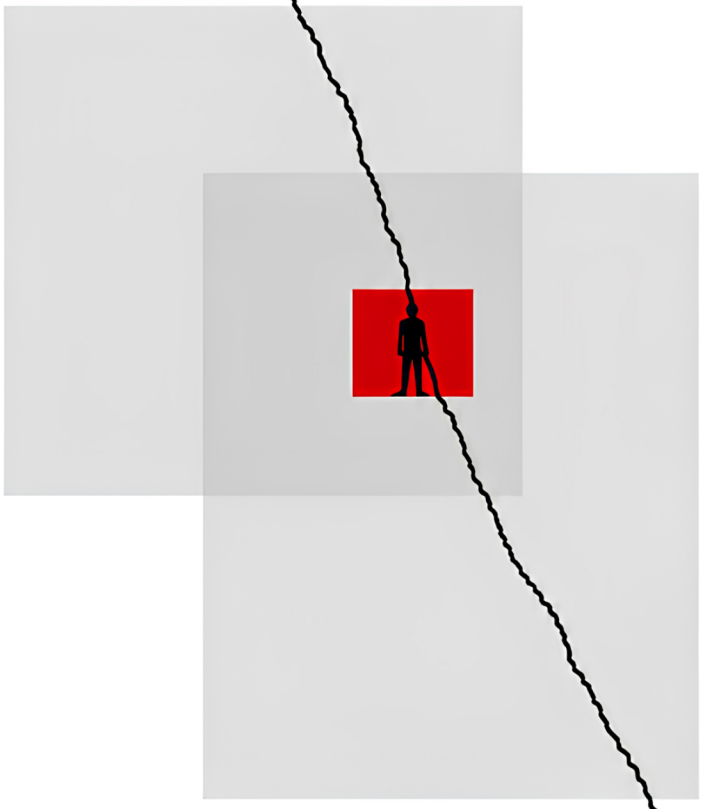
EARTHQUAKE-RESILIENT SPACE: I

DESIGN EDUCATION AND POLICY



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Earthquake-Resilient Space: Design, Education and Policy I

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PREFACE

The memory of the lives we lost and the profound suffering caused by the earthquakes of 6 February 2023 has once again reminded us of our scientific, professional, and social responsibility to create safe and resilient living environments. As we commemorate those we lost with respect and remembrance, we regard reflecting on earthquakes, conducting research, and producing knowledge collectively as an enduring responsibility. We believe that this responsibility must be fulfilled through efforts that learn from past experiences and translate the knowledge generated into education, design, practice, and public decision-making.

Our studies on earthquakes have placed at the centre of our academic agenda the importance of addressing questions concerning safe living environments at different scales and through the collective contributions of multiple disciplines. For us, the value of this accumulated knowledge lies in its capacity to foster new research, encounters, and collaborations. We therefore regard this book as a meeting ground that supports the continuity of our work, makes our shared concerns visible, and creates space for contributions from different fields of expertise.

Within this framework, we particularly wish to emphasise the need for architecture, interior architecture, and other design disciplines to have a stronger voice. We consider it essential that spatial organisation, accessibility, scenarios of use, interior arrangements, and decisions concerning furnishings and non-structural elements be addressed together with disaster preparedness and recovery processes. We advocate for the active involvement of design disciplines throughout the entire process, from defining research questions and developing assessment criteria to informing implementation decisions and policymaking. We regard working environments in which different fields of expertise listen to one another, share responsibilities, and develop decisions collaboratively as a fundamental condition of this approach.

We also address the relationship between design education and policy, which lies at the core of this book, within the same framework. We consider it important for design education to equip future professionals with the competence to assume responsibility for disaster resilience, collaborate across disciplines, and evaluate the societal consequences of spatial decisions. We believe that knowledge generated through research should be transferred into educational environments, professional practice, and public policy, while questions emerging from practice should, in turn, contribute to further research and education.

We believe that the responsibility we assumed following the earthquakes of 6 February must be sustained through a long-term academic and professional commitment. We therefore hope that this book will contribute to the continuation of earthquake-focused studies, bring together researchers from different fields around shared questions, and provide a foundation for new collaborations. We aim to strengthen the position of architecture and interior architecture as disciplines that generate knowledge, assume responsibility, and contribute to decision-making processes. We seek the lasting impact of academic production in the continuity of the collaborations established and in the capacity of the knowledge produced to make a tangible difference in people's lives.

In this respect, we find it particularly meaningful that our book, Earthquake-Resilient Space: Design, Education and Policy I, is being published on 29 October 2026, in the 103rd year of the Republic of Türkiye. We regard the publication of this volume on Republic Day as an expression of our shared responsibility, guided by the Republic's ideals of science, education, and social progress. We believe that the commitment to producing and sharing scientific knowledge for the benefit of society should continue to guide our efforts to create safer and more resilient living environments.

In this context, we would like to express our sincere gratitude to all the authors who contributed their valuable studies to this book, as well as to everyone involved in its preparation and publication. We hope that this volume will open new avenues for thought and productive discussion among researchers, educators, students, practitioners, and decision-makers.

With the hope that we will continue to think, produce, and work together towards safer, more inclusive, and earthquake-resilient living environments.

Editors
Prof. Dr. Şebnem Ertaş Beşir
Assoc. Prof. Dr. Tülay Canbolat
29 October 2026

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Seda KIZILTEPE

CHAPTER I

SOCIAL SUSTAINABILITY IN POST-DISASTER PUBLIC SPACE PRODUCTION: A COMPARATIVE ASSESSMENT OF CONVENTIONAL METHODS AND ADVANCED TECHNOLOGICAL APPROACHES

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1. Introduction

Beyond the physical losses they inflict on the built environment, disasters disrupt the continuity of everyday life, social relationships, and the bonds individuals establish with place. Post-disaster recovery thus constitutes a multidimensional process encompassing both physical reconstruction and the reorganisation of social life (Berroeta et al., 2024; Matsushitaa et al., 2025). Although addressing emergency shelter needs is the foremost priority in this

process, prolonged transitions to permanent housing necessitate the planning of temporary settlements as living environments that also accommodate social and cultural needs (Félix et al., 2013; Johnson, 2007; Valle & Romania, 2019).

In temporary settlements, public spaces facilitate the re-establishment of social relationships by supporting everyday encounters, solidarity, and collective activities (Zarkhah et al., 2025). Their relationship to the maintenance of a sense of belonging, place identity, and collective memory highlights their significance for social sustainability (Gregori, 2025). Nevertheless, approaches that prioritise speed of delivery, cost, and shelter capacity may fail to adequately consider the quality of communal spaces and the needs of diverse user groups (Johnson, 2007; Montalbano & Santi, 2023). In this context, the central issue is how the relationship between housing units and public life is articulated through design decisions at the settlement scale.

Parametric design, 3D printing, and digital participation tools offer new opportunities for developing design alternatives, integrating them with production processes, and evaluating them with users (Mehdizade, 2024; Berigüete et al., 2024). However, a direct relationship between technological capacity and social sustainability cannot be assumed. Inequalities in digital access and the conditions under which users are represented in decision-making processes may constrain the inclusiveness of these tools (Faldi et al., 2022; Luo et al., 2025). Accordingly, the assessment of advanced technologies should encompass local needs, participation, and conditions of public use alongside technical performance.

This study aims to compare the opportunities and limitations of conventional methods and advanced technologies in post-disaster public space production within the context of social sustainability. It examines how different approaches establish relationships between housing units and the settlement as a whole, and under what conditions they may support the reconstitution of social life. The literature-based comparative assessment is structured around six criteria: production processes, user participation, adaptability, inclusiveness, spatial diversity, and long-term continuity. Within this framework, the study discusses an integrated design approach in which technological opportunities are assessed in conjunction with social needs and public space is recognised as a fundamental component of post-disaster reconstruction.

2. Post-Disaster Socio-Spatial Transformation and Sustainability

2.1. Interrelationships between Sustainability, Architecture, and Space

Sustainability in architecture encompasses meeting human spatial needs while safeguarding natural resources and future life opportunities (Sev, 2009),

as well as creating built environments that are responsive to climatic conditions, sensitive to cultural values, supportive of quality of life, and adaptable to changing circumstances (Ghiasi, 2016). Alongside resource efficiency, this approach addresses the capacity of space to sustain social life.

Social sustainability has gained prominence, particularly since the early 2000s, within sustainability debates that have predominantly emphasised environmental and economic dimensions (Dempsey et al., 2011; Woodcraft et al., 2011). The aim of creating safe, inclusive, and equitable settlements that offer a high quality of life highlights the spatial dimension of social sustainability (Dempsey et al., 2011). Indeed, urban spaces in which social relations are reproduced, and which are thereby continually reproduced themselves, are inseparable from social life (Al, 2011). For this reason, the disciplines of architecture and urban design play a pivotal role in creating environments that support social relationships.

2.2. Social Sustainability and Public Space

Urban resilience to sudden disruptions depends on social processes. Within these processes, society is not merely affected by disasters but is also a key actor in strengthening resilience (Pelling, 2003). Community resilience, an important indicator of social sustainability, refers to the capacity to adapt to change and transform, rather than simply return to pre-disaster conditions (Magis, 2010; Manyena et al., 2011). Social interaction, trust, networks, and collective participation are shared components of both social sustainability and community resilience (Dempsey et al., 2011). Sustaining these components requires spaces that enable social interaction.

Public spaces are settings in which everyday life and social interaction unfold between buildings (Gehl, 1971). For this reason, approaching cities through the lens of human experience is important for understanding social structures and achieving sustainability (Gehl & Svarre, 2013; Jacobs, 1992; “What Is Placemaking?”, 2007). Memory, which is shaped within social life (Halbwachs, 1992), acquires tangible expression through physical spaces, enabling urban events and experiences to be transmitted to future generations (Rossi, 2006). In these respects, public spaces constitute an infrastructure that supports social networks, solidarity, and collective action in both everyday life and periods of crisis (Madanipour, 2014; Zarkhah et al., 2025). For this reason, the design quality of public spaces is important for advancing social sustainability and strengthening community resilience.

2.3. The Impacts of Disasters on Social Sustainability and Space

Disasters disrupt spatial, social, and temporal continuity through the loss of physical functionality, the weakening of social networks, and interruptions to everyday life (Matsushitaa et al., 2025). Accordingly, recovery entails not only the reconstruction of buildings but also the re-establishment of social life and a sense of continuity. Given that place identity emerges through the relationship between the physical environment, activities, and meanings (Relph, 1976), post-disaster space production must also account for belonging, memory, and social interaction (Berroeta et al., 2024) (Matsushitaa et al., 2025). Post-disaster practices of solidarity and collective memory preservation may support communities in adapting to changing conditions (Wesener, 2015). In this context, post-disaster spatial recovery should be understood as a process that extends beyond physical reconstruction to support social continuity and social sustainability.

2.4. Temporary Settlements and the Role of Public Space

Shelter is the primary need in the aftermath of a disaster; however, shelter deprivation entails not only a lack of physical protection but also a loss of dignity, identity, and privacy (Barakat, 2003; Félix et al., 2013). Quarantelli (1995) distinguishes four stages of post-disaster accommodation: emergency shelter, temporary shelter, temporary housing, and permanent housing. Delays in the transition to permanent housing transform temporary settlements into environments in which everyday life is sustained. For this reason, temporary housing should be understood not merely as a protective shelter unit but as a system that supports a return to social life (Félix et al., 2013; Johnson, 2007; Steinberg, 2007; Valle & Romania, 2019). Accordingly, the planning and design of temporary settlements must address social, cultural, and spatial needs alongside physical requirements.

