contact with their own existential reality.

Figure 4. Mortals and Immortals in Communion. (Left): View towards the podium of the East Terrace from the east, from the approximate location of the ancient approach path. Visual sourced from the 2000 version of the settlement area digital reconstruction model. From Learning Sites digital reconstruction of Nemrud Dagı, Türkiye (https://www.learningsites.com/NemrudDagi/NemrudDagi_models.php#WT). Accessed November 2024. | (Right): A contemporary view of the East Terrace statues. Visitors are highlighted with a fluorescent marker by the author. From A Complete Guide to Mount Nemrud: Discover the Summit and Its Mysterious Monuments by Ömer Faruk Kino, May 9, 2025, Onedio (https://onedio.co/content/a-complete-guide-to-mount-nemrut-discover-the-summit-and-its-mysterious-monuments-28564). Accessed June 2025.

It appears that the awareness of mortality at Nemrud is not merely a theoretical inference but is also corroborated by visitor experiences. Survey studies show that individuals visiting Nemrud experience a distinct emotional experience there, and the scale average indicates the intensity of this experience (Muka & Cinaj, 2015). This finding empirically supports the idea that the place functions not as a mere visual monument but as an existential stage that confronts mortal beings with their own transience. The awe, sense of belonging, or melancholy felt by the visitor are the emotional manifestations of the existential state Heidegger calls mortal consciousness.

A historical dialogue is established through the place between Antiochus's death-planning construct and the visitor's accidental inclusion in it. The king attempted to transcend death by transforming it into architecture; the visitor is invited to think of their own death while experiencing this architecture. In both cases, Nemrud is not a place where mortality is forgotten or hidden, but rather one where it is remembered, pondered, and thus sought to be given meaning. For Heidegger, being mortal is not a negative limit to our existence in the world but the essential building block that gives it depth and urgency. Mount Nemrud makes this building block visible on both a physical and symbolic level, offering a powerful phenomenological example of how mortals' dwell in this world. This is the spatial expression of an ancient and enduring claim: that dwelling is possible not by denying death, but by confronting it and making it part of a meaningful whole.

2.4. Divinities: The Call and the Withdrawal

The Divinities in Heidegger's Fourfold are not the personified or dogmatic, intervening gods of religions. As explained in the theoretical chapter, they are beings that point to the divine, the miraculous, and transcendent meaning; they show themselves and yet conceal themselves, appearing as a call or a sign, and they withdraw in an essential way. This state of divinity is not an absolute absence but, on the contrary, a mode of existence whose very distance carries a profound density of meaning, inviting humans to open themselves from the limits of their mortal existence toward the transcendent.

The colossal statues lining the East and West Terraces of Mount Nemrud—Zeus-Oromasdes, Apollo-Mithras-Helios-Hermes, Artagnes-Herakles-Ares, and deified Commagene—alongside the statue of King Antiochus I beside them, are the petrified expression of this Heideggerian concept of *withdrawing presence.* These statues neither speak nor move, their faces bear not the slightest hint of human emotion or reaction. They are impassive, solemn, inaccessible, and expressionless. This passivity and distance are not a lack or an artistic failure, but the representation of a conscious choice, a mode of existence that conforms to the Heideggerian definition of divinity. They are not gods of absolute availability and intervention, but beings who withdraw themselves, thereby clearing a space for humans to turn toward them, to interpret them, and to construct their own way of relating to them.

This withdrawn quality of the statues is reinforced by their spatial positioning and cultural identities. On the terraces, the statues of the gods and Antiochus share the same row, yet this togetherness does not signify equality or a mere side-by-side arrangement. The king partakes in the divine plane, but this participation does not make him identical to the gods. On the contrary, this arrangement is an architectural manifestation of the dialogue between the mortal and the transcendent/divine, and of the ontological distance between them. Furthermore, each statue is the product of a conscious cultural synthesis: Zeus is fused with the Persian god Oromasdes; Apollo with Mithras, Helios, and Hermes; and Herakles with the Persian god Artagnes (Jacobs, 2016; Versluys, 2017). This theological syncretism reinforces the idea that divinity can manifest in different cultural languages and forms, yet none can fully grasp it. Each name and form are a system of signs that points toward divinity without fully revealing it—a withdrawing system of signs. This aligns with Heidegger's description of the divinities' nature as self-showing and self-concealing.

The function of these distant statues is not so much to be objects of worship, but to issue a call. Their silence does not mark an emptiness, but an area of meaning awaiting fulfillment. They invite the visitor to reflect, interpret, and establish a relationship with this transcendence based on their own cultural and existential references. As Heidegger notes in *The Origin of the Work of Art,* a work establishes a world, and at the centre of this world there is usually a divine call (Heidegger, 2017). The statues at Nemrud do precisely this: they are placed at the centre of the world conceived by

Antiochus (a world of a kingdom descended from both Persian and Greek lines, sanctioned by the gods). Their silent, solemn presence functions as the ultimate source of meaning and legitimacy for this world, but it does not dictate this source; it merely calls. Before these statues, the visitor, regardless of personal belief, experiences that peculiar mixture of awe and alienation that comes from confronting the transcendent.

In conclusion, the divinities at Nemrud are not an iconographic show or a tool of religious propaganda. Within the Heideggerian Fourfold, they are beings that point beyond the limits of mortal existence, prompting the search for meaning, yet never imposing themselves as an absolute answer. The tension between the statues' massive physicality and their profound expressionlessness and distance reveals the very power of this state of withdrawing presence. They are as integral to this place functioning as a dwelling as the resistance of Earth and the rhythm of Sky; for a true dwelling is not merely a place of shelter, but also where mortals can call upon self-transcending meanings and enter into a silent dialogue with them. The spatial reality of Mount Nemrud is the petrified stage for this dialogue.

Conclusion and Implications

This study has demonstrated how reading Mount Nemrud through Heidegger's Fourfold moves it beyond being merely a monument or object of representation, allowing us to conceptualize it as an active dwelling and a ritualistic gathering place. Our finding is this: Nemrud's architectural and topographical construct is a Heideggerian act of opening a place; this act is accomplished by bringing together—simultaneously and in dialogue with one another—the resistance of Earth, the rhythm of Sky, the awareness of Mortality, and the withdrawn call of the Divinities. This is not a past event frozen by representation, but a living phenomenal field where these four existential dimensions are re-experienced in each "now."

The theoretical gain from this reading is its provision of two interdisciplinary perspectives on architecture and cultural heritage. First, within the context of architectural theory, this approach shows that the meaning of a structure can be measured not only through formal, iconographic, or functional analyses, but through its world-forming (weltbildend) power—that is, by how it embodies and brings together the fundamental conditions of human existence. Nemrud is also an exemplary instance of Christian Norberg-Schulz's genius loci (spirit of place). Its genius loci arise not from the iconography of the statues, but from the atmospheric and existential wholeness formed by the mountain's ascent, the relationship of the terraces with the sky, the behavior of wind and light, and the human-made arrangement (Norberg-Schulz, 1980). A visitor's arduous climb and quiet wait for sunrise becomes, unwittingly, part of this ancient ritual and of the dialogue established with the genius loci. Thus, Nemrud reveals architecture's power to invite not mere *seeing,* but *experiencing* and

participating. This claim is not confined to the theoretical level; it is also supported by empirical data on visitor experiences. It has been determined that visitors to Mount Nemrud undergo a distinct learning and emotional experience there (Korkmaz & Kafa, 2020, p. 1247). These findings demonstrate that the place is not a passive object of representation but, in Heideggerian terms, an active gathering place that transforms visitors on both cognitive and affective levels.

Second, within the context of cultural heritage studies and conservation practice, this phenomenological-ontological reading holds the potential to shift the focus of conservation from preserving the object to sustaining the place's capacity to produce meaning and its possibilities for experience. Viewing Nemrud as an archaeological object imprisons it in the past. Understanding it as a gathering place, however, directs conservation efforts toward respecting the resistance of Earth (erosion, earthquake), the rhythm of Sky (light, climatic conditions), and that unique atmosphere that awakens the visitor's awareness of mortality. This necessitates more nuanced solutions to the tension between tourist access and the preservation of ontological integrity. Conservation thus becomes not merely repairing stone but safeguarding the conditions that make possible the dialogue of the Fourfold that the place calls forth.

In conclusion, this study's ultimate message is this: Mount Nemrud, far beyond being a monument to the personal glory of King Antiochus I, has carved into space the ancient and universal question of how humans exist in the world. The Heideggerian and Norberg-Schulzian framework provides us with the necessary language to read this question. Nemrud shows us not only what the Kingdom of Commagene was, but how a place, by engaging mortal beings in a meaningful dialogue with earth, sky, and divinity, can become a dwelling, a world. Therefore, reading it not as a silent object in a world of representations but as an active subject that still speaks, calls, and transforms is a fruitful path for both theoretical thought and heritage practice. This reading liberates Nemrud from being a closed box of the past and turns it into a text open to the existential inquiries of the present and future.

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Chapter 11

PREDICTING USAGE DENSITY IN LANDSCAPE DESIGN USING A PYTHON-BASED ARTIFICIAL INTELLIGENCE MODEL

Ahmet BENLİAY[1], Mehmet Kıvanç AK[2]

1 Assoc. Prof. Dr., Akdeniz University, Landscape Architecture Department, Orcid: 0000-0002-0902-2658
2 Prof. Dr., Düzce University, Landscape Architecture Department, Orcid: 0000-0003-2671-1575

Introduction

Throughout history, "Landscape" has been a source of inspiration for poets, writers, musicians, painters, and designers. Therefore, the relationship between landscape and art is not limited to painting. Landscape and art are fundamental visual documents of civilization. Regardless of its definition, the concepts of art and aesthetics in landscape are closely related to space and its elements. Space is the state in which the environment is perceived and transformed into life by human and societal culture. (Çınar et al., 2024).

Cities are complex systems that go beyond physical space, where social interactions, public life, and experiences are collectively produced. Within this system, many spaces that are the subject of landscape architecture are fundamental public open spaces where different age, gender, and socio-cultural groups come together, indirectly affecting the quality of urban life. The quality of public open spaces plays a decisive role in individuals developing a sense of belonging to the city, ensuring social integration, and supporting physical and psychological well-being. In this context, parks and squares are considered not only recreational areas but also spatial backbones that ensure the continuity of urban life. (Gehl, 2011).

The success of landscape areas is directly related to the extent and conditions under which these areas are embraced by users. Usage intensity is a fundamental concept that expresses the number of users a public space is exposed to within a specific time and the ways in which these users utilize the space. This concept should be considered not only as a quantitative indicator of intensity but also as a multi-dimensional parameter revealing the quality of space-user interaction. Ignoring the temporal and demographic characteristics of usage intensity can lead to capacity problems in parks and squares, insufficient amenities, and a gradual decrease in spatial comfort.

In landscape architecture, the design process has for many years relied on the designer's professional experience, limited field observations, and user surveys. While these approaches have made significant contributions to analyzing the current usage situation, they have been insufficient in generating predictive decisions for the future. Jacobs (1961) emphasized that the fundamental element determining the vitality of public spaces is human density and continuity; however, he did not offer a methodological framework for how this density could be quantitatively estimated. Similarly, Whyte's (1980) studies examining public space behaviors, while highlighting the importance of user density, did not develop forward-looking prediction models.

Today, the increasing rate of urbanization, rising population density, and the diversification of public space users necessitate the adoption of more objective, repeatable, and data-driven approaches in landscape design. In particular, accurate analysis of varying usage densities across different time periods enables design decisions to be based on scientific principles. The nonlinear and dynamic nature of urban systems demonstrates that these areas cannot be addressed solely with static design principles. In this context, contemporary approaches that examine the complex structure of cities using mathematical and computational models are gaining increasing importance (Batty, 2013).