Post-disaster social recovery requires consideration of the needs of different groups and of social equity (Kaniasty, 2020; Monteil et al., 2020; Peacock et al., 2018). In this regard, temporary settlements may provide a basis for re-establishing disrupted social relationships and organising community solidarity (Valle & Romania, 2019). Nevertheless, post-disaster housing practices have been criticised for high costs and delayed delivery, as well as for the incompatibility of standardised designs with user needs and local culture, unplanned site selection, environmental impacts, and waste generation after use (Atalay & Gökmen, 2026; Félix et al., 2013; Felix et al., 2015; Hosseini et al., 2016; Johnson, 2007; Kahvecioğlu & Selçuk, 2025; Montalbano & Santi, 2023;

Peacock et al., 2018; Wagemann, 2017). These issues highlight the need to plan temporary housing areas in ways that contribute to long-term sustainability while providing shelter rapidly.

The sustainability of temporary settlements requires consideration of both their period of use and their subsequent transformation within the design process. In this regard, disassembly and reuse are important for reducing resource consumption and post-use waste associated with temporary housing (Akdede et al., 2026; Shahkar et al., 2021). However, the gradual permanence of temporary settlements characterised by poor quality of life and inadequate services may weaken communities' social and economic ties. For this reason, these settlements should be planned as temporary urban systems (Ruggiero, 2018), with the conditions governing their transformation assessed at an early stage (Akdede et al., 2026). Approaches that account for local resources, cultural compatibility, and user needs, while fostering collaboration between communities and governing authorities, provide a stronger basis for social sustainability than centralised, standardised solutions (Atalay & Gökmen, 2026; Johnson, 2007; Montalbano & Santi, 2023; Nazaruddin, 2025).

Following disasters, residents seek a sense of "home" and a secure social environment within temporary housing settlements. Unplanned modifications subsequently made to standardised solutions may, however, result in overcrowding, compromised privacy, structural problems, and inadequate access to daylight and green space (Duru & Sarıkaya, 2025; Wagemann, 2017; Yüksel & Hasırcı, 2012). Temporary interventions undertaken by communities in vacant urban spaces also have the potential to evolve into permanent practices (Wesener, 2015, 2017). These circumstances highlight the importance of local communities' active role in recovery (Brand et al., 2019) and of addressing communal space needs from the outset.

Public spaces support everyday encounters, solidarity, and the re-establishment of social networks within temporary settlements (Zarkhah et al., 2025). Well-designed communal spaces may contribute to the continuity of memory, identity, and belonging (Gregori, 2025). Although the potential of public spaces to enhance disaster resilience is frequently emphasised (Alawi & Chu, 2024; Ghezelloo et al., 2023; Jayakody et al., 2018), their design receives insufficient consideration in the improvement and planning of temporary settlements. During long-term recovery, the historic city, the temporary city, and the future permanent city become concurrent concerns. Across these environments, public spaces differ as familiar spaces, often incidental spaces,

and spaces with which residents have yet to identify, respectively (Chioni et al., 2021). Planning for continuity across these conditions may enable temporary communal spaces to establish a connection between pre-disaster memory and the future settlement.

3. The Public Space Question in Conventional Post-Disaster Shelter Models

Post-disaster temporary shelter should extend beyond physical protection to support the re-establishment of education, work, and social life. Accordingly, shelter units should be considered in relation to users' diverse needs and their connections to the surrounding settlement and communal spaces (Félix et al., 2013). In conventional post-disaster shelter models, the prioritisation of rapid, cost-effective production and large-scale implementation leads to standardised solutions. However, these solutions may inadequately accommodate users' ways of life, everyday routines, and differing needs, thereby giving rise to social and spatial problems (Ayvaz & Arpacıoğlu, 2024). This underscores the importance of designing post-disaster shelter models with sufficient flexibility to accommodate different household sizes, user needs, and practices of social life.

Standardised post-disaster shelter models have limitations with respect to personalisation, privacy, and a sense of belonging. Designing shelter units that can be adapted and personalised to accommodate users' diverse needs is therefore important (Gorfe & Arın Ensarioğlu, 2025). In these models, shortcomings in safety, accessibility, lighting, social amenities, and communal spaces also constrain the quality of public space. Indeed, not every open area between shelter units constitutes a high-quality public space; these areas must be organised to support safe circulation, children's play needs, and social interaction (Okutan & Müştak Sevindik, 2026).

Public space issues in conventional post-disaster shelter models can also be understood as problems of social sustainability. Spatial arrangements that are incompatible with users' cultural characteristics and needs may lead to a lack of privacy, psychological difficulties, weakened social ties, user dissatisfaction, and inequalities. These problems are associated with insufficient consideration of user needs and the absence of participatory planning approaches (Serter & Gümüşburun Ayalp, 2026).

Post-disaster shelter models should be addressed through an approach that encompasses the settlement as a whole, extending beyond individual units. Within this framework, squares, parks, pedestrian paths, and spaces for education,

healthcare, commerce, and social amenities are important for sustaining everyday life and supporting social recovery (Tarakçı & Kavut, 2026). Attention must also be paid to the relationship between the public spaces provided and the shelter units. Spatial configurations should mediate the transition from public to private space in ways that safeguard privacy while enabling social interaction, including neighbourly relations (Félix et al., 2013).

Public space design should establish a balance between social interaction and privacy. As shared facilities such as communal kitchens and toilets may give rise to privacy concerns, communal spaces should be planned as part of an integrated approach from the outset of the design process (Gorfe & Arın Ensarioğlu, 2025). Within integrated shelter models, units can be combined in modular configurations to accommodate different family sizes. Prioritising users' diverse needs allows spaces to be clearly defined and prevents the incidental formation of spaces, enabling shelter units, public spaces, and semi-public spaces to be conceived as components of a deliberately designed system (Ayvaz & Arpacıoğlu, 2024).

In conventional models, repetitive settlement layouts, undefined open spaces, insufficient green space and amenities, problematic pedestrian–vehicle relationships, and limited user participation undermine the quality of public space. Accordingly, temporary shelter sites should be conceived as settlements that sustain everyday life, rather than as arrangements consisting solely of repeated units (Can İğci & Saka, 2022). Safe pedestrian connections, communal open spaces, children's play areas, and social amenities form integral components of this settlement framework (Kalak et al., 2024). Such an approach can broaden the focus on individual shelter units characteristic of conventional models, enabling the development of an integrated shelter model that supports post-disaster social interaction, privacy, a sense of belonging, and social recovery.

Table 3.1. The Public Space Question in Conventional Post-Disaster Shelter Models

Key Features of the Conventional Model	Rapid Response Mass Production Unit-Centred Design Limited Priority Given to User Participation Priority Given to Economic and Functional Criteria Repetitive Layout
Resulting Problems	Repetition and Monotony Undefined Open Spaces Inadequate Social Spaces and Amenities Insufficient Green Space Inadequate Privacy and Safety User Dissatisfaction
Effects on Public Space	Weakened Place Attachment and Identity Limited Social Interaction Safety and Privacy Problems Reduced Long-Term Sustainability Reduced Public Space Quality
Approaches to Addressing the Problems	Ensuring User Participation Integrated Design Approach Production of High-Quality Public Space Green and Sustainable Design Adoption of Flexible Design Approaches Compatibility with Social and Cultural Life

In recent years, research on post-disaster shelter models has moved beyond established systems to explore alternative and more advanced approaches. These studies increasingly examine modular units that can accommodate diverse user needs while prioritising communal spaces. Abanoz and Vural (2023) reviewed temporary disaster housing worldwide and developed a new model based on cross-laminated timber (CLT) panels (Abanoz & Vural, 2023). The model allows standardised shelter units to be adapted to different sizes and functions.

Through their WikiGEB model, Can İğci and Saka (2022) proposed alternative production technologies and assembly systems for post-disaster shelter. Their system incorporates units that can be disassembled, reassembled, reused, and adapted to different uses, extending beyond the individual unit to

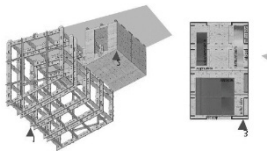
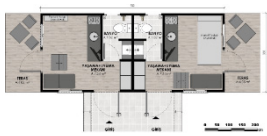
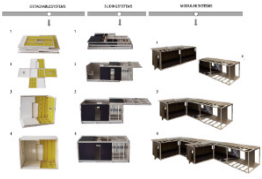
accommodate larger settlements (Can İğci & Saka, 2022). Ayvaz and Arpacıoğlu (2024) examined the spatial capacity of standardised container systems in relation to different user profiles and social relationships. Their study prioritised varying family sizes, communal and social spaces, and neighbourly relations (Ayvaz & Arpacıoğlu, 2024).

Kalak, Zenter, and Özmen (2024) developed a more flexible, modular, and portable system by modifying the fixed configurations of conventional shelter units. The proposed system is intended to facilitate communication and social interaction, safeguard privacy, provide communal spaces, and accommodate activities that sustain everyday life (Kalak et al., 2024). In response to the standardisation of conventional post-disaster shelter units and their limited adaptability to changing user needs, Mehdizade, Ayobi, and İnceoğlu (2025) developed a flexible model integrating parametric design and 3D printing. Based on a 5 × 5 m modular grid, the system enables shelter units of varying sizes to be generated in accordance with different requirements (Mehdizade et al., 2025).

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The models developed in the reviewed studies indicate a shift beyond standardised post-disaster shelter configurations towards broader spatial systems. In light of this shift, the central public space problem in post-disaster shelter models can be defined as the insufficient consideration of relationships between shelter units, social and communal spaces, privacy, and interpersonal interaction within the design process. The models developed in the reviewed studies are compared in Table 3.2 with regard to public space.

Table 3.2. Assessment of Proposed Models for Conventional Post-Disaster Shelter in Terms of Public Space

Study	Proposed Model	Model Drawing	Implications for Public Space
Abanoz and Vural (2023)	CLT modular temporary disaster housing		A system that varies according to the number of users
Can İğci and Saka (2022)	WikiGEB model		A system offering alternative settlement layouts
Ayvaz and Arpacıoğlu (2024)	Modular settlement		A system responsive to diverse user and spatial needs
Kalak, Zenter, and Özmen (2024)	Flexible modular system		A system that enables shared spaces and supports everyday life
Mehdizade, Ayobi, and İnceoğlu (2025)	Parametric and 3D-printed modular system		A system incorporating public space characteristics and capable of accommodating user needs
Güder and Baş (2026)	Life Capsule		A system that enables shared spaces and open areas

4. Public Space Production through Advanced Technologies

Recent transformations in architectural and construction production have reshaped the relationship between design and production. Digital design,

artificial intelligence, parametric modelling, robotic fabrication, and 3D printing are transforming this relationship, supporting the development of design alternatives that respond to diverse requirements.

Whereas conventional systems generally yield uniform solutions, advanced technologies enable the generation of design alternatives capable of adapting to existing or anticipated conditions. This development is particularly significant for post-disaster shelter provision. People affected by disasters have diverse needs associated with age, household size, disability, everyday practices, and cultural requirements. Production using advanced technologies can respond to these needs (Erdoğan & İmir, 2026).

Advanced technologies support public space production by enabling individually designed units to be integrated into settlement-scale configurations. Their contribution extends beyond determining unit dimensions to incorporating parameters such as intervening spaces, distances between units, intensity of use, pedestrian access, and communal areas (Mehdizade et al., 2025). Through these capabilities, advanced technologies can inform the entire process of public space production, from initial design to settlement development.

4.1. 3D Printing Technologies

3D printing is defined as an additive manufacturing process in which material is deposited in successive, controlled layers according to a digitally generated geometry to produce a physical structure. In construction-scale 3D printing, different printing systems enable a direct transition from digital design to physical production (Batikha et al., 2022; Hassan et al., 2024).