In recent years, the rapid increase in artificial intelligence research and machine learning methods has led to their emergence as powerful analytical and predictive tools in the disciplines of architecture and landscape architecture. These methods can analyze complex relationships between numerous variables and enabling the prediction of future usage scenarios. Regression-based machine learning models offer significant and effective results in quantitatively predicting usage intensity based on

temporal, environmental, and demographic variables. Among these studies, the Python programming language stands out; it is widely preferred due to its open-source libraries, flexible structure, and powerful data processing capabilities (Lutz, 2013).

An examination of studies in the literature on urban open space use in landscape architecture reveals that the vast majority focus on user satisfaction, perception, and recreational preferences. However, a significant portion of these studies evaluate usage density based on the existing situation and do not offer predictive models before the design process. Yet, the stage where design decisions have the greatest impact on space is the early design phase before implementation. Reliable usage density estimates obtained at this stage will enable more sound fundamental design decisions such as area capacity, the number of amenities, and spatial organization.

The Concept of Public Open Space and Usage Intensity

Public open spaces are defined as areas open to all segments of society where individuals carry out their daily life practices. Parks and squares are among the urban spaces where both physical and social interaction is most intense. Usage intensity is a key indicator of how well these spaces are used within a specific time and is directly related to the functionality of the area and user satisfaction (Jacobs, 1961).

Occupancy intensity is not limited solely to the number of people in an area; it also encompasses the amount of time users spend in space, the activities they engage in, and their relationship with the spatial amenities. Therefore, evaluating occupancy intensity requires considering both quantitative and qualitative dimensions.

Temporal Continuity and User Behavior

The use of public open spaces varies depending on the time of day and day of the week. The continuous nature of human behavior prevents sudden and sharp changes in usage intensity. However, traditional analyses often treat the time variable as discrete and static. This makes it difficult to realistically represent usage intensity.

Cyclic time modeling approaches, which take temporal continuity into account, can more accurately reflect usage transitions throughout the day. This approach provides an important theoretical basis for understanding the dynamic nature of open space use in landscape architecture (Batty, 2013).

Artificial Intelligence and Data-Driven Design Approaches

AI-based models have the ability to simultaneously evaluate numerous variables in the analysis of urban spaces. Machine learning methods generate predictions for the future based on past data and can be used as a decision support tool in the design process (Batty, 2013; Kitchin, 2014). In landscape architecture, these approaches hold significant potential for predicting user behavior and optimizing spatial organization. In recent years, AI applications in urban planning and design disciplines have become increasingly common in areas such as land use estimation, user behavior analysis, and spatial performance evaluation (Yigitcanlar et al., 2020).

In the field of landscape architecture, data-driven and AI-supported approaches enable more sensitive design studies of public open spaces to meet user needs. The static treatment of parameters such as user density, spatial preference, and time-space relationships using traditional methods fails to adequately explain dynamic human behavior. Therefore, recent studies emphasize the need to

evaluate public space use in conjunction with temporal and demographic variables (Gehl, 2011; Marcus & Francis, 1998).

The theoretical approach adopted in this study considers usage intensity not as a static value, but as a dynamic process considered temporal and demographic variables. Thus, the AI-supported model contributes to the development of user-centered and data-driven decisions in park and square design.

This study differs from existing literature addressing land use density in landscape design in three key aspects. Firstly, it does not limit itself to descriptive analyses of public open space use, but rather adopts a predictive approach to land use density. Furthermore, it estimates this density quantitatively based on the number of people, rather than abstract ratios. Secondly, unlike traditional hour-based assessments that disregard temporal continuity, it integrates a temporal modeling approach, which considers the cyclical nature of human behavior, into the landscape architecture design process. Thirdly, it designs the Python-based artificial intelligence model not merely as a technical analysis tool, but as a designer-oriented decision support system that can be directly used in the early design phase. In these respects, the study offers a unique methodological and practical contribution to the development of data-driven design approaches in the discipline of landscape architecture.

2. MATERIALS AND METHODS

2.1. Data Set, Model and Evaluation Criteria

The data set used in this study was created synthetically and scenario-based, using trends derived from field observations regarding park and square usage. The main purpose of creating the data set is to allow for the simultaneous evaluation of temporal, environmental, and demographic variables that affect usage intensity in park and square design. Two different data sets were produced within the scope of the study; the first data set, containing a limited number of observations, and the second data set, which is more comprehensive and represents every day of the week, were combined to perform model training.

The key variables in the generated dataset are presented below:

- Temporal variables: Time of day (modeled cyclically) and day of the week, but primarily weekday/weekend situation,
- Demographic variables: Age groups (child, youth, adult, elderly) and gender (female, male),
- Environmental variables: Climatic comfort status,
- Target variable: The number of people expected to be present in the park or square.

In this study, the intensity of use was expressed in terms of the number of people instead of an abstract percentage value. This approach ensures that decisions such as space capacity, adequacy of reinforcement elements and spatial organization are based on more concrete data in the design process. Age groups are defined to represent the different mobility and usage habits of park and square users. The children's group emphasizes playgrounds and safe circulation axes, the youth group emphasizes social meeting and active recreation areas, the adult group emphasizes resting and walking areas, and the elderly group emphasizes accessibility, safety, and comfort criteria.

During the data preprocessing process, missing value was checked, categorical variables were converted into numerical form in accordance with the model, and the dataset was divided into training

and test subsets. In addition, the time variable has been handled in a cyclic structure in order to reflect the continuity of human behavior more realistically.

Considering that the use of parks and squares is continuous throughout the day, representing the time variable only with exact hour values does not produce realistic results. The intensity of use is not expected to change suddenly in the close time periods such as 11:30 and 12:00. Therefore, in the study, the clock variable was modeled using sine and cosine components, like the method used by Batty in 2013, to maintain its cyclical structure. This approach has enabled the transition of usage intensity during the day to be represented more smoothly and realistically; it also contributed to a more accurate perception of the day and night cycle by the model. Cyclic time modeling is a widely used method in literature in terms of maintaining temporal continuity, and it was preferred in this study to increase the accuracy of usage intensity estimation.

Python programming language was used in the development of the model. Python's open-source structure and wide library support have enabled data processing and machine learning applications to be carried out effectively. The following libraries were used in the study:

- Pandas: Data reading, editing, and preprocessing operations,
- NumPy: Numerical calculations and mathematical conversions,
- Scikit-learn: Establishment, training, and evaluation of machine learning models,
- Matplotlib: Graphical visualization of model outputs,
- Google Colab: The platform where codes are run and managed online.

This allowed both data processing and model training to be conducted in an online environment without requiring additional software installation.

In this study, a multiple output regression model was used, which could predict multiple outputs simultaneously. Model; It is structured in such a way that it can predict the total number of people, as well as age groups and gender distributions together. This approach allows for a multidimensional assessment of park and square usage.

The training of the model was conducted using approximately 80% of the dataset; the remaining 20% is reserved as test data. During the training process, the predictive performance of the model was evaluated, and the effects of different variables on the intensity of use were analyzed. After the coding developed on Colab, the software has been made Standalone with a modern GUI for expert opinion.

2.2. Expert Opinions and Software Evaluation

In the Delphi technique and expert interviews, there is a minimum number of 7-10 experts depending on the method, content, and methodology. To ensure diversity and saturation in expert interviews, 5 landscape architects, 5 urban designers and 5 data scientists were determined to be fifteen in total. Since the subject is both "Design" and "Software/Statistics", Data Scientist experts were also included in the study. Expert evaluation was conducted under the following topics.

- Interface and ease of use (Usability & UI),
- Accuracy and consistency of outputs (Validation),
- Professional benefit and decision support (Perceived Usefulness),
- Development and Shortcomings.

For this purpose, 5 questions to be answered as 5 Likert (1 Completely disagree, 2 Disagree, 3 Undecided, 4, Agree, 5 Completely agree) and 2 open-ended questions were created, and the evaluations of the experts were received in the software support put forward. The questions are given in Table 1.

Table 1. Questions asked in expert interviews.

Code	Objective	Definition
LQ1	Interface	The app's parameter input screen and result graphs are clear and user-friendly.
LQ2	Accuracy	The predictions produced by the model coincide with your professional experience.
LQ3	Parameter Qualification	The inputs used in the model are sufficient to predict parking usage.
LQ4	Benefit	This software facilitates and accelerates decision-making in park design and management processes.
LQ5	Sustainability	The model outputs can be used for energy efficiency or maintenance planning.
OEQ1	Advantages	What is the app's greatest strength?
OEQ2	Disadvantages	What is the most critical deficiency that needs to be improved?

The answers given were examined on a question basis and discussed with the help of mean values and standard deviation values. Together with these, statistical criteria commonly used in the evaluation of the performance of a model were used to determine the system suitability. In this context, mean absolute error (MAE) and explanatory coefficient (R^2) were used as the main evaluation criteria. Thanks to these criteria, the level of deviation between the number of people predicted by the model and realistic scenarios and the explanatory power of the model were revealed. The performance values obtained were interpreted by considering the synthetic structure of the data set used.

3. RESULTS

The artificial intelligence model developed in this study is designed not only as a technical code output, but also as a user-interactive decision support tool that can be used directly in the landscape design process. For implementing and testing the model, an application has been developed in the Google Colab environment using the Python programming language. This environment allows users to access the model and test different scenarios with ease without requiring additional software installation (Lutz, 2013; Python Software Foundation, 2024).

Artificial intelligence stands out as a powerful tool in analyzing multivariate and complex data sets. Evaluating the intensity of use in parks and squares together with temporal, environmental and demographic variables make it difficult to reveal the relationships between the variables with traditional methods. The artificial intelligence approach used in this study can learn the complex relationships between these variables and generate meaningful predictions for different usage scenarios.

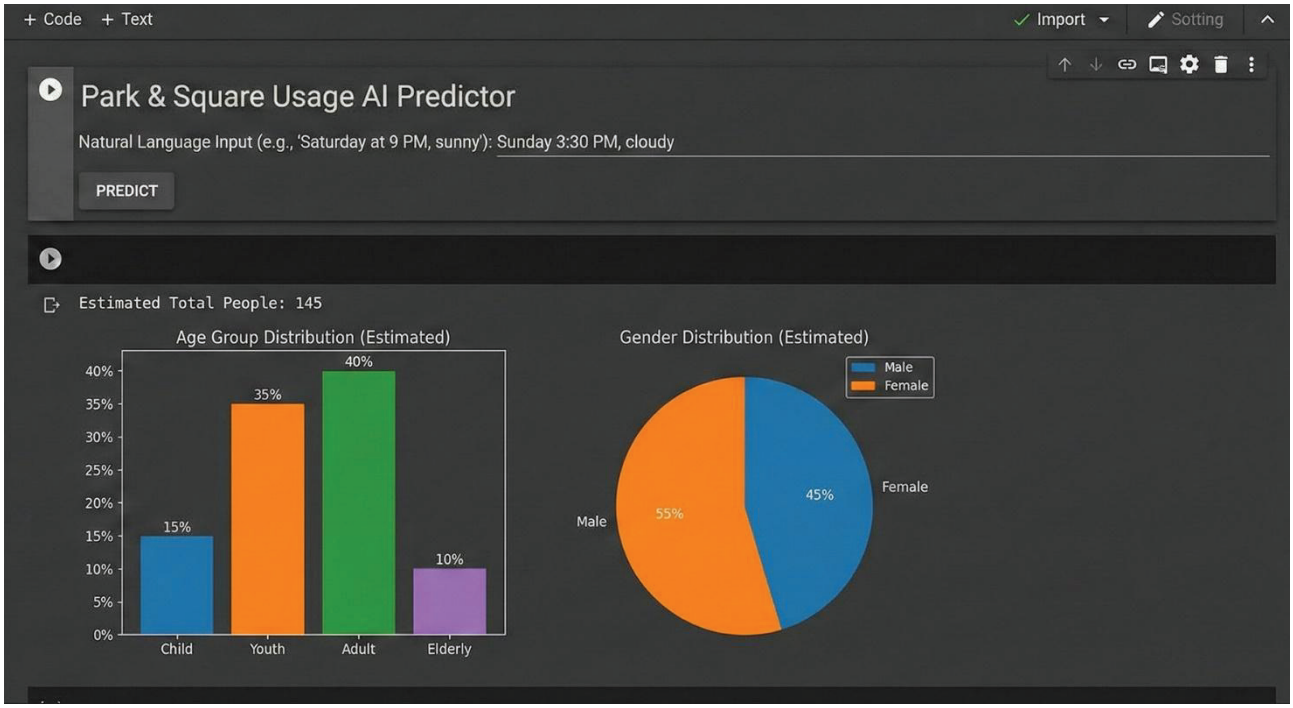
The Python programming language provides a suitable environment for such applications thanks to the rich libraries it offers in data analysis, machine learning, and visualization. Developed using Python, this application contributes to obtaining practical, fast, and interpretable results in the landscape architecture design process by hiding technical analysis processes from the user. In this respect, the system developed is considered as an innovative tool that supports data-based decisions in park and square design.