In responding to post-disaster needs, 3D printing technologies offer not only rapid production but also opportunities for formal variation. This enables production that responds to diverse user needs and adapts to different conditions, rather than relying on uniform mass-produced solutions. The implementation of 3D-printed designs requires the coordinated assessment of material suitability, production equipment, energy consumption, specialist expertise, and infrastructure at the application site (Hassan et al., 2024).

4.2. Rapid Construction and On-Site Production Opportunities

On-site production of shelter systems in post-disaster settings is particularly important from a logistical perspective, including cost-effectiveness, resource efficiency, storage, and system management. Production from models developed for 3D printing may enable different types of shelter units to be fabricated

using the same production system. However, realising this potential advantage requires the availability of the printing system, materials, energy and water supplies, specialist personnel, and quality control infrastructure within the disaster-affected area (Hassan et al., 2024).

Accordingly, assessing the advantages of 3D printing solely in terms of printing speed may be insufficient. Successful production requires an entire operational process encompassing the transportation of the system to the site, its installation and operation by technical specialists, the procurement and preparation of materials, and quality control. The practical applicability of 3D printing therefore depends on the availability of a functioning production system (Batikha et al., 2022; Hassan et al., 2024).

4.3. Material Diversity (Concrete, Local Earth, and Sustainable Composites)

Material selection is a key factor influencing the sustainability performance of 3D printing systems. The environmental impacts of cement-based printing have prompted ongoing research into lower-carbon binders, recycled constituents, and alternative materials. Research on sustainable 3D concrete printing primarily seeks to reduce its carbon footprint and raw material consumption while improving durability and thermal performance (Habibi et al., 2024).

Another study explored the use of locally available earth from disaster-affected areas in this production process, focusing on the potential for low-carbon, earth-based production without the addition of cement. This approach may reduce the need for material transportation by using suitable local resources in disaster-affected areas. However, locally available materials must be assessed for post-disaster use against criteria such as durability, moisture resistance, printability, long-term serviceability, and reliability in use (Curth et al., 2024).

4.4. Stationary and Mobile Production Units

Whether 3D printing is undertaken through stationary or mobile production units is a fundamental factor shaping post-disaster implementation and its associated organisational processes. In stationary systems, components are fabricated at a designated facility and subsequently transported to the installation sites. This arrangement facilitates control over production conditions, quality monitoring, and detailed fabrication within the facility. However, the need to transport completed components to disaster-affected areas entails logistical demands and may hinder implementation where transport infrastructure has been damaged. Mobile production units enable equipment and materials to

be transported to the affected area, allowing fabrication to take place at the installation site. Consequently, large building components can be produced and installed on site, while units with varying geometries can be fabricated directly in response to different needs (Batikha et al., 2022; Hassan et al., 2024).

The feasibility of mobile production after a disaster depends, in the first instance, on the transportability of the 3D printing system to the affected area. Its operation also requires a suitable installation site, technical personnel, adequate energy and water supplies, and quality control procedures. The selection of stationary or mobile production systems should therefore be based on an assessment of the conditions and resources available in the disaster-affected area. Rather than adopting a single production model for all disaster scenarios, a more appropriate approach is to employ stationary, mobile, or combined production systems according to regional needs (Batikha et al., 2022; Hassan et al., 2024).

4.5. Parametric Design

Parametric design enables the generation of design alternatives through relationships between defined parameters and constraints, allowing these alternatives to be adjusted in response to changing conditions (Badwi et al., 2022; Dino, 2012). Given its potential to facilitate the understanding and design of complex systems, parametric design has gained prominence in recent years in urban design as well as at the building scale (Kelly, 2014; Monedero, 2000). By establishing connections between design and production processes, it can support building optimisation, the integrated evaluation of design, and accelerated production (Mehdizade, 2024).

The incorporation of diverse inputs, including sustainability, environmental compatibility, user needs, and urban identity, strengthens the potential of parametric design to generate flexible and adaptable spatial solutions (Gaha, 2023; Schumacher, 2016). Studies addressing public space demonstrate that parametric and related data-driven approaches can be applied across different scales and components. Examples include considering environmental comfort alongside human experience and social interaction in the design of public space shading structures (Ameijde et al., 2022), accommodating changing needs in post-disaster modular settlements (Mehdizade & Ayoobi, 2026), configuring open spaces in response to varying uses and environmental conditions (Liu, 2025), and evaluating parks according to patterns of use (Fan et al., 2024). These applications indicate a range of opportunities through which such approaches may contribute to social sustainability.

4.6. Digitalisation of Community-Based Participatory Design Processes

As technological advances transform the design process, incorporating community expectations and needs remains essential. Data obtained from surveys, observation, and behavioural mapping have the potential to inform the assessment of human–space relationships in parametric design (Ameijde et al., 2022; Chi et al., 2021; Fan et al., 2024). However, users' roles should not be confined to providing data. Integrating local and experiential knowledge into decision-making is important for inclusiveness and a sense of belonging (United Nations) (Saad-Sulonen & Horelli, 2010). In this regard, the development of technologies that translate human experience into design data is making users' roles within the design process increasingly prominent.

Technologies such as Virtual Reality (VR), Building Information Modelling (BIM), Geographic Information Systems (GIS), and Digital Twins (DT) offer new opportunities to visualise design alternatives and involve diverse stakeholders in decision-making processes (Berigüete et al., 2024). Gathering ideas through digital platforms (Chen, 2025), incorporating community input into parametric models (Chhaya, 2025), and map-based participation (Özden et al., 2025) exemplify the expanding forms of participation enabled by digital tools. Their inclusiveness depends not only on access to these tools but also on the extent to which feedback informs decisions. The representation of vulnerable groups and the development of design awareness are therefore important considerations (Özden et al., 2025; Saad-Sulonen & Horelli, 2010). Visualising alternative scenarios may facilitate evaluation among stakeholders (Çalışkan et al., 2021). Advanced technologies thus transform both the design process and the designer's role while also broadening the range of actors involved.

The opportunities offered by advanced technologies are accompanied by limitations that depend on conditions of access and implementation. Inequalities in digital access may restrict participation (Faldi et al., 2022; Luo et al., 2025). Citizens' influence within automated decision-making systems, data privacy, ethical considerations, and requirements for interdisciplinary expertise must be taken into account (He & Chen, 2024). Citizens' influence within automated decision-making systems, data privacy, ethical considerations, and requirements for interdisciplinary expertise must be taken into account (Harding & Shepherd, 2017). Accordingly, the purposes and conditions of using these technologies should be defined with regard to both their opportunities and their limitations concerning access, participation, and the design process.

4.7. Integrated Spatial Organisation of Public Functions

Advanced technologies influence not only design and decision-making processes but also the ways in which public space is produced and experienced (Lundberg, 2025; Pasalar & Hallowell, 2022). Given that space is shaped through interactions among people, technologies, and social practices (Forlano, 2013), and that public space encompasses social relationships beyond its physical infrastructure (Duivenvoorden & Hartmann, 2025; Melik, 2008), the use of technological tools should be considered in conjunction with spatial configuration, management, and user behaviour (Duivenvoorden & Hartmann, 2025; Schoulund et al., 2021; Yang et al., 2019; Zhang et al., 2026). The contribution of technology thus becomes evident not only in the generation of new design alternatives but also in their evaluation in relation to use and social relationships within public space.

The capacity of parametric design to interrelate different scales and variables contributes to the development of solutions that respond to changing environmental and social conditions in cities (Çalışkan et al., 2021). It can be employed alongside artificial intelligence, digital twins, modular systems, and smart materials throughout design, implementation, and monitoring processes (Table 4.7.1). Translating these contributions into public benefit depends on due consideration of accessibility, cultural diversity, and ethical conditions (Wagner, 2026).

Table 4.7.1. Applications of Advanced Technologies in Public Space

Technology / Tool	Function in Public Space	Relevant Sources
Artificial intelligence and multi-sensor data	Adaptive design and optimisation based on real-time environmental and use data	He and Chen (2024), Liu (2025)
Digital twins	Monitoring, simulation, and evaluation of space in response to feedback	Li (2025), (Luo et al., 2025)
VR, BIM, GIS, and digital participation tools	Visualising design alternatives, spatialising user data, and supporting stakeholder participation	Berigüete et al. (2024), Badwi et al. (2022), Özden et al. (2025)
Generative algorithms	Software generates spatial combinations suited to the local topography, demographic structure, and programme.	(Afonso & Lu, 2021)
Parametric modelling, modular design, and adaptive materials	Developing spatial components adaptable to changing environmental conditions, user intensity, and local needs	Gasparini (2022), Mehdizade and Ayoobi (2026), Shi et al. (2025)

4.8. Advanced Technologies in Post-Disaster Public Space Design

Researchers increasingly use advanced technologies in post-disaster spatial design (Rawat et al., 2024). Data-driven tools support the integration of immediate needs with considerations of long-term urban liveability (Alawi & Chu, 2024; Jayakody et al., 2018; Rawat et al., 2024). Research on temporary settlements similarly examines the limitations of standardised, inflexible solutions (Felix et al., 2015) and increasingly explores design approaches that accommodate extended periods of use (Mehdizade & Ayoobi, 2026; Yürekli & Gün, 2026). Computational design may facilitate the rapid generation of alternative settlement configurations through the integrated assessment of density, emergency requirements, and accessibility. Its contribution extends beyond expediting decisions to enabling a critical examination, at the design stage, of how settlement decisions made during the emergency phase may subsequently shape everyday life.

Various technological tools are also employed throughout production and use. Off-site prefabrication may reduce preparation time and on-site labour requirements (Shahzad et al., 2022). Parametric tools and augmented reality

may facilitate the reassembly of dismountable components (Vahdati et al., 2022), while BIM may support the monitoring of components throughout their life cycle (Montalbano & Santi, 2023). Façade simulations and insulation strategies can be employed to improve seasonal thermal comfort within shelter units (Rapone et al., 2024). In addition, 3D printing facilitates design testing by translating digital designs into physical models and components (Mehdizade, 2024).

Beyond production and use, advanced technologies have the potential to contribute to the preservation of post-disaster collective memory. Virtual reality, photogrammetry, and 3D laser scanning may support the continuity of collective memory and a sense of place through the documentation and re-experiencing of damaged spaces (Dolcetti et al., 2025; Franco et al., 2025). This potential is particularly relevant to incorporating spatial histories and social experiences into future design decisions.

Community participation in design decision-making is important for ensuring that these technological possibilities respond to local needs. While centrally planned open spaces may be insufficient to support social integration, community-led initiatives can develop gathering spaces that respond to local requirements (Brand & Nicholson, 2016; Ghezelloo et al., 2023). Computational planning that considers both rapid intervention and long-term use should therefore be undertaken in conjunction with community participation (Charlesworth & Fien, 2022; Chioni et al., 2021; Marek et al., 2017; Varzeshi et al., 2026).

At the scale of public space, these technologies can inform the assessment of parks, squares, open space networks, evacuation routes, and assembly areas (Varzeshi et al., 2026). Although the inadequacy of public space in temporary settlements is frequently emphasised in the literature, studies that translate this need directly into design remain limited. Mehdizade and Ayoobi (2026), for example, propose modular alternatives that connect housing units with services and communal spaces through a parametric, modular system. Yürekli and Gün (2026), in turn, propose open and semi-open spatial configurations that accommodate user modifications and neighbourly interaction. These examples demonstrate the possibility of incorporating social needs into computational design.

5. Comparative Analysis of Conventional Methods and Advanced Technologies

Differences between conventional methods and advanced technologies in post-disaster public space production should be evaluated not only in terms of construction processes and production capacities but also in relation to the

spatial connections established between shelter units and the settlement as a whole. The studies reviewed in the preceding sections indicate that standardised shelter models, while offering advantages in rapid intervention and replicability, may have limitations in accommodating diverse user needs, ensuring the quality of communal spaces, and supporting social relationships at the settlement scale (Félix et al., 2013; Johnson, 2007; Wagemann, 2017). In contrast, parametric design, digital fabrication, and participatory technologies enable multiple spatial variables to be considered jointly and alternative settlement configurations to be developed (Badwi et al., 2022; Berigüete et al., 2024; Mehdizade & Ayoobi, 2026). Nevertheless, the contribution of these capabilities to social sustainability depends less on the availability of technological capacity than on how it is employed in design and implementation.

Within this framework, the comparative analysis is organised around six criteria: production processes, user participation, adaptability, social inclusiveness, spatial diversity, and long-term continuity. These criteria provide a basis for evaluating the relationship between the technical characteristics of production methods and the social functions of public space.

5.1. Production Processes, User Participation, and Adaptability

Although standardised production in conventional post-disaster shelter models facilitates the rapid establishment of settlements, it may not adequately accommodate variations in household composition, patterns of use, and requirements for communal spaces. Modifications subsequently made by residents to temporary housing highlight the need for adaptability. However, when such modifications are not anticipated during the design process, they may compromise safety and spatial quality (Félix et al., 2013; Wagemann, 2017; Duru & Sarıkaya, 2025).

Advanced technologies enable more flexible relationships between design and production processes. Parametric design supports the development and comparison of alternatives through defined variables and constraints (Badwi et al., 2022; Dino, 2012), while modular systems may facilitate the development of units of varying sizes and alternative settlement configurations (Mehdizade & Ayoobi, 2026). Similarly, 3D printing technologies offer opportunities to translate varied designs into physical production. Nevertheless, production time extends beyond the printing operation itself, necessitating consideration of equipment, materials, energy, expertise, and infrastructure requirements (Batikha et al., 2022; Hassan et al., 2024). The production advantages of advanced technologies

therefore cannot be assessed independently of the existing conditions in the disaster-affected area.

The social value of these capabilities depends on incorporating local knowledge and user experience into decision-making (Saad-Sulonen & Horelli, 2010; Özden et al., 2025). Accordingly, digital tools contribute more effectively when they facilitate participation and the collective discussion of design alternatives.

5.2. Social Inclusiveness and Spatial Diversity

Social sustainability in post-disaster temporary settlements requires different user groups to have safe and equitable access to public spaces and to be able to use them in accordance with their everyday lives. Although standardised settlement layouts may provide the same physical solution for different users, they may not yield equitable outcomes in terms of access to and use of public space. Undefined spaces between units do not always provide adequate conditions for safe circulation, children's play, everyday encounters, and community activities. For temporary settlements to function as living environments, accessible and legible connections must be established between shelter areas and communal spaces (Valle & Romania, 2019; Zarkhah et al., 2025).

Advanced technologies offer opportunities to assess diverse age groups, mobility conditions, intensities of use, and public functions across multiple settlement alternatives. Map-based participation tools and visualisations may also facilitate discussion of these alternatives with users (Berigüete et al., 2024; Özden et al., 2025). Nevertheless, inequalities in access to digital participation channels may result in the underrepresentation of certain groups in decision-making (Faldi et al., 2022; Luo et al., 2025). Inclusiveness therefore depends not only on the spatial diversity generated but also on whose input informs the alternatives and how they are determined.

5.3. Assessment against Sustainability Criteria

The sustainability of post-disaster temporary settlements should be assessed in terms of their duration of use, maintenance, compatibility with local conditions, and social continuity, alongside initial cost and speed of delivery. Designing temporary structures for disassembly and adaptation to other uses has the potential to reduce resource consumption and post-use waste. However, overlooking the possibility that these settlements may become permanent can adversely affect long-term quality of life (Ruggiero, 2018; Shahkar et al., 2021; Akdede et al., 2026).

Parametric design and digital fabrication may support the assessment of material use and alternative settlement scenarios during the design stage. Nevertheless, computational requirements, expertise, equipment, and implementation conditions also determine the applicability of these methods; technological capabilities alone do not constitute evidence of social or environmental sustainability (Harding & Shepherd, 2017; He & Chen, 2024).

Accordingly, the assessment of conventional methods and advanced technologies should be guided by the spatial and social needs each can address under different conditions, rather than by an assumption of the absolute superiority of one method over another. Table 5.3.1 compares these approaches in relation to the social sustainability of public space. The comparison distinguishes the opportunities offered by advanced technologies from the conditions that must be considered when applying them in practice.

Table 5.3.1. Comparison of Approaches to Post-Disaster Public Space Production in Terms of Social Sustainability

Assessment Criterion	Key Limitations of Conventional Approaches	Opportunities Offered by Advanced Technologies	Conditions for Assessment
Production and implementation	Standardisation and limited adaptation to local conditions	Alternative production methods and settlement layouts	Implementation capacity, resources, and compatibility with local needs
User participation	Limited user representation in decision-making	Digital participation, visualisation, and collaborative evaluation	Representation of groups with limited digital access and their influence on decisions
Access and safety	Secondary attention to open spaces and pedestrian connections	Testing circulation, evacuation, and assembly scenarios	On-site verification of accessibility
Social interaction and privacy	Unclear thresholds between shared and private spaces	Comparing alternatives for shared spaces and spatial transitions	Observing actual use and social relationships
Inclusiveness	Insufficient consideration of diverse needs	Generating and discussing alternatives according to user profiles	Equitable access, safety, and conditions of actual use
Adaptability	Failure to anticipate modifications during occupation	Adaptation to changing household and shared space needs	Assessment of safety, cost, and implementation feasibility
Long-term continuity	Inadequate planning of occupation duration and transformation	Early consideration of reuse, monitoring, and transformation	Attention to local maintenance, management, and connections with the city
Public space quality	Undefined open spaces and limited functional diversity	Alternatives for shared spaces, circulation, and spatial transitions	Support for social interaction, privacy, and everyday life

The comparative assessment indicates that the principal contribution of advanced technologies lies less in directly achieving social sustainability than in facilitating the integrated consideration of spatial variables associated with this objective during the design process. Accordingly, the success of these methods should be evaluated not only in terms of their technological characteristics but also in relation to how the resulting solutions function under actual conditions of use.

6. Discussion

The literature and comparative assessment indicate that the central problem in post-disaster public space production is the insufficient integration of shelter units with social life. The extended periods of use of temporary settlements require communal spaces that support everyday life and social relationships to be considered from the outset of the design process (Félix et al., 2013; Valle & Romania, 2019; Zarkhah et al., 2025). Accordingly, the success of interventions should be assessed in terms of both physical adequacy and the re-establishment of everyday life.

Standardisation and the inadequacy of communal spaces are associated not only with production techniques but also with site selection, resource allocation, and decision-making processes (Johnson, 2007; Montalbano & Santi, 2023). It is therefore inappropriate to regard conventional methods as socially inadequate and advanced technologies as inherently inclusive. The comparison in Table 5.3.1 demonstrates the need to assess both approaches in terms of accessibility, privacy, participation, and long-term use. The principal contribution of advanced technologies lies in enabling these variables to be evaluated jointly across different scenarios. However, proposing spaces that support social interaction through parametric design and digital tools does not guarantee that social relationships will be strengthened in practice. The spatial opportunities afforded by design should therefore be tested through user experiences and on-site observations.

User participation is also a determining factor in the contribution of technological tools to social sustainability. Collecting views through digital methods does not necessarily mean that users influence design decisions. The quality of participation depends on the extent to which local knowledge and experience inform design priorities. Given inequalities in digital access, these processes should be supplemented by face-to-face interviews, observation, and collaborative evaluation (Faldi et al., 2022; Luo et al., 2025). Within this

framework, users should be recognised not only as individuals who evaluate predefined alternatives but also as actors who determine which needs and relationships are considered in design.

A further dimension of social sustainability concerns the transfer of social relationships established in temporary settlements to permanent settlements. Continuity between the historic, temporary, and future city (Chioni et al., 2021) requires public spaces to be designed with regard to long-term use and transformation, alongside immediate needs. Although technological tools can support the development of alternative scenarios in this process, social continuity is associated with local governance capacity, maintenance provision, and users' appropriation of space.

These considerations indicate that a direct relationship cannot be assumed between technological innovation and social recovery. For architecture and urban design, the central concern is how technological capabilities are employed to advance social sustainability objectives. Nevertheless, the literature-based nature of this study limits the direct comparison of the social performance of different methods. Future research examining accessibility, communal space use, privacy, participation, and place attachment in actual settlements would contribute to assessing the social impacts of the proposed design approaches.

7. Conclusion

This study examined post-disaster public space production within the context of social sustainability, comparing the opportunities offered by conventional methods and advanced technologies. The literature review indicates that temporary settlements should be planned to integrate shelter units with communal spaces that sustain everyday life and social relationships. Within this framework, public space should be understood as more than the open areas remaining between units; it constitutes a settlement component that supports social interaction, solidarity, belonging, and collective memory. The success of post-disaster interventions should therefore be assessed not only in terms of production speed and physical adequacy but also through their contribution to re-establishing these relationships.

The comparative assessment indicates that, although conventional methods offer advantages in rapid intervention and standardised production, they may have limitations in accommodating diverse user needs and ensuring the quality of communal spaces. Parametric design, 3D printing, and digital participation tools offer opportunities to develop alternative spatial configurations, assess

shelter units and public spaces together, and incorporate user needs into the design process. Nevertheless, technological diversity and production flexibility are not direct indicators of social sustainability. Translating these capabilities into social benefit depends on the suitability of spatial solutions for local conditions, users' participation in decision-making, and the performance of settlements under actual conditions of use.

A human-centred, integrated approach should therefore be adopted in post-disaster architectural interventions. Such an approach requires housing and public space to be designed together, users to be actively involved in decision-making, and accessibility, privacy, and cultural compatibility to be addressed. The duration of use of temporary settlements, their maintenance conditions, and their transformation into permanent environments should also be considered from the outset. Technological tools should support these objectives, with their selection guided by local resources, implementation capacity, and community priorities.

By examining different production approaches through social sustainability criteria, this study provides a comparative assessment framework for post-disaster public space design. However, its literature-based analysis does not directly measure the social impacts of the proposed technological solutions in practice. Future research should test this framework in actual post-disaster settlements through user experiences, spatial use patterns, and long-term transformation processes. Ultimately, the success of post-disaster architectural production should be assessed not merely by how rapidly shelter units are produced or which technologies are employed, but by the extent to which the resulting living environments enable social relationships to be re-established and sustained.