In the developed application, input expressed in natural language regarding the use of parks or squares can be obtained from the user. For example, expressions such as "Saturday at 21.00, sunny weather" or "Sunday 15.30, cloudy" are automatically interpreted by the system. Time information, day type (weekday/weekend) and environmental conditions in the entered text are separated; The clock variable is converted into cyclic (sine-cosine) form in a way that maintains temporal continuity. In this way, only a plain text input is taken from the user and all the numerical inputs needed by the model are automatically generated.

One of the key features of the model is that demographic information, such as age group or gender, is not directly requested from the user. Instead, the developed artificial intelligence model simultaneously estimates the total number of people expected to be in the park or square, as well as the age groups and gender distributions of these users, based on the temporal and environmental data entered. This approach simplifies user interaction while highlighting the predictive power of the model.

Once the estimation process is complete, the model outputs are presented to the user both numerically and graphically. While the total number of people is given as a directly interpretable output in terms of park and square design; Age groups and gender distributions are visualized through graphs. These visualizations allow designers to assess which user groups predominate quickly and understandably over different time periods. The image from the prepared coding screen is given in Figure 1.

Figure 1. Google Colab Screenshot



The software and the model created for use in expert opinions have been given a modern look with the GUI and turned into Standalone software. The final software view is given in Figure 2.

Figure 2. Screenshot of the GUI-supported Interface Created for Expert Interviews

Expert interviews were held with the latest version. The Likert scores given to the questions asked during these interviews are given in Table 2. Landscape architects from the expert group consisting of fifteen people were classified as PM, Urban Designers as KT, and Data sciences as VB code values. The Open-ended question answers of the same expert evaluation group were combined and given in Table 3.

Table 2. Expert Interviews Likert Scale Question Answers

Code	LQ1	LQ2	LQ3	LQ4	LQ5
	Interface	Accuracy	Qualification	Benefit	Sustainability
PM-1	5	4	3	5	4
PM-2	4	3	2	4	3
PM-3	5	5	4	5	5
PM-4	3	4	3	4	4
PM-5	4	4	3	5	4
KT-1	4	5	5	5	4
KT-2	5	4	4	5	3
KT-3	4	3	3	4	4
KT-4	3	4	4	3	3
KT-5	5	5	5	5	5
VB-1	3	5	4	4	3
VB-2	5	4	5	5	4
VB-3	4	3	3	4	2
VB-4	5	5	4	5	4
VB-5	4	4	5	4	4

Table 3. Answers Given to Open-Ended Questions in Expert Interviews.

Code	Open-Ended Commentary Summary (Critical Point)
PM-1	"Tree species data that does shade analysis is lacking, but the overall logic is great."
PM-2	"It doesn't take wind corridors into account; winter forecasts may be inaccurate."
PM-3	"The perfect tool for the shift plan of the maintenance teams in the municipality."
PM-4	"The graphs are mixed, but the estimate of 'Number of seating units' would be very useful."
PM-5	"It cannot fully capture the increase in intensity during flowering periods."
KT-1	"A correlation can also be established with the density of housing in the surrounding area and park use."
KT-2	"It is good at estimating the pedestrian load of the streets leading to the square."
KT-3	"The parameter of proximity to public transport stops should be weighted."
KT-4	"The interface is a bit slow. But it is a useful tool."
KT-5	"It is used directly for the pre-feasibility report in urban renewal projects."
VB-1	"If Random Forest is used instead of ANN's, the prediction time may be reduced."
VB-2	"The method of cleaning the outliers in the data set is successful."
VB-3	"There is a risk of 'overfitting' in the model because the training data is scarce."
VB-4	"The integration of Python libraries and API speed is fine."
VB-5	"It should be provided and fixed on the spot instead of coming from the weather API."

4. DISCUSION

When the forecast results obtained from the developed artificial intelligence model are examined, significant temporal and demographic trends regarding the use of parks and squares emerge. The model outputs show that the intensity of use varies significantly depending on various times of the day and the weekday-weekend distinction. This situation is based on the idea that the use of parks and squares does not exhibit a static structure, which is also given by Gehl, 2011 and Whyte, 1980; It matches that it has a dynamic character depending on the temporal and user profile.

According to the findings, it is seen that children and young user groups prefer parks and squares mostly in the afternoon and afternoon hours. A significant increase has been observed in the usage rates of these age groups, especially at weekends. This shows that children and young people use parking spaces more intensively during time periods outside of school and working hours. On the other hand, it is estimated that adult and elderly user groups participate more in the use of parks and squares in the morning and evening hours. This finding reveals the relationship between daily life rhythms and park usage habits of different age groups.

When the model outputs regarding gender distribution are examined, it is seen that there are differences between male and female users in terms of usage intensity depending on time periods. It is estimated that male users are numerically more concentrated in some hours, while female users increase in other time periods. This differentiation shows that the use of parks and squares should be evaluated not only on the total number of people but also on the user profile. As noted by Arnberger (2006), it is understood that design decisions, especially those such as security, lighting, and accessibility, should be considered with these demographic differences in mind.

The graphical visualization of the model outputs has significantly facilitated the interpretation of the obtained findings. The graphs created according to age groups and gender clearly reveal which user group uses parks and squares more intensively in which time periods. With these visualizations,

designers can compare different scenarios and make quick assessments of the user profile for specific time periods.

The findings show that considering the intensity of use over the number of people in this study offers significant advantages in terms of design. It provides concrete data that can be used directly on issues such as the estimated number of people, the evaluation of the space capacity in park and square design, the determination of the number of seating units as reported in expert opinions, the adequacy of shaded areas and the width of circulation areas. In addition, estimates of the user profile reveal the necessity of spatial arrangements for different age groups.

The fact that the data set used in the study is scenario-based and synthetic requires the results obtained to be evaluated within the framework of certain assumptions. Nevertheless, the model can capture general trends in park and square usage and generate consistent predictions for different time periods. This shows that the developed artificial intelligence model can be considered as a predictive decision support tool that can be used in the early design phase. Average and Standard Deviation of Expert Interviews Likert Scale Question Answers is given in Table 4.

Table 4. Average and Standard Deviation of Expert Interviews Likert Scale Question Answers

Code	**LQ1**	**LQ2**	**LQ3**	**LQ4**	**LQ5**	**Profession**
	Interface	Accuracy	Qualification	Benefit	Sustainability	
LA Ave.	4.2	4.0	3.0	4.6	4.0	3.96
LA ST Dev.	0.748	0.632	0.632	0.490	0.632	0.824
CP Ave.	4.2	4.2	4.2	4.4	3.8	4.16
CP ST Dev.	0.748	0.748	0.748	0.800	0.748	0.784
DS Ave.	4.2	4.2	4.2	4.4	3.4	4.08
DS ST Dev.	0.748	0.748	0.748	0.490	0.800	0.796
Total Ave.	**4.20**	**4.13**	**3.80**	**4.47**	**3.73**	**4.07**
Total ST Dev.	**0.725**	**0.695**	**0.886**	**0.599**	**0.752**	**0.806**

When the evaluations given in the expert opinions are examined, it is seen that the evaluations given are not separated from each other with a great approach. LQ3 asked within the scope of 'Proficiency' was the question answered by Landscape Architects with the lowest average score (SD=0.632). On the other hand, it was determined that the highest average score was given to the LQ4 question within the scope of 'Benefit' by the same group. When the values are examined, it is seen that they respond with a moderate spread above the value of 3. Summary of Answers Given to Open-Ended Questions in Expert Interviews Table 5.

Table 5. Summary of Answers Given to Open-Ended Questions in Expert Interviews.

Code	**Open-Ended Commentary Summary (General Opinion)**
Landscape Architects	They found the tool useful but suggested expanding the parameters to include more specific details, such as vegetation and ecology.
Urban Designers	They were satisfied with the system's success at the urban scale, with a particular focus on accessibility data.
Data Science Experts	They found the technical infrastructure to be robust but recommended expanding the dataset and optimizing the algorithms.

The results obtained from expert interviews show that the model can capture general trends in park and square use and can be used as a predictive decision support tool. As a result, the findings presented in this section reveal that the use of parks and squares differs in terms of time and demographics; It shows that the developed model is a tool that can analyze these differences and provide meaningful inputs to the design process. The results obtained once again emphasize the importance of user-oriented and data-based approaches in park and square design.

5. CONCLUSION

The findings obtained from this study clearly reveal the importance of considering user profiles and temporal usage habits in park and square design. The model outputs show that different age groups and genders use parks and squares at various times of the day with different intensities. As reported by Alexander et al., (1977) and Gehl (2011), this situation reveals that designing public open spaces with the assumption of a single type of user may be insufficient in terms of spatial comfort and functionality.

During the time periods when child users are busy, safe playgrounds, soft floor materials, spatial arrangements that allow parental supervision and controlled circulation axes come to the fore. In areas where young users are more concentrated, seating groups that support social interaction, open spaces that provide flexible use and meeting points gain importance. For adult and elderly users, the presence of shaded areas, ergonomic seating arrangements, unobstructed pedestrian access, and recreational facilities stand out as key design components. These differences show the necessity of flexible and multifunctional solutions that are sensitive to the user profile in park and square design.

The artificial intelligence-based model developed in this context is considered as a supportive tool that provides insights to designers in the park and square design process. The estimates produced by the model based on the number of people allow design decisions to be based on numerical data rather than abstract assumptions. As stated by Batty (2013), the estimates obtained for different time periods and usage scenarios, especially in the early design phase, make it possible to construct the spatial organization more consciously.

However, the study has some limitations. The fact that the data set used was scenario-based and synthetic shows that the results obtained do not exactly reflect real user behaviors. Studies supported by real field data will be able to increase the accuracy level of the model and strengthen the reliability of the prediction results. However, despite this limitation, the study reveals that predictive models can be developed that can guide the design process, even in cases where real data access is limited.

The following recommendations may be taken into account in future studies:

1. Collecting real field observations and user counting data and retraining the model with this data,
2. Performing comparative analyses with different machine learning and deep learning algorithms,
3. Development of more comprehensive models that include the physical characteristics of parks and squares (area size, reinforcement elements, vegetative design, accessibility, etc.),
4. Strengthening spatial analysis by integrating model outputs with geographic information systems (GIS).