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CHAPTER II

REFRAMING POST DISASTER RECONSTRUCTION THROUGH GENIUS LOCI AND SPATIAL MEMORY

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1. Introduction

Space is not just a place with walls, it is a space that is filled with human experience, time and culture. The concept of Genius Loci (the spirit of place) was developed by Christian Norberg-Schulz (1980) and is constantly reimagined in seismic geographies through repeated patterns of destruction and trauma. The memory of the earthquake has two opposite effects on spatial perception: on the one hand, the sense of security diminishes space to a mere shell and absolutizes the need for technical resilience; on the other hand, the symbolic traces of destruction become an integral part of social identity. These vibrations, which interfere with the spatial rhythm of the day, take the reconstruction process beyond the engineering issues and into the realm of spatial memory repair. The conceptual framework presented in this section is supported by the systematic content analysis of the 136-article core corpus provided later in the study. The core issue of post-disaster recovery and sheltering is the extreme loss of the "sense of place. Place-placelessness, as described by Edward Relph (1976), is why shelter solutions that are quickly produced according to international humanitarian standards have a negative impact on belonging. A uniform modular approach that ignores local climate, vernacular building arts and spatial memory can offer immediate physical security, but also a profound sense of alienation and placelessness. This is reflected in the results of the content analysis: 40.4% (n=55) of the 136 articles scanned directly address the issue of

temporary/permanent sheltering and resettlement processes (e.g., Aytar Sever & Tarakçı, 2025), meaning that the focus of the literature is on the problem of placelessness. Yi-Fu Tuan's (1974) notion of "topophilia" on the other hand, provides an explanation for the emotional ties people have to particular places, despite the seismic risks and experiences of loss. This paradox of risk-belonging is also reflected strongly in the corpus. Risk perception and vulnerability studies (17.6% n=24) of the corpus (e.g., van der Kloet et al., 2023, 2024) empirically demonstrate, in various geographies, how topophilia can challenge rational security calculations. A broken retaining wall or a monument that has become a debris field can eventually become a place for social memory to be read. Altman and Low's (1992) place attachment model places the psychological recovery of disaster victims in a socio-spatial context of this reproduction process. Empirical evidence from seismic regions like the 1999 Marmara, 2011 Van and 2023 Kahramanmaraş earthquakes, Italy, Japan and New Zealand shows that policies that follow a tabula rasa approach in the transition from temporary to permanent housing cause place loss in the long term. This standardized production takes away the disaster victims' ability to create space, and makes them passive consumers. The 21 studies (15.4%) in the corpus that place the theme of place attachment at their center strongly support this premise. In the context of temporary/permanent settlements, Fakıoğlu and Mızrak (2026) use place attachment as an interpretive diagnostic tool in Hatay and Antakya, respectively, while Qian et al. (2025) explore socio-spatial reconnections after disasters from the perspective of a "sense of place" approach in China and Chile, respectively. New architectural and interior architectural solutions are being developed that provide a sense of belonging without forgetting the seismic memory. These strategies are based on adaptive reuse, involving disaster victims in participatory design, using local materials for vernacular syntheses, and on scar architecture practices that retain traces of destruction. In addition, digital memory tools and augmented reality (AR) technologies are contemporary tools for documenting lost or transformed spaces in the virtual dimension, which is an important way to preserve seismic memory. The content analysis that follows, however, shows that although these approaches are conceptually well developed, they are not well represented in the literature in terms of empirical studies. The post-disaster reconstruction literature has been dominated by the paradigms of structural engineering, seismic risk calculations, and macro-urban planning, historically. The purpose of this book chapter is to address this disciplinary gap by proposing a bibliometric mapping that connects the phenomenon of seismic resilience with

phenomenological concepts like Genius Loci, topophilia and spatial memory. The main goal is to shift the focus of disaster architecture from being a structural issue to being a space, privacy, belonging and spirit of place issue. The analysis of 1219 documents retrieved from the Scopus database, using the PRISMA-ScR protocol, the Bibliometrix and VOSviewer tools, creates a methodological link between the qualitative belonging theories and the quantitative data mining. The study asks the question of whether there has been a paradigm shift from structural-technical focuses to socio-cultural approaches and aims to answer the following three main research questions:

1. RQ1. What are the themes and geographies of the concepts of Genius Loci, place attachment and spatial memory in the seismic resilience literature?
2. RQ2. How much and how deep are the restorative approaches that seek to replicate Genius Loci (participatory design, scar architecture, adaptive reuse, etc.) discussed in the literature?
3. RQ3. What are the structural gaps in the literature in terms of disciplinary, methodological, geographical, digital and temporal aspects and what are the research priorities that these gaps suggest for the discipline of interior architecture?

In line with these objectives, the remainder of the chapter is structured as follows: The second section explains the PRISMA-ScR protocol and how the corpus was obtained. The third section shows the bibliometric mapping results based on the macro data set of 1,219 records. The fourth section focuses on the systematic thematic and geographic content analysis of the 136-core article corpus. The results of the research gaps are discussed in the fifth section, and the sixth section concludes the study by providing implications for the architecture and interior architecture disciplines.

2. Method: PRISMA-ScR Protocol and Data Extraction Strategy

The study investigates the development of the concepts of seismic memory and Genius Loci in the literature through the scoping review methodology. PRISMA-ScR guidelines were followed to ensure the transparency of the research process (Tricco et al., 2018). The research is divided into two levels: a macro-level bibliometric mapping (n=1,219, Section 3) and a thematic content analysis of the core corpus on the theme of post-disaster spatial belonging (n=136, Section 4). The search was carried out on the Scopus database with the

optimized string “place identity” and “seismic disaster” and “space/shelter”. A total of 1,219 documents were found in the search, which was limited to English and Turkish academic texts published between 1982 and 2026. To avoid screening blindness, the Rayyan reference management system was used (Ouzzani et al., 2016). 18 duplicate records were first eliminated and the remaining 1201 articles were screened with the Population, Concept, and Context (PCC) framework. The concepts of Genius loci, place attachment and interior architecture were coded as inclusion criteria, whereas non-seismic or purely technical terms like structural analysis, flood and tsunami were coded as exclusion criteria. After the screening, 1,065 records were excluded: 1,010 for “wrong context” (non-earthquake disasters) and 55 for “wrong concept” (purely structural/engineering analyses). The remaining 136 articles met the eligibility criteria and formed the final core corpus (Figure 1).

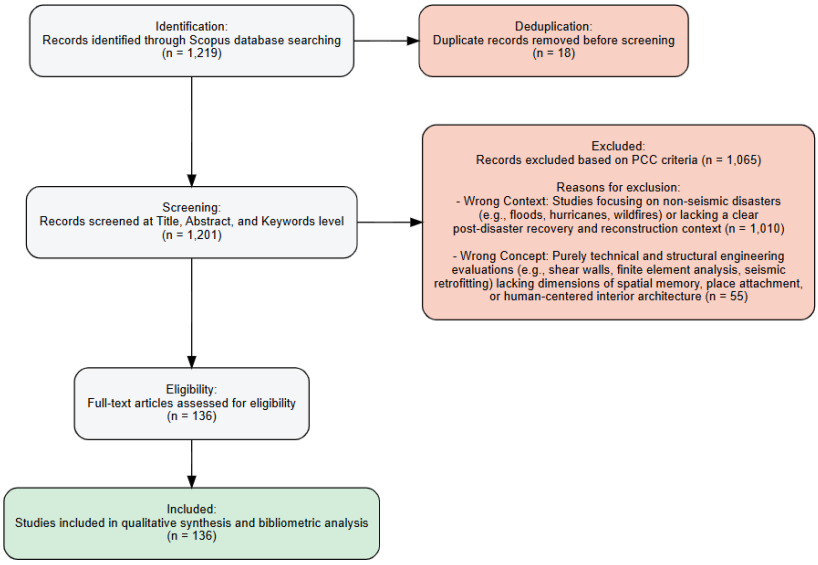


Figure 1. PRISMA-ScR record selection flow diagram

In the two-tiered structure, the macro analysis (n=1,219) was mapped based on using Bibliometrix (Aria & Cuccurullo, 2017; Aria & Cuccurullo, 2026; Aria et al., 2026) and VOSviewer (van Eck and Waltman, 2010). The core corpus (n=136) analysis involved coding articles on two axes: (i) Geographic context: the country/disaster name mentioned in the title; (ii) Disaster type: the type of disaster mentioned in the title. (ii) Thematic category: a multi-label coding (16 categories) based on expressions in the title. Since an article can be

included in more than one theme, the total frequency exceeds 136. The schema was created with a mixed approach encompassing five restorative strategies (participatory design, scar architecture, etc.) and 11 inductively emerging additional themes (place attachment, shelter, risk perception, etc.). Geographic and thematic codings were done from the bibliographic record (title), as a major methodological constraint. This means that there is a risk of under-representation geographically; in fact, 33.8% of the corpus was placed in the general category because it did not have a case name in its title. The results are thus only a minimum estimate of the geographic concentration.

3. Findings

The evolution of literature in the field of post disaster reconstruction, spatial memory and Genius Loci concepts is explored in this section using a macro dataset of 1219 articles from Scopus. The bibliometric mapping of the post disaster shelter literature (2000-2025) (Tarakçı, 2025b) bis a breakthrough in scientific production after 2017. The field is dominated by engineering and environmental perspectives and architecture and interior architecture perspectives are limited. The results of Bibliometrix and VOSviewer show the stages of development, thematic clusters and interdisciplinary trends of the research area. This macro mapping offers the background context to appreciate the position and relative weight of the 136 article core corpus in Section 4. The general profile of the macro data is summarized in Table 1, using the Main Information output of Bibliometrix. The 1219 documents collected from 718 sources range from 1982 to 2026 and exhibit an impressive annual increase of 12.5 percent. The average number of citations per document is 25.85, which is high, reflecting the field's maturing academic impact as well as its volume. The relatively low average document age of 4.57 years confirms the corpus consists mostly of current literature. The most common document type is articles (72.2 percent), followed by books, book chapters and conference papers.

Table 1. General bibliometric profile of the macro dataset

Indicator	**Value**
Time span	1982-2026
Sources	718
Documents	1219
Annual growth rate	12.5%
Average document age	4.57 years
Average citations per document	25.85
Total references	227065
Keywords Plus	3200
Author keywords	3131
International co-authorships	25.76%
Article	880
Book	202
Book chapter	104
Conference paper	33

The general literature review (1982-2026) shows an annual increase of 12.5 percent in post disaster spatial belonging and place attachment studies. Until 2010, the scientific production was limited and horizontal. It has been in an exponential growth phase particularly since 2011, after the global disasters such as the Great East Japan Earthquake. This momentum accelerated after 2020 and by 2025 had increased to around 180 articles per year. This annual scientific output is shown in figure 2.

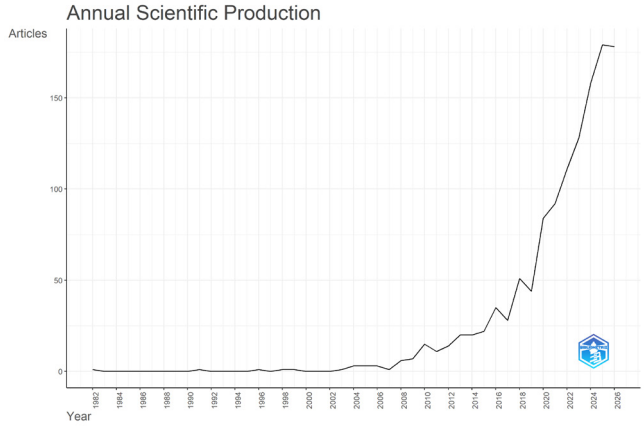


Figure 2. Annual scientific production, 1982-2026 (n=1,219)

The average number of citations per year is shown in Figure 3, and the typical citation lag of the literature is evident. The average citation value was briefly boosted to 38 by a handful of early studies in 1996 and 2008. The average citation value, however, dropped back to 3 to 8 after 2010 when the volume of publications began to grow at a fast rate. This pattern suggests that the potential for citations in the current production is not fully realized. Sensitivity is therefore important for impact assessments to record age.

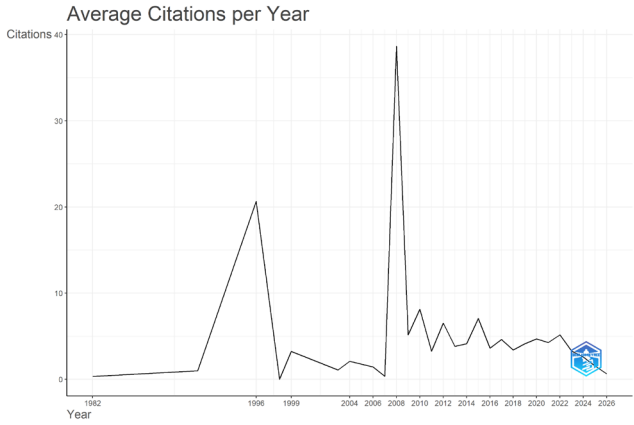


Figure 3. Average citations per year, 1982-2026

The field's developmental stages are explained by the cumulative growth curve in figure 4. Cumulative production was virtually unchanged prior to 2020 and then jumped into a logistic growth phase following 2020. It is expected to reach 90 percent in the mid 2030s. This is an indication that the field is not mature, but rather a young field of research that is still in exponential growth.