In conclusion, the findings discussed in the discussion section show that artificial intelligence-based approaches can contribute to the development of user-oriented and data-based design decisions in the discipline of landscape architecture. The developed model offers an innovative approach that addresses the temporal and demographic dimensions of usage density in park and square design.

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Chapter 12

ETFE MATERIAL APPLICATIONS IN BUILDING ENVELOPES

Nurcan Tuna SARITAĞ[1] , Mustafa DERELİ[2]

1 Mimar, Necmettin Erbakan Üniversitesi, Fen Bilimleri Enstitüsü, nurcanntuna@gmail.com,

ORCID: 0009-0000-1225-8111.
2 Doç. Dr. Necmettin Erbakan Üniversitesi, Güzel Sanatlar ve Mimarlık Fakültesi, Mimarlık Bölümü, mustafa.dereli@erbakan.edu.tr, ORCID: 0000-0003-4678-873X.

INTRODUCTION

With the depletion of natural resources and technological advances, there has been a shift towards synthetic materials produced in laboratory environments. Concerns about sustainable living have led to a search for innovation in many areas. Alternative productions to familiar materials have emerged. Architecture is one of the areas where these concerns are most keenly felt. As a result of all these developments, solutions have been sought for the search for new materials to be used in architecture. The particularly fragile and heavy nature of glass has led to experimentation with new transparent building materials. ETFE (Ethylene Tetrafluoroethylene), produced artificially, is seen as a solution in the search for new materials. In addition to providing climate control and insulation, its low friction coefficient on the surface gives it stain-resistant properties. It is a low-cost material that requires almost no maintenance thanks to its lightweight and durable surface. Its applications in architecture have begun to diversify, and application details have been developed to enhance material performance in various structures. In this context, the application types and details on building facades have been examined.

ETFE MATERIAL

ETFE (Ethylene Tetrafluoroethylene) is a fluoropolymer material produced by artificial means. Its main components are hydrogen sulfate and trichloromethane, combined with fluorite, a common mineral. It was discovered in the United States in the 1940s by a company called DuPont. It stands out from other polymer materials due to its resistance to friction and abrasion, its resistance to radiation, and its ability to provide insulation at both high and low temperatures (LeCuyer, 2008).

LITERATURE REVIEW

Robinson-Gayle et al. (2001) viewed ETFE as a covering material that allows maximum use of daylight indoors without adding weight to the structure, suitable for roofs and atriums with large spans. (Lau et al., 2016; Masih et al., 2015) examined daylight performance in spaces where ETFE was applied; Lau et al. (2016) viewed ETFE as a material that helps create homogeneous illumination, while Masih et al. (2015) stated that providing homogeneous illumination may be insufficient for structures with special functions and that additional lighting may be required. Furthermore, the flexibility of ETFE provides architects and engineers with broad design boundaries and freedom of expression (Robinson-Gayle et al., 2001).

Eyüboğlu and Yanılmaz (2023) evaluated the possibilities that ETFE, considered an alternative to glass, offers for sustainable architecture in their study and described it as a highly valuable building material. Boylu and Ekinci (2024) stated in their study that the weight-creating effect of choosing lightweight materials such as ETFE on structures is minimal. Shafa (2024) drew attention to the importance of ETFE as a smart material in green architecture, emphasizing that it can produce aesthetically pleasing products, especially in public buildings, in line with the concept of sustainability.

The studies conducted have been reviewed, and the advantages of ETFE material in terms of structure and architecture have been examined. However, no study has been found regarding the application details of the material and the developed detailed solutions. This study was written to fill this gap.

ETFE IN ARCHITECTURE

The emergence of interest in ETFE in architecture arose as Europe shifted from fossil fuels to renewable energy sources such as solar energy. Furthermore, aging tests conducted in Germany and Arizona showed no change in its mechanical and optical properties, providing the assurance that paved the way for architectural applications.

ETFE material has been known since the 1940s, but its first example in architecture was its use as roofing material for plant houses at Burgers' Zoo in Arnhem, Netherlands, in 1982 (Figure 1) (LeCuyer, 2008).

Figure 1- Burgers' Zoo plant house interior and ETFE-covered roof (LeCuyer, 2008)

As aesthetic concerns in architecture have increased, architects have become preoccupied with the desire to provide transparent surfaces and have been drawn to the use of glass. However, glass is both a heavy and fragile material that cannot provide sufficient flexibility in geometric terms, and it has also failed to deliver the necessary performance in terms of energy sustainability. To overcome the disadvantages of glass, polycarbonate-based materials have been tested as alternatives in architecture (Robinson-Gayle et al., 2001).

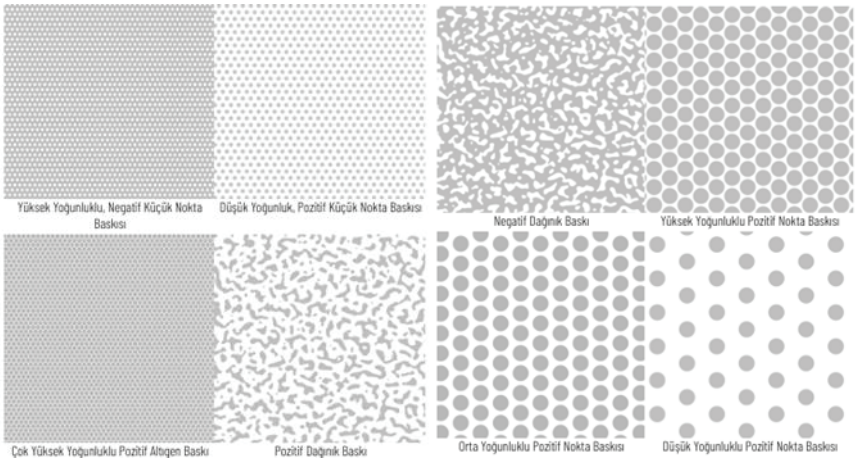


Figure 2 - ETFE Printing Types (URL-1)

Hu et al. (2017) state that ETFE material is a great alternative for transparent buildings in terms of its life cycle. Various types of prints have been produced and made available for use to control daylight and prevent the greenhouse effect in spaces (Figure 2).

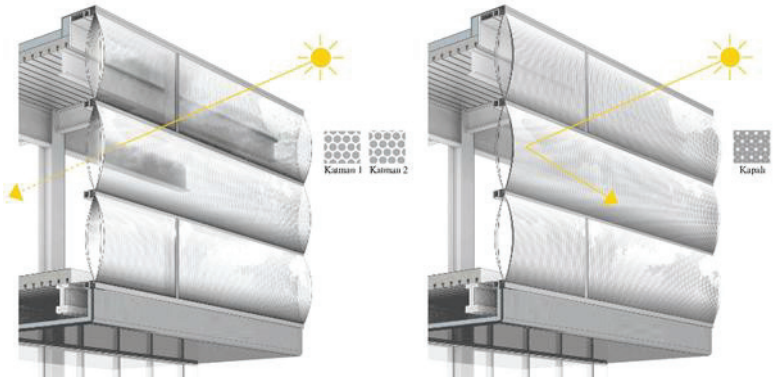


Figure 3 - Daylight transmittance diagram of ETFE cushions (URL-2)

Although ETFE is a material with very high solar light transmittance, this value can be adjusted to the desired level by increasing the number of layers or by inflating it to act like a diaphragm (Figure 3). Its flame-retardant chemical property is another advantageous feature (Srisuwan, 2016). In the event of possible tears, ETFE cushions are removed from their aluminum beds and replaced with new ones. Although it is a self-cleaning material, serious contamination problems are also solved in this way (Robinson-Gayle et al., 2001). ETFE material is considered environmentally friendly and sustainable due to its very low energy consumption during production, transportation, and manufacturing (Hu et al., 2017). Thanks to its inert nature, ETFE causes very little environmental pollution (Robinson-Gayle et al., 2001).

METHODS and RESULTS

ETFE material, which offers numerous advantages to structures with different functions, has become one of the materials used in architecture in recent years. Different detail solutions have been developed according to the advantages it provides to structures. It has found application in structures

when used with different system equipment. ETFE material's facade cladding applications have been examined, and different details have been observed. Within the scope of the study, qualitative analyses supported by visuals were used as the data collection method. Four structures were included in the study based on the advantages they offer to structures and the detail solutions developed in the structure, namely:

1- Water Cube-National Aquatics Center

2-The Shed

3-The Eden

4-Allianz Arena.

USE OF ETFE AS FACADE CLADDING AND APPLICATION DETAILS

1- WATER CUBE-NATIONAL AQUATICS CENTER

(a) (b)

Figure 4- (a) Water Cube evening facade lighting (URL-3), (b) Water Cube daytime facade view (URL-4)

Building Specifications

Year of Construction	Location	Architecture
2003-2008	Beijing, China	PTW Architects

The structure, which opened in China in 2008, was designed by PTW Architecture (Figure 4). The designer drew inspiration from soap bubbles for the concept of the building. To achieve this form, a structural skeleton was prepared for all facades and the roof using Vierendeel truss frames (Figure 5), and three-layer ETFE was used for the inflatable facades and four-layer ETFE for the roof. Over 22,000 steel beams were connected with more than 12,000 steel nodes for the frame (Figure 6).

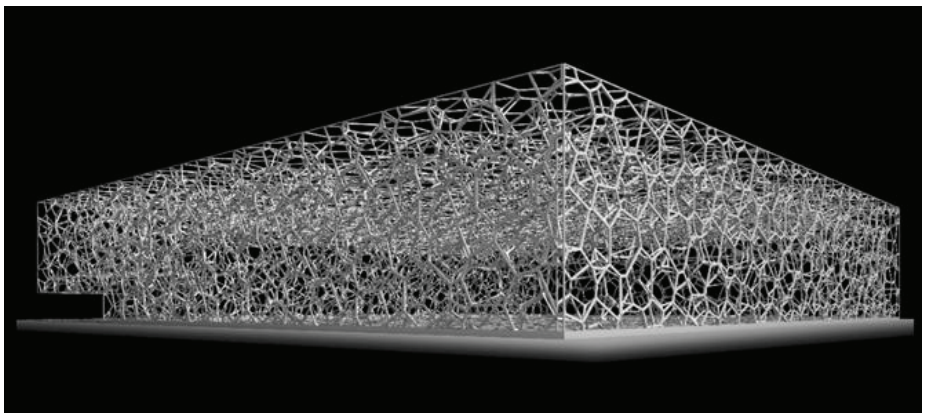


Figure 5 - Water Cube-National Aquatics Center structural skeleton system (URL-4)

(a) (b)

Figure 6- (a) Steel beam, node detail (URL-3), (b) Water Cube structural section (URL-6)

The skeleton system that forms the structure consists of two separate sections: internal and external. Thanks to the ETFE used in the structure, it provides a 30% energy saving compared to glass material. ETFE's light transmittance is resistant to degradation over time, and its high heat

resistance protects the building from potential fires. The material has a very low friction coefficient, which prevents it from accumulating dust (URL-5).