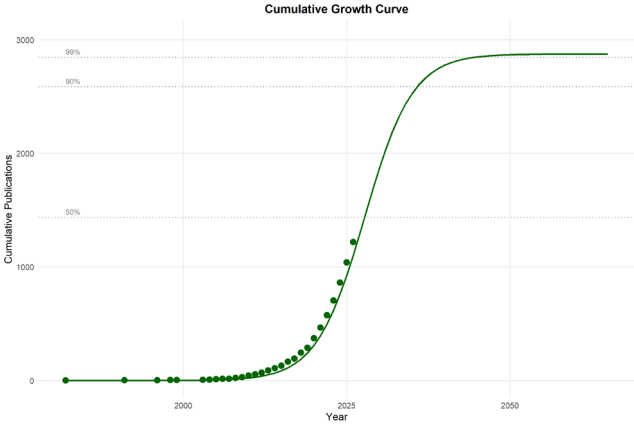


Figure 4. Cumulative growth curve, 1982-2026

The life cycle analysis based on the Gompertz growth model of Bibliometrix predicts the annual publication volume will peak around 2027.7 with a high fit value of R^2=0.991. Figure 5 shows this projection. This finding highlights the timeliness of the study. It demonstrates that this book chapter is at a critical juncture where the research agenda is still in the early stages of development on the upswing of the maturation curve.

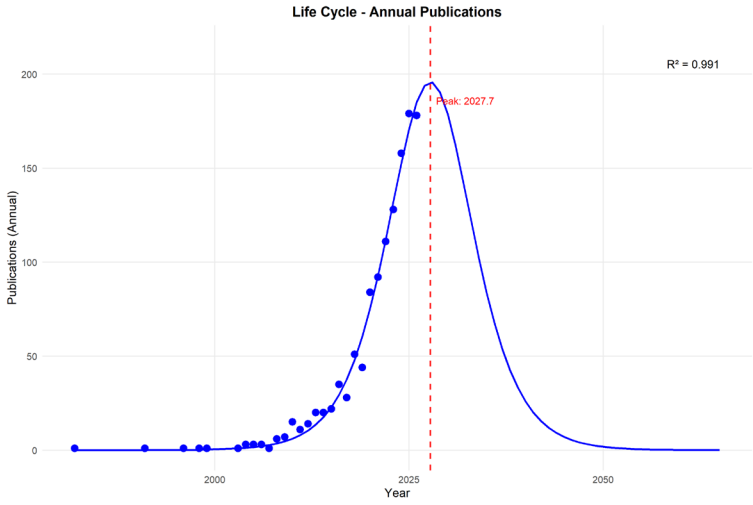


Figure 5. Life cycle model - annual publications and projected peak (2027.7)

The most published and cited sources are International Journal of Disaster Risk Reduction (94 documents and 33 citations) and Sustainability (33 documents and 33 citations). These sources are described in detail in Figure 6. Land and Progress in Disaster Science are following with 15 documents each. The Journal of Housing and the Built Environment and International Journal of Disaster Resilience in the Built Environment and Natural Hazards also have high rankings. The distribution indicates that the discussion of spirit of place and spatial memory has transcended architectural theory and become part of large scale disaster management and sustainability policies. The dominance of the International Journal of Disaster Risk Reduction is also confirmed in the 136 article core corpus presented in the next section. It is also the most read publication organ there.

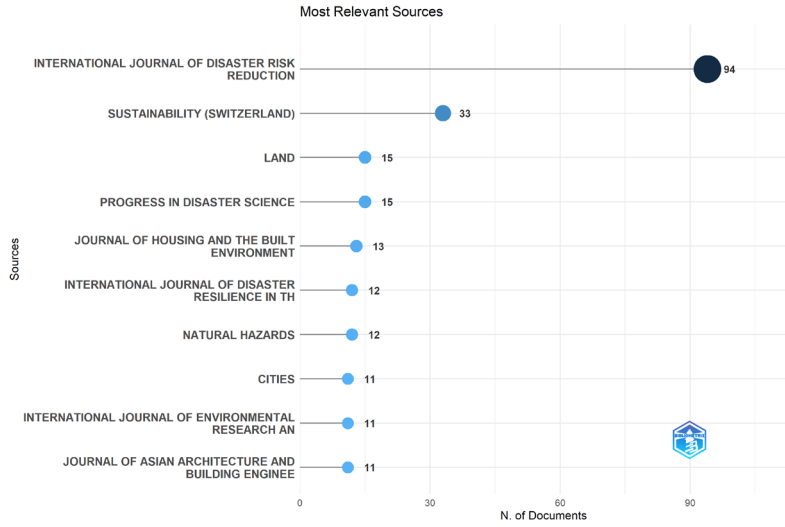


Figure 6. Most relevant sources (n=1,219)

Callon's Strategic Diagram with Centrality and Density metrics was used to analyze the conceptual structure of the research area in four main quadrants. Table 2 shows the numerical values of these four quadrants according to the cluster metrics of Bibliometrix.

Table 2. Strategic diagram cluster metrics

Cluster	Centrality	Density	Frequency	Position
"China", "Place Attachment", "Neighborhood"	6.42	18.04	1483	Motor Themes
"Disaster Management", "Climate Change", "United States"	7.72	14.95	1331	Basic Themes
"Human", "Disaster", "Humans"	5.11	31.69	1037	Niche Themes
"Disasters", "Housing", "Disaster Recovery"	5.04	14.96	751	Emerging or Declining Themes

Motor Themes are high centrality and high density. The main driving force of the literature is "place attachment", "neighborhood" and "China" clusters.

China has offered enormous empirical data to the literature particularly since the Wenchuan earthquake in 2008. Place attachment is the most developed and well-formulated theory at the urban level. Basic Themes have high centrality and low density. The concepts with the highest centrality values, such as "disaster management", "climate change" and "United States", are the basis of the literature. They are still relatively weak internally because of their wide and interdisciplinary scope. Niche Themes have low centrality and high density. The most specialized and isolated subclusters are human and individual focused approaches, such as "human", "disaster", "humans". Emerging or Declining Themes are low centrality and low density. The concepts "disasters", "housing" and "disaster recovery" are found here with the lowest metrics. This means that place attachment has not yet been developed into a central and integrated concept in the literature as has been done with post disaster housing recovery. This validates the conceptual gap which is the major problem of the study. This strategic diagram is shown in figure 7.

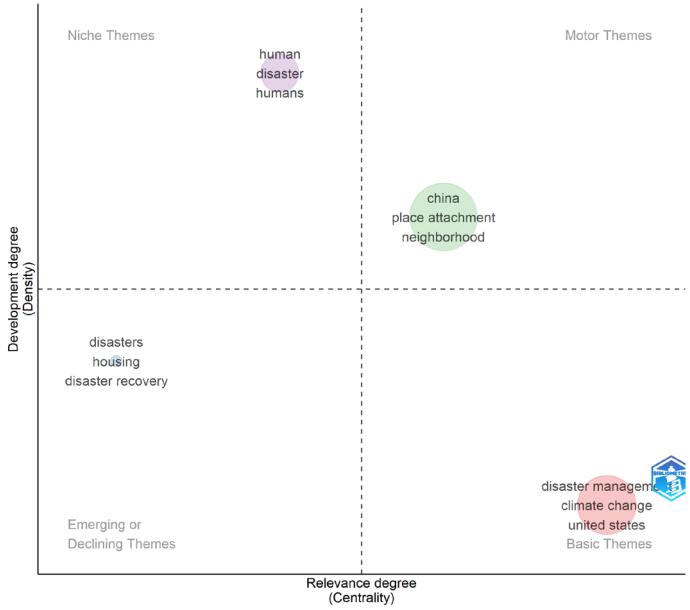


Figure 7. Strategic diagram / thematic map (four clusters)

The Multiple Correspondence Analysis (MCA) conceptual structure map shows a dominant axis that accounts for 77.29 percent of the total variance. Figure 8 shows this map. At one end of this axis, space is centered on and qualitative concepts such as place attachment, sustainability and urban planning. The other

end contains demographic and medical terminology like adult, male, female and human. This polarization shows that the field draws on two epistemological traditions. One is space and design oriented socio spatial research. The other is population and health related epidemiological research. The two traditions have not yet been integrated well in the literature.

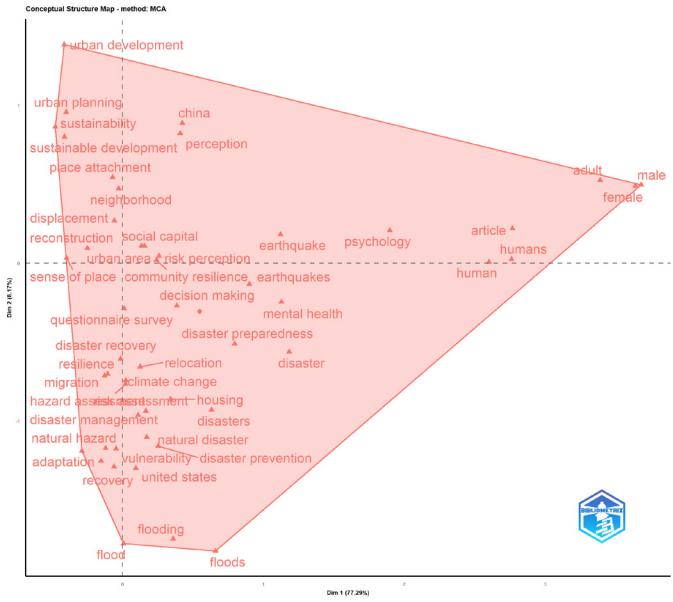


Figure 8. Conceptual structure map - MCA method

The treemap in Figure 9 and the word cloud in Figure 10 complement the strategic diagram. The seven most frequently repeated keywords of the corpus are: “disaster management”, “disasters”, “climate change”, “place attachment”, “china”, “human” and “disaster”. This frequency ranking suggests that the place attachment concept is an important but not predominant concept in the conceptual agenda of the field. On the other hand, words such as interior architecture, genius loci or spatial memory do not appear in this high level frequency list.

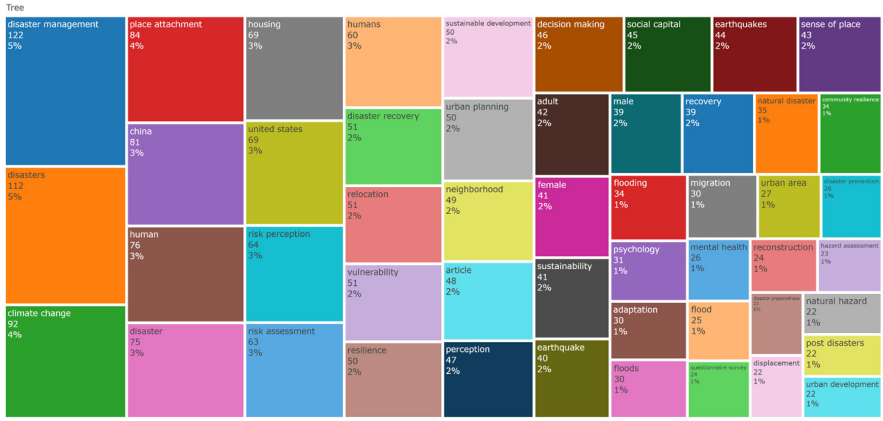


Figure 9. Keyword frequency treemap



Figure 10. Keyword word cloud

The literature is divided into four main clusters in the co occurrence networks generated by the VOSviewer and Bibliometrix algorithms. The first is the basic themes cluster based on disaster management, climate change and risk. The second is the motor themes cluster related to place attachment, neighborhood and China. The third is the green cluster involving urban planning, sustainable development and community resilience. The fourth is the niche themes cluster on human and demography. This network is shown in Figure 11, both with a general cluster view and detailed node labels.

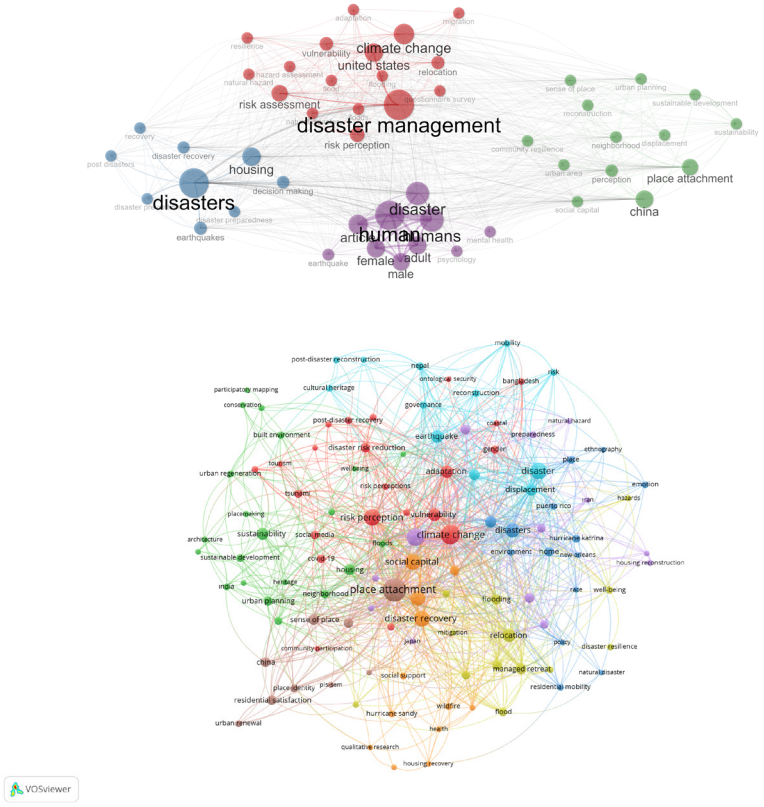


Figure 11. Author keywords co-occurrence network:
(a) general cluster view, (b) detailed labeled network

The hierarchical clustering dendrogram in Figure 12 shows the infrastructure of these four clusters. At the top, there are two large branches that branch off. One branch contains the demographic and methodological words such as adult, female, male, article, human and psychology. The other branch unites all disaster, space and policy terms. In the second branch, the place attachment themed subcluster is clearly distinguished from the disaster management themed subcluster. This separation is consistent with the Motor Theme and Basic Theme distinction found in the Strategic Diagram at the hierarchical clustering level.

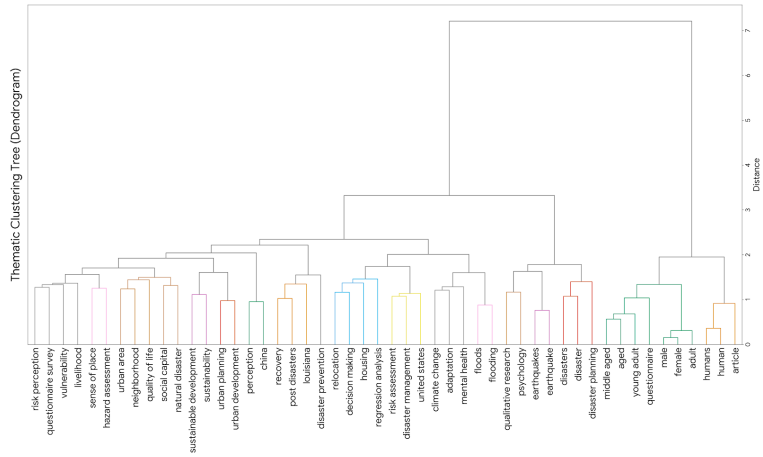


Figure 12. Hierarchical clustering dendrogram of author keywords

The Trend Topics graph in Figure 13 highlights terms like seismic hazard, current and Turkey as the newest and most accelerated topics for the 2025 to 2026 period. The previous 2023-2025 time frame was dominated by terms such as middle aged, behavioral research, social behavior, china and urban planning. Turkey was among the most current and rising terms of the literature due to the direct effect of the earthquakes that occurred in Kahramanmaraş in February 2023. This macro scale finding is the reason why Turkey is the most mentioned country in the 136 article core corpus that will be presented in the following sections.

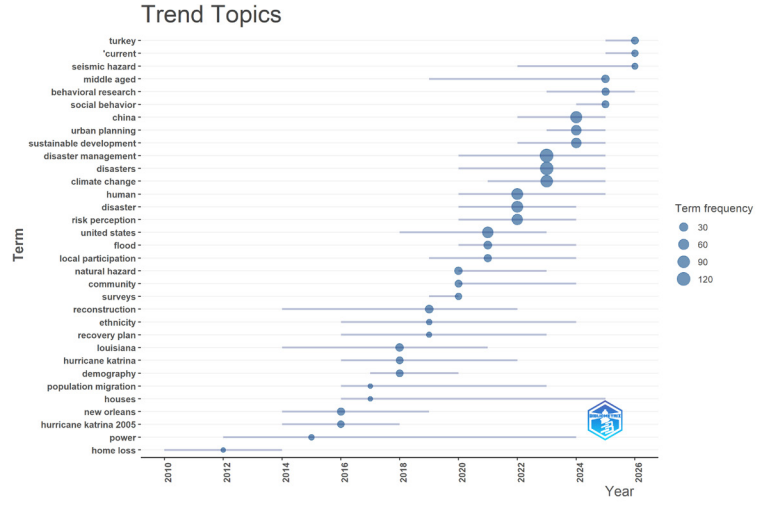


Figure 13. Trend topics, term frequency by year

The field has been in an exponential growth phase since 2011, as shown by macro scale bibliometric mapping. The annual production curve is headed toward a maximum of about 2027.7. The conceptual center of gravity concentrates on medium scale urban and social concepts like place attachment and neighborhood. The co occurrence network barely mentions the term for interior architecture. This macro map, however, includes all 1219 records, not just seismic disasters, but purely structural engineering studies and works not related to spatial belonging. It does not, therefore, directly reveal the architectural and interior space focused core of the field. The core corpus of the articles, which is reduced by the PRISMA ScR protocol, is the next part of the study. It describes the actual content of the place attachment motor theme identified by the macro map and uncovers the geographies and restorative strategies that are empirically generated.

4. Systematic Content Analysis of the Final Corpus (n=136)

The final corpus (n=136) was then analyzed systematically. This section presents the systematic content analysis of the 136 core articles that constitute the original contribution of the study. It goes beyond macro bibliometric mapping and directly addresses post-disaster spatial belonging and Genius Loci. The analysis is organized in general descriptive features (4.1), five restorative strategies for reproducing Genius Loci (4.2), thematic dimensions that support or intersect with these strategies (4.3), and a comparative reading of geographic concentration (4.4).

4.1. General Features: Publication Year, Journal, and Geographic Distribution

4.1.1. Temporal Distribution

The final corpus reveals a definite trend of acceleration in the field over the past five years. As Figure 14 illustrates, while only 8.1% (n=11) of the 136 articles were published between 2006 and 2015, this rate increased to 16.2% (n=22) in the 2016-2020 period and to 23.5% (n=32) in the 2021-2023 period. In the 2024-2026 period, it leaped to constitute nearly half of the corpus (52.2%; n=71). This acceleration is certainly related to the strong research impulse that has emerged since the earthquakes in Kahramanmaraş on February 6, 2023; many of the articles scanned directly refer to the socio-spatial impacts of this disaster. In addition, 31 records (22.8% of the corpus) are from an incomplete

calendar year at the time of the scan. This share, therefore, is partly due to the impact of early online publications (in-press/online-first). This does not change the overall direction of the annual growth trend, but rather suggests that the data for 2026 should not be compared directly with full years.

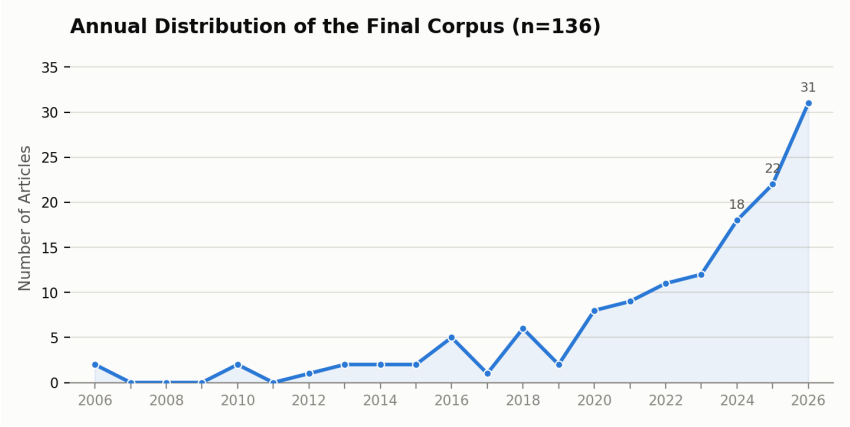


Figure 14. Annual distribution of the final corpus (n=136)

4.1.2. Journal/Source Distribution

The distribution by publication outlet offers valuable insights into the disciplinary identity of the field. The most dominant publication outlet is the International Journal of Disaster Risk Reduction with 19.9% (n=27) of the corpus. It is followed by Sustainability (Switzerland) (n=7; 5.1%), Progress in Disaster Science (n=6; 4.4%) and the International Journal of Disaster Resilience in the Built Environment (n=6; 4.4%). The four journals make up 33.8% of the corpus (Table 3). Interestingly, all four major journals are general interdisciplinary journals that focus on disaster management, sustainability and built environment resilience. No journal dedicated to interior architecture, spatial psychology, or environment-behaviour studies (Journal of Environmental Psychology, 1 record; Journal of Interior Design, 0 records) is in the top ranks, however.

Table 3. Most frequent journals/sources (n=136)

Journal/Source	Number of Articles	Percentage
International Journal of Disaster Risk Reduction	27	19.9%
Sustainability (Switzerland)	7	5.1%
Progress in Disaster Science	6	4.4%
International Journal of Disaster Resilience in the Built Environment	6	4.4%
Bulletin of Earthquake Engineering	2	1.5%
Natural Hazards	2	1.5%
Journal of Asian Architecture and Building Engineering	2	1.5%
Open House International	2	1.5%
Sustainable and Resilient Infrastructure	2	1.5%
Architecture	2	1.5%
Other (72 different sources, 1 article each)	78	57.4%

4.1.3. Geographic Distribution

When the classification is based on the geographic context explicitly mentioned in the title (see methodological limitation note in Section 2.4), the empirical weight of the literature is found around specific "seismic fault lines". Türkiye is the top country with 18 articles (13.2%) containing the word Türkiye in the article title. It is followed by Indonesia and China with equal shares (each n=10; 7.4%), Japan (n=9; 6.6%), Italy and Nepal (each n=8; 5.9%), Iran and New Zealand (each n=6; 4.4%), and Chile (n=5; 3.7%) (Figure 15). One or a few studies are available for the more marginal case areas of the US, Taiwan, the Netherlands, Morocco, Haiti, India, and Sri Lanka. Conceptual, methodological, or multi-country general studies (without a specific country name in the title) make up 33.8% (n=46) of the corpus.