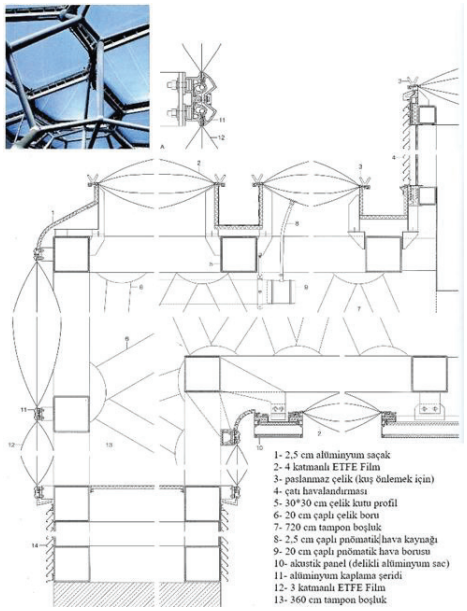
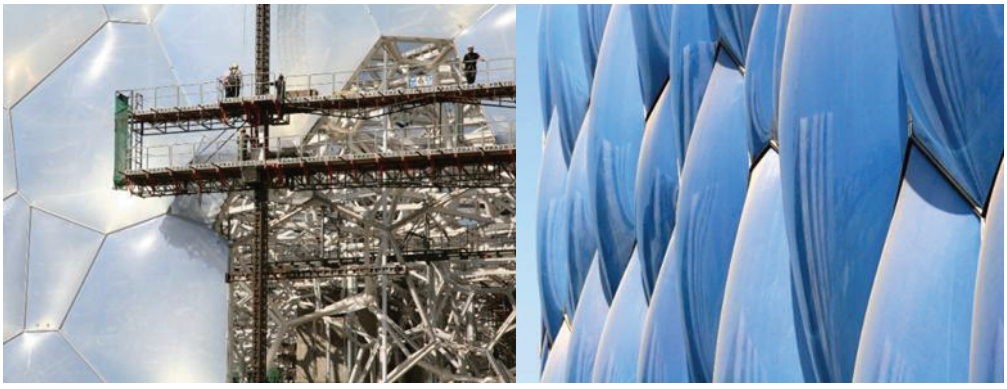


Figure 7 - ETFE cushion system detail (URL-7)

The roof and facades are connected to each other with aluminum eaves, creating a unified facade concept. ETFE cushions are used on the inner and outer parts of the skeleton system designed in a double-walled structure (Figures 7-8). While 4-layer ETFE was used with a 720 cm buffer zone on the roof covering, 3-layer ETFE was used with a 360 cm buffer zone on the facades. The anchors to be used for the installation of the ETFE material and the skeleton system were connected to each other with 30*30 cm box profiles. Spikes were designed with stainless steel wires to prevent birds from contaminating the ETFE. Additionally, grooves were left between the ETFE sheets to prevent tearing and to allow rainwater drainage.



(a) (b)

Figure 8-(a) Installation of ETFE cushions (URL-3), (b) Water Cube facade ETFE cushions (URL-4)

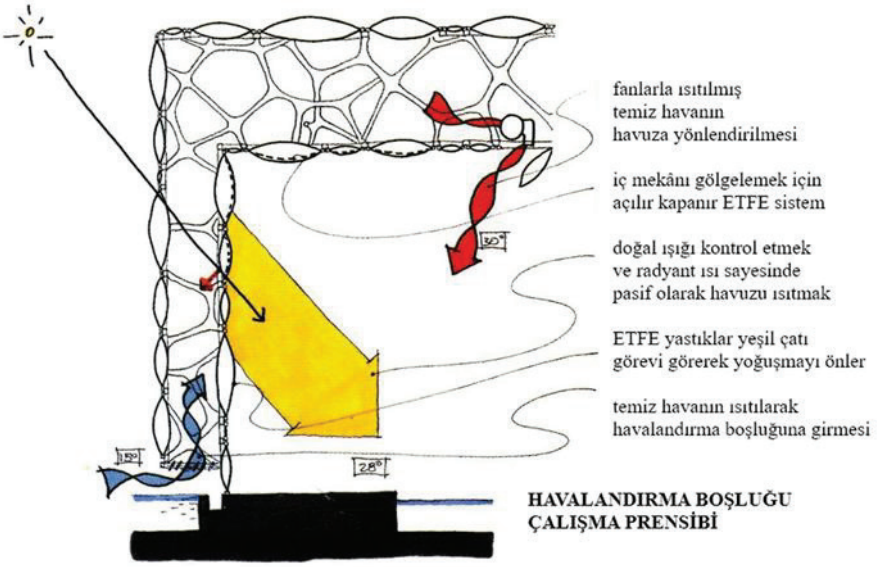


Figure 9 - Ventilation gap operating principle (URL-7)

The use of double-walled ETFE gives the building green building efficiency. The wide roof and facade cladding illuminate the building while also providing ventilation through the fans within the structure. The interior lighting can be maintained at the desired level thanks to the ETFE cushions' opening and closing mechanism (Figure 9). The mechanism, which allows for the control of sunlight, enables the climate control of pools with solar energy and also allows for passive heating (Figure 10).

(a) (b) (c)

Figure 10-(a,b,c) Water Cube interior visuals (URL-4)

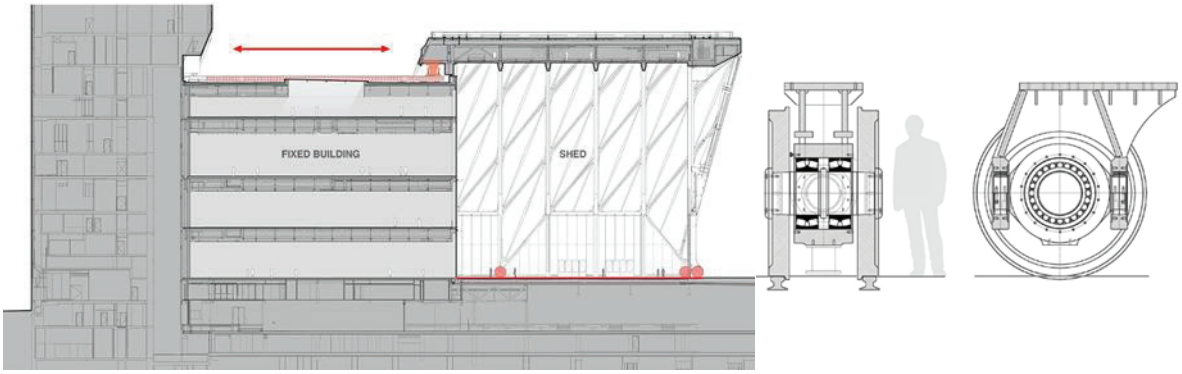
2-THE SHED

Figure 11 - The Shed (URL-8)

Building Specifications

Year of Construction	Location	Architecture
2019	New York, USA	Diller Scofidio + Renfro and Rockwell Group

The building designed by Scofidio + Renfro and Rockwell Group in New York was opened in 2019 (Figure 11). The exhibition center has a floor area of 18,500 m². Designed for large-scale performance art, installations, and various events, the building stands out with its telescopic outer shell. The outer shell slides along tracks on the ground, allowing the building to expand into the adjacent plaza and create a new space (Figure 12). The upper canopy can be extended, and the large opening doors on the east and north facades can be operated, enabling interaction with public spaces (URL-9).



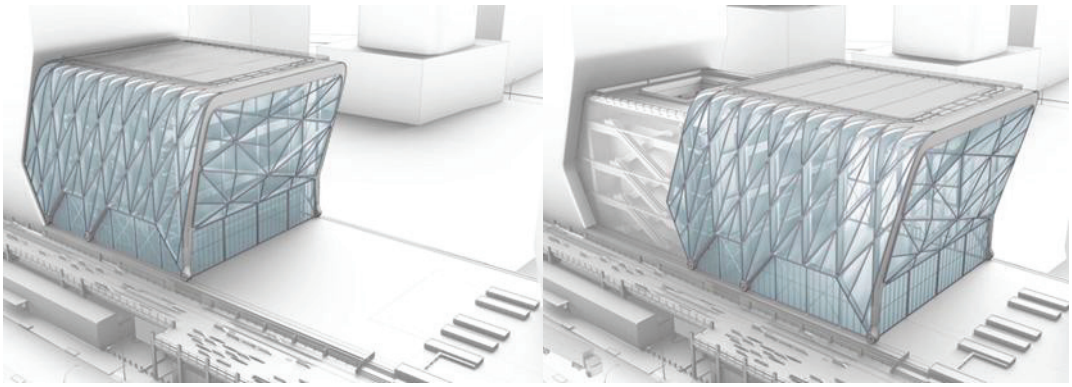
(a) (b)

Figure 12- (a) The Shed telescopic outer shell (URL-10), (b) Telescopic outer shell bogie wheels (URL-10)

(a) (b)

Figure 13-(a,b) Covering the Diagrid frame with ETFE cushions (URL-11)

The 37-meter-high movable shell is formed by covering the steel diagrid frame with ETFE cushions (Figure 13). ETFE cushions with lengths approaching 21 meters were used at certain points of the structure, making them the largest panels ever produced (URL-8).



(a) (b)

Figure 14-(a) The Shed telescopic outer shell in the closed state (URL-9), (b) The Shed telescopic outer shell in the open state (URL-9)

The fact that ETFE is a very lightweight material has facilitated the movement of the structure's shell on rails. The telescopic outer shell allows the structure to expand by 1087 m² thanks to bogie wheels (Figure 14) (URL-24). ETFE not only lightens the structure's mass but also provides thermal comfort thanks to its insulation properties. ETFE also provides acoustic support for the multi-purpose space.

3-THE EDEN

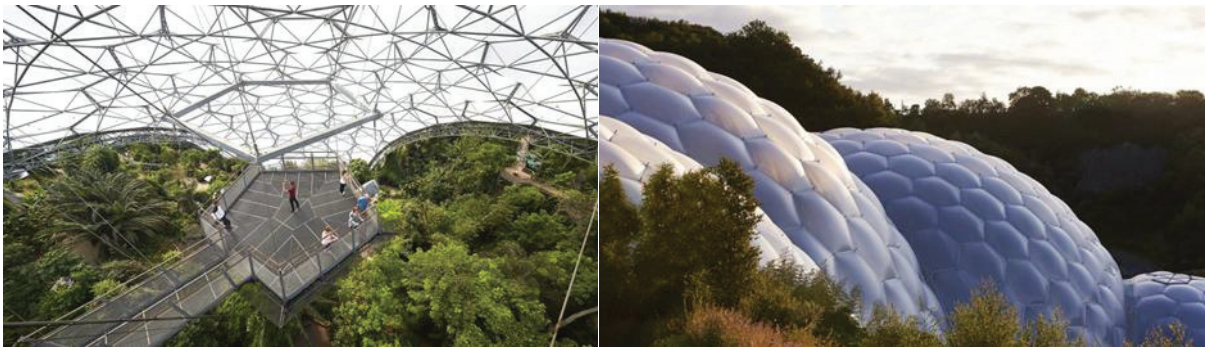
(a) (b)

Figure 15- (a,b) Distribution of Eden greenhouses on the land (URL-12)

Building Specifications

Year of Construction	Location	Architecture
2001	Cornwall, England	Nicolas Grimshaw & Partners

The project was designed in 2001 by Nicolas Grimshaw & Partners as a multi-domed greenhouse structure in the Cornwell region of England, providing an opportunity for large-scale plants to be cultivated, displayed, and studied (URL-13). Built on top of an 80-meter-deep abandoned fertile clay pit, The Eden project was constructed with the aim of reusing the land (URL-14). It was designed with three separate biomes according to the needs of the plants: a closed system for humid tropical climate plants and warm temperate climate plants, and an open system for plants that thrive in climates similar to the temperate Cornwall region (URL-15).



(a) (b)

Figure 16- (a) Interior view of The Shed (URL-12), (b) Exterior view of The Shed (URL-12)

The structure features a tall and wide geodesic dome to accommodate the tall plants typical of tropical climates (URL-15). ETFE, a strong, transparent, and lightweight material, was chosen for the

geodesic dome. The ETFE cushions provide maximum daylight transmission and adjustable light transmission, ensuring optimal indoor climate control.

Figure 17 - Photo of the construction of the Eden geodesic dome taken by Simon Burt (URL-15)

The dome is 240 m long, 55 m high, and has a diameter of 110 m at its widest point. The geodesic dome consists of 625 hexagons, 15 pentagons, and 190 triangles, and is covered with 30,000 m² of ETFE membrane (URL-14, URL-15).

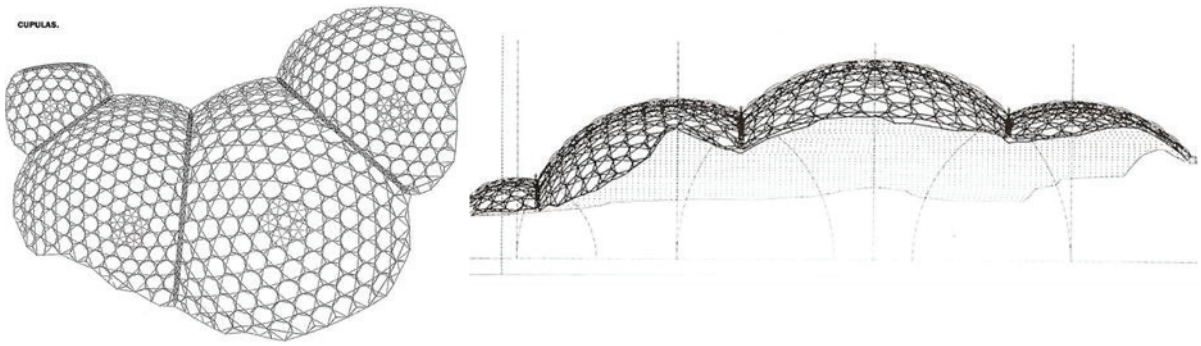


Figure 18- The Eden Geodesic Dome image (URL-16)

The edges of the dome are fixed onto a foundation concrete that surrounds the structure. Designing such a dome was geometrically unimaginable at the time. Three-dimensional models were created to connect each hexagonal frame of the geodesic dome, which consists of honeycomb modules, forming a curved surface. Thanks to the 3D model created, it was determined which parts the construction teams would need and where, and instructions were given to the machines to cut the steel beams to the appropriate dimensions. This allowed the construction teams to easily assemble all the parts by simply following the instructions (URL-15).

4- ALLIANZ ARENA

(a) (b)

Figure 19- (a) Allianz Arena evening facade image (URL-17), (b) Allianz Arena daytime facade image (URL-17)

Building Specifications

Year of Construction	Location	Architecture
2005	Munich, Germany	Jacques Herzog & Pierre de Meuron

The Allianz Arena football stadium was designed in 2004 in Munich, Germany, by Jacques Herzog and Pierre de Meuron. It has a seating capacity of 66,000. The stadium stands out for its chameleon-like ability to change its appearance and for the light it creates in the open space around it, like a beacon. The stadium achieves its striking appearance thanks to the shell covering its structural skeleton. The structure, which appears white during the day, is bathed in colorful lights after dark. The illuminated shell system is made possible by ETFE cushions (Figure 20). The illuminated shell, which can be customized according to the colors of the football teams playing there, offers a visually appealing spectacle at all times (URL-18).

(a) (b)

Figure 20- (a) Installation of the lighting system for ETFE cushions (URL-19), (b) Lighting of ETFE cushions (URL-19)

The stadium facade was clad with 2,874 pieces of 0.2 mm thick ETFE material inflated into a cushion shape and applied to a steel structure prepared using 22,000 tons of steel (URL-20).

(a) (b)

Figure 21-(a,b) Installation of ETFE cushions in their places (URL-22, URL-19)

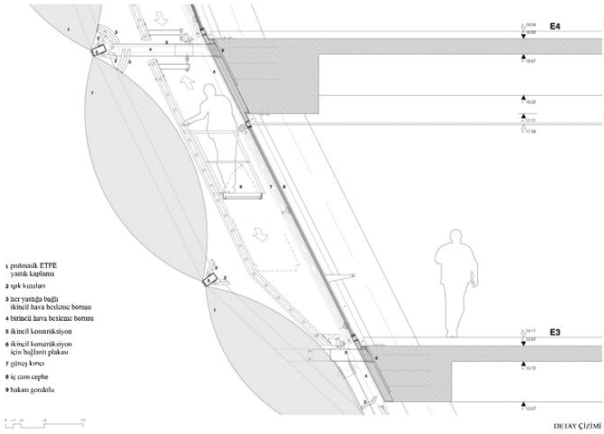


Figure 22 - Section showing the facade detail of Allianz Arena (URL-21)

Maintenance gondolas installed between steel structures enable ETFE maintenance and the resolution of potential malfunctions. The stadium's ventilation is provided by air supply ducts that work in conjunction with the steel frame system behind the ETFE (Figure 22).

(a) (b)

Figure 23-(a) spring-loaded steel plate bed (URL-22) that will move with expansion, (b) spring-loaded steel plate (URL-22)

Spring-loaded steel plates have been designed to prevent ETFE cushions from deforming in response to sudden temperature changes or heat increases. This system was first observed at the Allianz Arena (Figure 23).

CONCLUSION

ETFE material has been used primarily as an alternative to glass. ETFE, which creates an aesthetic appearance in architecture, comes in both single-layer and multi-layer cushion forms. Due to its extreme lightness, it is preferred because it does not create extra load on the structure, as seen in the example of The Shed. In addition to its low weight, another major advantage is its high transparency. The material, which is highly permeable to daylight, can also be used to provide shading by adjusting the level of permeability with various types of printing, thus avoiding the greenhouse effect in the space. This provides climate control in the space where it is used. It provides thermal and acoustic comfort in buildings and is notable for its suitability for use in structures such as gyms and stadiums. ETFE cushions can be installed with LED lighting to make the building mass appear as an installation product from the outside. Being an environmentally friendly and recyclable material, it contributes significantly to sustainable architecture. Thanks to its ease of installation and durability for years, it can be used for many years.

Application details vary depending on the project, but the basic concept involves inflating single-layer or multi-layer ETFE onto a steel structure and installing it in a cushion form. While ETFE material is resistant to tearing, intervention areas have been created by leaving gaps between ETFE panels to allow for potential interventions. These areas also enable the drainage of rain and snow water. The installation of ETFE cushions at Allianz Arena, together with spring-loaded steel plates, has produced solutions that avoid any deterioration that may occur as a result of expansion, keeping the material's performance at the highest level. As the application area of the material increases, it has been observed that solutions to potential problems and various detailed solutions to improve material performance have also emerged.

In this study, where we examined examples from around the world, we observed that the highly efficient ETFE material is not used sufficiently in Turkey. Incentive programs should be implemented to encourage the adoption and widespread use of this material in our country.

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Chapter 13

FROM TOPOS TO SYSTEM: RETHINKING SPACE IN THE DIGITAL AGE

Fatma Nur TONGAL [1]

Ayşegül DURUKAN [2]

1 Master's Student, Akdeniz University, Graduate School of Natural and Applied Sciences, Department of Interior Architecture, Antalya, Türkiye. ORCID: 0009-0004-1448-2933
2 Assoc. Prof. Dr., Akdeniz University, Faculty of Architecture, Department of Interior Architecture, Antalya, Türkiye. ORCID: 0000-0002-0888-5531

Introduction

The widespread adoption of digital technologies in the twenty-first centruy has led to a fundamental paradigm shift in interior design. Within the framework of traditional architectural thought, space has long been understood as a static construct defined by physical boundaries. At the same time, the user has been positoned as a largely passive occupant of this spatial order. However, the contemporary integration of smart sensors, artificial intelligence algorithms, and real-time data processing systems into interior environments profoundly disrupts this conventional relationship between subject and space. Today, interior spaces increasingly operate as dynamic systems capable of observing user behaviors, processing such data, and autonomously adjusting spatial conditions. This transformation raises a critical theoretical question regarding the evolving ontological status of space itself. In this context, it becomes necessary to reconsider whether Aristotle's concept of topos, formulated şn the fourth century BCE and defining space as extension and place, can still adequately account for interior space in digital age (Aristotle, 2001), or whether contemporary interior experiences shaped by digital and interactive layers that transcend physical boundaries require a conceptual framework beyond the Aristotelian understanding of space. This study examines the epistemological and phenomenological transformation of interior spaces in the digital age from a usercentered perspective. It argues that contemporary interior environments have evolved into active systems that perceive user behavior, interpret data, and transform spatial conditions in real time. Through this processi interior space shifts from a passive shell to an active participant, thereby dissolving the traditional subject-space dichotomy and constructing a new form of relationality. Within this framework, the study traces the historical evolution of the concept of space from antiquity to the digital age, conceptually analyzes three principal typologies of digital space, including virtual space, cyberspace, and augmented space, and positions smart home systems as a tangible manifestation of this emerging spatial paradigm.

The historical transformation of the concept of space has resulted from the relationship humans establish with their environment. The concept of space is in a defining relationship with approaches of perception, interpretation, and representation. The concept of space emerged from Hellenic thought. During this period, terms such as *topos, khora, pou* and *locus* were used to refer to 'place' or 'space' (Peters, 1967). According to Aristotle, defining space as a bounded area means that space is constantly connected to a concrete entity. Therefore, in Aristotelian thought, space is not an abstract structure that exists on its own. Indeed, space is inherently understood and derives its significance from the entities it encompasses; a conception of space that is independent, disconnected from being, and absolute is not recognized within this framework of thought (Bolay, 1993). Thanks to the discovery of the perspective technique, space has acquired a rational, measurable quality. As A. Pérez-Gómez and L. Pelletier (2000) emphasized, the perspective developed with the Renaissance added depth to the concept of space. In this manner, space, initially defined by physical boundaries, has transformed into an order based on representations. This historical development demonstrates that space is not merely a physical environment but a complex, multi-layered phenomenon. It is created and continuously transformed by human society, perception, and lived experience (Çınar, Yirmibeşoğlu and Erdoğan, 2024).

During the 17th and 18th centuries, when the scientific revolution was dominant, Cartesian and Newtonian notions of space existed. According to H. Lefebvre (1991), during this period, space became an entirely mathematical concept. Space has now become a rationalist understanding defined by measurable, material, and geometric accuracy. In the 20th century, the phenomenological approach criticized this rationalist approach. According to M. Heidegger (2008), space is not a static region in which objects remain stationary; rather, it is a multifaceted concept generated through experiential, perceptual, and practical processes, independent of the physical location of humans. This historical evolution shows that the idea of space has taken shape according to the conditions in which it exists within society. As a member of human civilization, he/she arranges his/her role in alignment with

societal structures. A. Pekpostalcı (2009) states that "Space is a mirror reflecting the individual himself/herself." The current understanding of space can be examined within a new spatial dimension that considers both physical and digital layers. In this context, space is positioned at the intersection of the virtual and physical worlds, centered around user-focused approaches.

The transition from physical space to digital space has become a process that requires a redefinition of the human-space relationship due to technological advancements. This process occurred in the late 20th century as electronic communication technologies became widespread."Space is a social product." indicating that space is not merely a physical entity but is produced through social relations and practices (Lefebvre, 1991). With digitalization, this concept extends beyond boundaries, expanding towards screens, data, and interfaces. P. Virilio (1991) argued that the velocity vector in the digital age reconfigures space, replacing the depth of time offered by the digital era with the physical space's depth. In W. J. Mitchell's (1995) words, "The network invalidates geometry." In this context, structures with specific functions, such as banks, libraries, and stores in the physical world, can now move and be accessed easily over the network without the need for movement or distance. In this digital age, experience is no longer about physically being between buildings and walking; it has become a bodiless journey formed by clicking links in cyberspace.

The transformation of the material space concept in interior architecture has begun with moving away from a space understanding composed solely of physical components. This new approach considers space as an interactive environment recreated through user experience, perceptual processes, and interactions. In this context, the discipline of interior architecture does not define space merely by its boundaries, walls, and materials. K. Lee (2022) argues that indoor space arrangements should go beyond mere physical organization, highlighting that the sensory-emotional connection formed through body-space interaction reevaluates the concept of materiality. This user-centered approach encourages sensory consideration of the surfaces, atmosphere, temperature, and acoustics offered by the material environment. Thanks to digitalization, this transformation allows us to get closer to the most current state. With sensors, interfaces, and data systems integrated into indoor spaces, the spaces have moved away from a fixed depth and become fluid, responsive, and multi-layered. As A. F. Ashour (2021) states, indoor spaces are now more dynamic and responsive due to technological advancements, no longer remaining static. This situation has transformed the space from a passive entity into an active interface that interacts with the user.

The Redefinition of Space Experience by Digital Technologies

Digital technologies are undergoing a fundamental change in how people communicate and use space. This change shifts the space from a limited area composed of walls, floors, and roofs to interfaces where data flows, integrating physical and virtual dimensions, and maintaining continuous communication with users. As a result, the temporal aspect of spatial experience also changes. The experience between humans and space is sequential and linear in physical space, but it is simultaneous and multi-layered in digital space. In this context, the current state of the space has become a system focused on user behaviors, preferences, and needs, and shaped accordingly. The positive impact of the digital age on human life has made it increasingly common and widely adopted. Additionally, the space has transformed a single-layer structure to a hybrid structure. As A. Durukan (2016) emphasizes, to meet the changing living standards of modern society, it is necessary to utilize technology in space design and adopt smart space solutions. Therefore, interior architecture should now adopt a design language grounded in behavior, data, and interaction.

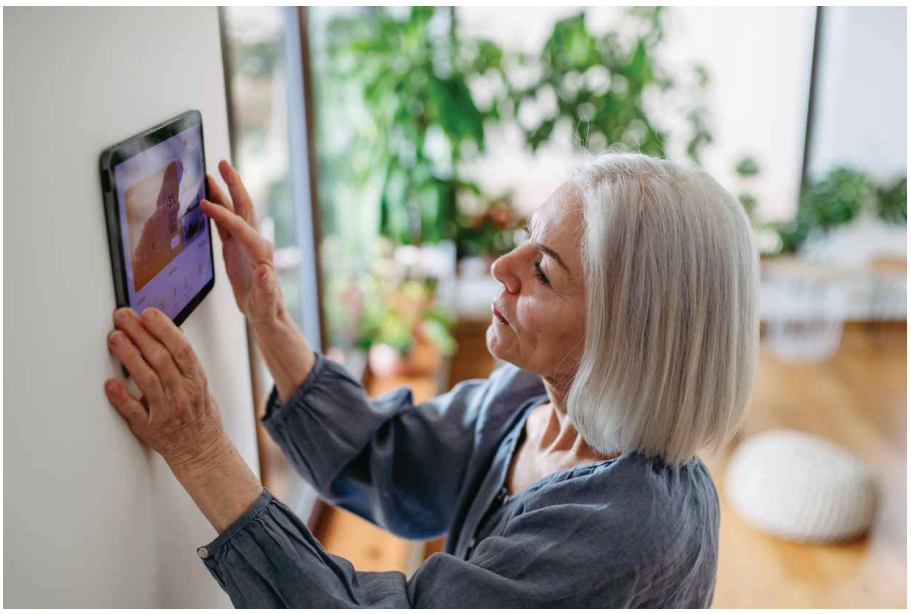

Figure 1. *A representative visual showing the transformation of indoor experience through digital interfaces. CHES Electric (2023). https://cheselectric.com/blog/what-is-smart-home-technology/ (accessed on 12/25/2022).*

The digital space is conceptualized in the literature through three main typologies: virtual space, cyberspace, and augmented space. Although these typologies differ in nuance, they share a common feature: the continuous, dynamic interaction between humans and space. In this section, each typology will be examined within the framework of user-centered spatial approaches.

Virtual Space

The concept of virtual space is a term shaped by many disciplines. O. Ettlinger (2007) defines virtual space as 'the general space we see through pictorial images.' It refers to a spatiality that we do not physically exist in but experience perceptually. M. Heim (1993) suggests that the virtual realm, with its structure separate from natural physical space, contains representations of information rather than the material existence of objects and gives the user the feeling of directly engaging with physical realities. J. Baudrillard (1994) argues that society has moved away from reality and that simulation has replaced the real. According to him, codes, models, and signs now take the place of reality. He refers to this situation as 'hyperreality.' Today's VR technologies are used both as presentation tools and as original design environments, thanks to new spatial applications focused on user experience. Virtual space not only encompasses a technical area but also adds a new layer to the user experience and perception. Today, architects use VR technologies to present their projects in virtual environments and to design virtual worlds, creating structures suited to the environment and not constrained by physical limitations. This process significantly broadens the application of original work and the concept of space within the discipline of architecture. Virtual space enables the simulation of physical space using acquired information. Therefore, it provides an environment where user experience can be objectively evaluated and optimized.

Cyberspace

The concept of cyberspace was first used by W. Gibson (1984) in his novel Neuromancer. W. Gibson (1984) describes cyberspace as "a consensual hallucination experienced daily by billions of legitimate operators from every country." This definition emphasizes that cyberspace is a non-material experience realm created in the mind and on screens. In a similar vein, N. Özgen (2018) states that the concept of cyberspace refers to the acquisition, structuring, and application of information through networks and intermediaries. The acquisition, analysis, and structuring of data in virtual space can be understood as a reflection of cyberspace. In this context, cyberspace is an experiential realm that exists beyond the physical, in the mind and on the screen. From an interior architecture perspective,

cyberspace is the support of the physical dwelling with digital interfaces. This enables working from home, socializing remotely, and entertainment applications that involve digital elements, creating an intersection between the interior space and cyberspace. This intersection focuses more on the user's spatial experience rather than physical boundaries. What distinguishes cyberspace from a virtual environment is its networked architecture, which enables collective experiences.

Augmented Space

Augmented space is a hybrid environment where physical and digital realms are integrated. L. Manovich (2005) derived this concept from the existing augmented reality (AR) technology. Augmented reality is the opposite of virtual reality (VR). While VR users experience a virtual simulation, AR users experience digital layers in the physical space. A. De Souza e Silva (2006) argues that this experience arises from the blurring of boundaries between physical and digital spaces. This concept shifts traditional interfaces to mobile interfaces, bringing social communities into physical spaces. L. Manovich (2005) described augmented space as an area marked by intense data flow, where physical space is considered. In this context, it is argued that every point in this space receives various data from other points. This approach provides a current framework for user-centered space design: space is now transforming into a structure determined by the user's location, movements, and preferences. Augmented space plays a vital role in indoor environments. Projections on surfaces, AR interfaces, holograms, and data visualizations offer opportunities to experience hybrid space beyond the characteristics of the physical environment. In this experiment, the physical state of the space is transcended, creating a complete spatial experience through the influence of digital layers. This hybrid space embodies a user-centered spatial approach and supports the concept of a smart home.

Smart Home: The Concretization of a User-Centered Spatial Approach

M. R. Alam et al. (2012) characterize a smart home as an ''application of computing technology ubiquitously deployed, wherein the environment is monitored by ambient intelligence to deliver context-aware services and enable remote home management.'' By incorporating features such as comfort, health, safety, and energy savings, homes have become intelligent and a part of the information processing field. M. Li et al. (2018) describe a smart home as a building that combines the Internet of Things, computer and control systems, imaging, and communication technologies, linking various systems inside the house through a network. Thanks to this integrated structure, automation requirements are met, enabling users to manage their daily lives easily, comfortably, and in control.

In the history of the smart home concept, this phrase was used in 1984 by the American Association of House Builders. However, the origin of this concept dates back to the early 1960s, when hobbyists built such homes, which were referred to as 'wired homes'. Thanks to this development, the foundation of smart homes has been established (Harper, 2003). The first milestone in the development of smart home technology was the entry of electricity into homes in the 20th century, transforming indoor life through electrical appliances and devices. The other milestone is the reflection of information technologies into the home. This situation has accelerated the development of smart home technology by creating new opportunities. The transformation of smart homes can be examined in two stages: pre-IoT and IoT-based. In the pre-IoT era, ECHO IV and the Kitchen Computer in the late 1960s were examples of home automation. The X10 standard developed in the 1970s was used in residential installations. The advent of the internet in the mid-1990s marked a significant milestone in the development of smart homes. In the IoT-based era, the Nest Learning Thermostat was produced in 2010. With this device, the user-set temperature automatically adjusts the environment. In 2014, Amazon developed a smart speaker. This device can be programmed with voice commands (Bugeja, 2021). Many devices have been produced since the beginning of 2020. These devices have become even smarter thanks to advanced sensor and artificial intelligence technologies. As a result of this development, smart homes have evolved beyond isolated devices into integrated systems.

IoT Integrated Indoor Spaces

In smart homes, the lighting system is not just about remotely controlled lamps; it is also designed to maximize energy efficiency. In this context, the smart lighting dimming control strategy, enabled by 'daylight harvesting' technology, reduces the amount of artificial light used inside the building by utilizing natural light when available (Ramadhani *et al*., 2022). The method proposed by P. Obioma *et al*. (2025) offers an IoT-based DIY innovative lighting system supported by a lighting control algorithm. The design integrates occupancy and presence sensors as a communication module, enabling real-time wireless interaction and remote monitoring regardless of location. As a result, significant power savings are reported.

In smart homes, climate control can be adjusted based on real usage patterns, air forecasts, and user responses, unlike traditional thermostats or program-based controls. This system significantly improves energy efficiency while also enabling the HVAC to learn and adapt to the environment (Chauhan, 2025). In addition to energy savings, one of the advantages of IoT-enabled HVAC systems is the ability to improve maintenance and reliability. These systems monitor equipment temperature, pressure, and vibration data in real-time to detect potential failures before they occur and enable predictive maintenance (Chauhan, 2025).

In digitalized indoor environments, Environment Intelligence and user experience influence how the space is perceived, used, and interacted with. This understanding significantly transforms the design language. Ambient Intelligence (AmI) operates unobtrusively by integrating artificial intelligence into quotidian environments, enabling intelligent systems to operate without explicit user perception (Dunne et al., 2021). It is when a user interface provides helpful and predictable support across multiple situations. Environmental intelligence envisions user-centered systems that enhance service provision and foster more effective human interactions. Within such environments, innovative interfaces embedded in everyday objects can recognize individual users and deliver personalized data in a manner that is often seamless and imperceptible (Ducatel *et al*., 2001). The 'Smart Living Room' application developed by A. Leonidis *et al*., (2019) not only considers the space as an activity area but also includes entertainment applications, a control system, an intervention server, and a customizable smart assistant. The incorporation of human-centered design into space has been made possible and facilitated by current experiments. In residential design, the Ambient Intelligence (AmI) approach has led to the reimagining of spaces as systems that can interact with users. Within this framework, smart furniture, responsive lighting systems, and adaptable surfaces have become fundamental components that detect user behaviors and dynamically regulate the spatial experience.

Figure 2. *A conceptual representation of a modern residential interior where IoT technologies are embedded within the indoor environment. Created with AI (Google, 2025; OpenAI,2025).*

The experiential process arising from the structural formation of the smart home actually unfolds across space on political, cultural, economic, social, and semantic levels. Smart homes can be personalized because the interaction between humans and the space addresses users' needs

and establishes meaningful relationships. Y. Yu *et al*. (2024) examined user comments received by robot vacuum cleaners that can be integrated into smart home devices. Satisfaction factors identified include 'functionality,' 'smartness,' and 'advanced capacity,' while dissatisfaction factors include 'insufficient smartness' and 'connection issues.' These results show that, in the smart home experience, the intuitive design of interfaces, the learning curve, and users' demographic characteristics directly influence the smart home experience. M. Yüksel and H. Demirci (2024) assess the integration of smart home technologies by examining how well these systems enhance users' lives and their impact on daily routines. Since user experience is directly related to the functionality and inclusiveness of systems, developed systems must comply with these design criteria. The ability to remotely control materials integrated into spatial design significantly simplifies users' everyday lives (Durukan, 2016). The technological capabilities of smartphones have become essential tools that facilitate users' lives across many areas. These devices serve purposes such as acting as computers, providing data storage, enabling remote control, and enabling the control of smart materials involved in space design. Additionally, integrating with smart home interfaces and being user-focused also enables customization based on the user's profile.

In interior architecture, the reflection of digital technologies and smart systems in the design process can be examined through the redefinition of both the methodological and professional scope of interior architecture. M. Kokorska (2024) states that in modern housing, technological innovations are now a reality and a prerequisite. As a result, daily life has become easier, and users' concerns about safety have decreased. The integration of IoT into life has made everything it touches smarter. M. Kokorska and M. Marinov (2019) argue that thanks to digital advancements, modern interior design is evolving towards a 'digital interior,' and they have identified four main features of modern interior design: Integration (the integration of IoT into communication devices and furniture within the scope of high efficiency and comfort), Transformation (spatial adaptability), Green Solutions (efficiency in energy and water consumption), and Flexibility (adapting to possible scenarios). A. Tomaş and N. Dostoğlu (2020) state that technological progress has integrated technical features into residential design, improving users' quality of life. These developments have made it inevitable for architectural practice to be integrated with different disciplines: interior architects are expected to have more knowledge about sensor technologies, data analytics, and user interface design, rather than just material, color, and form knowledge.

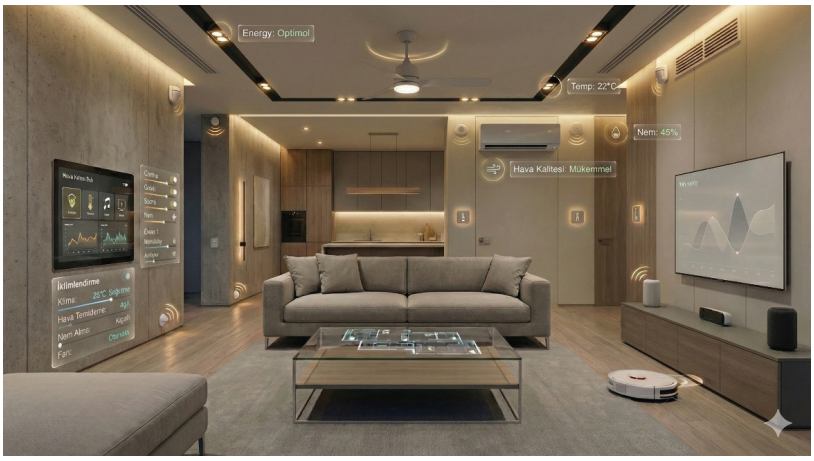

Figure 3. *The reflection of ambient intelligence within the domestic interior.Created with AI (Google, 2025).*

The inclusion of smart home technology in interior design practice directly impacts the design process. In traditional interior design approaches, the designer considered the space as defined by a specific physical arrangement for a given period of time. However, with digitalization, space has become a mechanism that transforms according to the user, time, and conditions, influenced by the user. This situation requires interior architects to redefine their design processes and areas of expertise.

Home automation systems include smoke sensors, door access control, burglar alarm systems, energy measurement, panic buttons, lighting, and underfloor heating systems. While these systems positively impact a person's comfort of living, they also contribute to energy savings. As part of green solutions, smart faucets, smart rainwater tanks, and HVAC system efficiency improvements are also included.

The Future of Space: Transforming Design Fields

The transformation of material and surface technologies not only affects the structural establishment of space but also influences its development as a system capable of responding to environmental conditions, user needs, and technological inputs. In each historical period, the construction of space has been framed within the technical limitations and material knowledge of that era. In the past, architectural design processes were limited by the possibilities of existing building materials. In contrast, today, the development of new materials has come to the forefront in line with design requirements (Çakmak, 2021). Until the Industrial Revolution, material selection in construction focused on ease of acquisition, practicality, and functionality; however, the perspective on building materials shifted thereafter. Material selection has increasingly relied on technical measures such as durability, performance, and engineering calculations (Addington and Schodek, 2025). M. Addington and D. Schodek (2005) classified materials based on their behavior: Type I (property-changing) materials can respond autonomously to chemical, thermal, mechanical, magnetic, optical, or electrical changes in the environment and can transform under the influence of these conditions. For example, a photochromic material can change its color in response to changes in the amount of ultraviolet radiation incident on its surface. Type II (energy-converting) materials can convert energy from one form to another, and this transformation is reversible at the moment of conversion. For instance, photovoltaic cells that convert light into electricity fall into this category. Within the scope of user-centered spatial approaches, these materials are considered systems that can respond to user needs and environmental effects, focusing on living comfort and quality.

As a result, materials focused on comfort and quality of life that can respond to users' needs and environmental impacts will be produced for future spaces. These materials are designed not only for the physical environment but also for the essence of life itself. The smart materials produced should utilize technology to ensure all their functions (heating, cooling, lighting, etc.) are simple and error-free.

Interaction and user behavior have become selective parameters that derive meaning from the relationship between humans and space. With digitalization, the future of space is increasingly shaped not just by the smart materials used and the form, but by the interaction between humans and space. In this transformation, the interaction between usage behavior and perception is at the core. The current space has an infrastructure that receives, processes, reacts to, and transforms data beyond its boundaries into an experience through user behavior. Interaction is not only a mental process but also involves the body and context. P. Dourish (2001) states that interactions rooted in bodily experience are inherently irrational and derive their meaning through interpersonal and bodily engagements. In this context, interaction in the space of the future involves the body actively participating in the process of meaning between humans and space. In user behaviors, what matters more is what the designed space offers to the user rather than the user's behavior itself. This is related to how suitable the space is. Whatever the space offers, the user's behaviors are shaped accordingly.

The visualization logic predicted by H. Lefebvre (1991) has fully transformed into a structural reality. The human's connection with space is now focused on visual perception on screens rather than bodily perception. The sense of touch provided by contact is now framed within the sterilized 'visuality regime' of digital. In this new order, as contact disappears, we also lose our sensory depth, and visuality alone serves the body instead.

The future of user-centered design requires redefining the relationship between humans and

spaces through data-driven, learning, and predictive systems. The future of user-centered spatial approaches will be shaped by the integration of technologies into indoor environments enabled by artificial intelligence and machine learning. In interior architecture practice, the ability of spaces to learn from user behavior and respond to it indicates transformation. In this context, the space becomes an 'intelligent' system that anticipates and responds to the user's needs. S. Yiannoudes (2016) states that with the development of digital technologies, machines are no longer just functional tools but have become systems capable of perceiving their environmental and user context. Thanks to developments, machines are collecting data, and ecological intelligence is increasing. In this context, these advancements make it necessary for design practice to become an interdisciplinary field. Interior designers are now expected to have a greater understanding of data analytics, user experience design, and artificial intelligence than just aesthetic and functional design.

User participation should be placed at the center of the design process. User experience and the system's ability to personalize are directly proportional to the success of smart home systems. Therefore, interior designers have begun to pay closer attention to methods such as user research, behavior analysis, and experience design alongside current design approaches. As a result, interior architecture in the digital age requires an approach that combines technical competence and sensitivity. Future spatial practices are shifting towards an integrated hybrid experience that unites physical and digital layers. In this context, user-centered spatial approaches are more than just a design trend; they represent a profound transformation in the ontological status of space. Space is no longer a passive framework but an active system that communicates with the user.

As a result, examining the transformation of indoor spaces in the digital age from a user-centered perspective shows that traditional space definitions are insufficient to explain contemporary interior architecture practice. The research findings reveal that the concept of space has undergone three critical transformations from antiquity to the digital age: (1) Ontological transformation: space has evolved from a material '*locus*' to a data-based 'system'; (2) Epistemological transformation: spatial knowledge has shifted from geometric measurements to user behavior data. (3) Phenomenological transformation: spatial experience has shifted from a static perception to a dynamic interaction. This tripartite transformation confirms the study's central argument: the integration of digital technologies into interior spaces eliminates the subject-space dichotomy, thereby constructing a new form of relationality. The analysis of virtual, augmented, and cyber space typologies shows that space is now a hybrid structure that perceives user behavior, processes this data, and transforms spatial conditions in real time. The evaluation through smart home systems concretizes how this theoretical framework is reflected in practice: IoT sensors, artificial intelligence algorithms, and automation systems are transforming the residence from a passive shelter into an active living ecosystem.

These findings produce two critical conclusions for the interior architecture discipline. First, the role of the interior architect is being redefined; they are no longer merely designers shaping the physical environment, but are evolving into 'system designers' who orchestrate human-space-technology interactions. Second, spatial design processes are also transforming. There is a shift from static plans to dynamic scenarios, from formal composition to behavioral algorithms, and from delivering the final product to continuously adapting systems. Therefore, the study explains why user-centered spatial approaches are indispensable in the digital age at three levels: (1) Theoretical level (providing a conceptual framework for the integration of physical, digital, and perceptual layers of space); (2) Methodological level (demonstrating how user behavior data can be used in interior design); (3) Practical level (proposing new design approaches that require the synthesis of material design and digital technology).

In addition, it has some limitations because it adopts a theoretical, literature-based approach as its working methodology. Firstly, empirical data measuring the tangible effects of user-centered spatial approaches have not been provided. Future research should evaluate the effects of different smart home

systems on user experience through controlled experimental environments or long-term field studies. In particular, mapping user satisfaction, changes in spatial preferences, and behavioral adaptation processes using both quantitative and qualitative methods is critical for testing the validity of this theoretical framework. Secondly, this study has not sufficiently addressed cultural and contextual differences. The adoption of smart home technologies varies across societies in terms of privacy perceptions and expectations for spatial control. Comparative studies need to understand local spatial practices and forms of cultural resistance beyond Western-centric technology narratives. Specifically in Turkey, the social acceptance dynamics of smart home systems, perceptions of privacy, and their interaction with traditional housing culture should be systematically researched. Thirdly, the study has limitedly discussed the ethical and political dimensions of digital space. Critical issues such as data surveillance, algorithmic control, digital inequality, and technological dependency need to be thoroughly examined from an interior architecture perspective. It is especially necessary to question the power relations behind the rhetoric of 'user-centeredness,' including who is using whose data and whose interests are being served. Finally, the development of interdisciplinary, measurable, and original methodological frameworks for user-centered spatial design is urgently needed. In this context, hybrid research models that bridge interior architecture, computer science, data science, behavioral psychology, and sociology are required. Developing 'user behavior analysis tools' that can be integrated into design processes, 'dynamic metric systems' that evaluate spatial performance, and 'responsible design protocols' that ensure ethical standards are of strategic importance in guiding the transformation of interior spaces in the digital age.

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