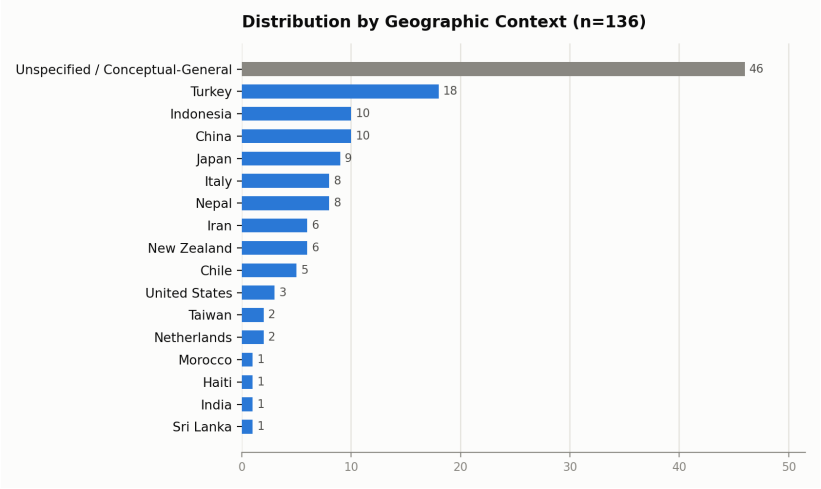


Figure 15. Distribution by geographic context specified in the title (n=136)

The data in this table should be interpreted with the caveat noted in Section 2.4. The actual percentage is probably higher than the reported 13.2%, as studies written in Turkish, published in Turkish journals, or authored by Turkish researchers but not including the country name in the title (e.g., some in the "Unspecified" category) are not included. Many of the studies that only focus on the 2023 Kahramanmaraş earthquakes (Pehlivan et al., 2026; Kurşun & Zubaroglu Ioannides, 2026; Fakıoğlu & Mızrak, 2026; Özarslan et al., 2025; Şen & Şen, 2026; Amirov, 2026; Akar et al., 2026; Tarakçı, 2026; Giyik, 2026; Acehan & Senyigit Sarikaya, 2026; Usta & Özdemir, 2025) have clear geographic markers in their titles such as "Türkiye," "Hatay," "Antakya," "Kahramanmaraş Studies such as Kalkan and Alptekin (2026) were not included in the title of the study, but they were written in Turkish and published in a Turkish architectural journal (METU Journal of the Faculty of Architecture) were kept in the "Unspecified" category. In this context, Türkiye's contribution to the literature after the 2023 earthquakes strengthens its status as the case area with the highest empirical input in terms of numbers, around a single disaster series, by a single country. Five main strategies are grouped around innovative approaches that seek to replicate the spirit of place without erasing seismic memory within the corpus: place attachment measurement, the effect of sheltering processes on belonging, participatory design, scar architecture/ heritage conservation, and digital memory tools. The thematic categories are represented in Figure 16 as weights in the corpus.

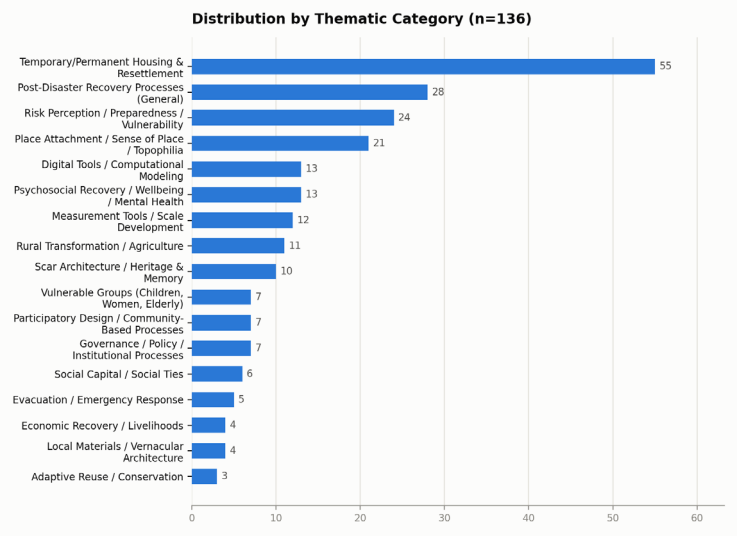


Figure 16. Distribution by thematic category (n=136, multi-label coding)

It is important to note that the interior architecture discipline is not yet a visible actor in this technological transformation, although these studies demonstrate that digital tools have come from a documentation to a predictive modelling. One of the most under-represented categories in the corpus is the use of traditional building practices, which is mostly found in Indonesian cases. Rahim et al. (2024), and Arief et al. (2023) examine the sustainability and environmental adaptation of local architecture. Fard et al. (2010) discuss cultural identity in Bam earthquake housing. This limited representation indicates that vernacular construction techniques are seriously neglected in the empirical research agenda. There are other thematic elements in the corpus that contribute to restorative strategies. The literature is mainly concerned with the functional aspects of recovery, rather than belonging, as revealed by general recovery (n=28) and risk perception/vulnerability (n=24) studies (Downey, 2021; Phillips, 2015). The psychosocial recovery and mental health axis (n=13) is an important dimension in the corpus (Kurşun & Zubaroglu Ioannides, 2026; Savadori et al., 2024); Wu (2020) in his longitudinal study on the elderly emphasizes the temporal dimension in this area. The spatial experience of women and children is not reflected in the conventional shelter policies, as highlighted by studies on vulnerable groups (n=7) (Pehlivan et al., 2026; Özarslan et al., 2025; Taner Derman & Türen, 2025; Acehan & Senyigit Sarıkaya, 2026; Zijlstra et al., 2022). Research on governance and social capital (n=13) (Allegranti, 2023,

2025; Ghezelloo et al., 2024; Otsuyama, 2023) indicates that belonging is a collective process that is linked to institutional arrangements.

Furthermore, rural transformation (n=11) (Amirov, 2026; Giyik, 2026), scale development (n=12) (Fırat et al., 2026; Gültekin & Bulut, 2025), and evacuation (n=5) themes offer specific contributions to the field. Every seismic fault has given a distinctive "disaster signature" to the literature. The Türkiye literature is mainly focused around February 6, 2023, when the focus was on temporary shelters, acute psychosocial impacts, and vulnerable groups, while the Japan literature (Ghezelloo et al., 2024; Otsuyama, 2023) highlights the long-term recovery perspective of the 2011 earthquake. China (Zhang et al., 2024; Zhao et al., 2022, 2025; Wu, 2020; Xu et al., 2024) reflects state-led large-scale rural settlements; Italy (Savadori et al., 2024; Demir & Turan, 2025; Galadini, 2022; Imbroglini et al., 2020) the tension between the conservation of historic city centers and disaster resilience; Nepal (Spoon et al., 2020) the short-term dynamics of rural communities; New Zealand (Pawson & Blakie, 2025) "managed retreat" practices; and Iran (Kamani-Fard et al., 2012, 2013; Fard et al., 2010) visual/phenomenological analyses of cultural identity. Notwithstanding this abundance, one of the major gaps in the research is the absence of systematic studies that make direct cross-comparisons between national literatures.

5. Discussion

The 136 articles in the corpus do not contain any studies with the words "interior architecture" or "interior design" in the title. This disciplinary gap is directly linked to the fragility of interior architecture education policies (Tarakçı & Kurnalı, 2026; Tarakçı et al., 2026); in fact, although the number of courses related to disasters and limited/micro space has increased in higher education institutions after the 2023 earthquakes, the courses are still mostly theoretical and "elective," which indicates that disaster risk reduction competencies have not yet become a compulsory pedagogy in the studio. Research on the profile of interior architecture graduate theses in Türkiye also indicates that (Tarakçı, 2025a), while the research is shifting towards human-centered temporary housing and sustainability topics, the number of theses on these subjects is still not enough and there is a need for urgent curriculum reforms to be integrated into the global design discourse. While Tarakçı's study on biophilic performance in school buildings and Dinç and Köse's (2026) study on psychological interactions in permanent housing refer to the quality of interior space, they do not directly

place the discipline as interior architecture. This is corroborated by the journal distribution: none of the four journals with the highest number of articles in the corpus (33.8%) specialise in interior architecture or spatial psychology. The interior space, which is crucial for psychological healing, is overlooked in this image of urban planning and geography. Quantitative and culturally adapted psychometric tools to measure post-disaster "sense of place" and belonging are lacking. There are only 12 studies (8.8%) in the corpus in the "measurement tools/scale development" category. Apart from Gültekin and Bulut's (2025) APAS Turkish adaptation and Fırat et al.'s (2026) rural satisfaction scale, studies are generally based on qualitative determinations or descriptive surveys. This situation makes it impossible to make a systematic Genius Loci measurement between various disasters and further emphasizes the absence of a comparison of literature across nations. The literature is primarily shaped around the fault lines of Türkiye (13.2%), Indonesia (7.4%), China (7.4%), Japan (6.6%), Italy (5.9%), and Nepal (5.9%). Many of the countries in the Global South, which are at high seismic risk, are represented by only a single study, such as Morocco (Amini Alaoui et al., 2024), Haiti (Svistova & Pyles, 2018), India. The dynamics of belonging in various disaster management regimes are still unknown, and this quantitative imbalance is reflected in the infancy of studies on the use of digital twins, virtual/augmented reality, and large language models (LLMs) (n=13; 9.6%). The majority of the research (Akar et al., 2026; Yuandita et al., 2026) is based on simulation and remote sensing data, with the exception of Blagojević and Baker's (2026) LLM-based disaster recovery modeling. The potential of digital memory to safeguard the "spirit of place" at the sensory level is rarely empirically tested, and the use of technology in spatial design is still limited. The processes of disaster victims developing belonging and clinging to the space through "self-identification" practices directly trigger psychosocial healing in standardized temporary housing units (STHU) set up in emergencies, like AFAD containers (Tarakçı & Kavut, 2024). Concurrently, the selection and construction of these housing units is a critical need to consider the different systems, including modular, membrane, traditional and compact, with the help of a multi-criteria analytical model such as AHP-TOPSIS (Tarakçı, 2026a, 2026b). Most research has been conducted on the first five-year emergency reconstruction process, with 52.2% (n=71) of the corpus published in the 2024-2026 period, which was mainly caused by the earthquakes in 2023. Longitudinal post-occupancy evaluation (POE) studies measuring the development of belonging decades after the transition to permanent housing are lacking. The

study on elderly welfare following the Wenchuan earthquake (Wu, 2020) and the study on the re-evaluation of disaster preparedness (Xu et al., 2024) are useful exceptions. This time lag is an important research opportunity, especially in the context of Türkiye.

6. Conclusion

The chapter in this book explores the relationship between seismic resilience and Genius Loci, topophilia and spatial memory through a two-level analytical process. The macro analysis of 1,219 records, based on the Scopus, shows that the number of publications has increased exponentially since 2011, with a strong focus on place attachment. The 136-article PRISMA-ScR corpus is used in content analysis to confirm the empirical basis of this trend. The study provides answers to the research questions (RQ) as follows: RQ1: The concepts of Genius Loci and place attachment mainly appear in the axes of temporary/ permanent housing (40.4%) and risk-vulnerability (17.6%). They focus on certain seismic fault lines in Türkiye, Indonesia, China, Japan, Italy, and Nepal. Only place attachment measurement (15.4%) and digital computational modeling (9.6%) have relatively mature empirical data among the five restorative strategies. Although conceptually promising, participatory design (5.1%), scar architecture (7.4%), adaptive reuse (2.2%) and vernacular material integration (2.9%) are still under-represented empirically. The literature shows gaps in the five dimensions: disciplinary (invisibility of interior architecture), methodological (no standardized measurement tools), geographic (Global South representation deficit), digital (infancy of integration), and temporal (no longitudinal POE studies). The results have three practical implications for architecture and interior architecture. First, the design of shelters after disasters requires more than just structural safety and speed. It should include interior morphology, privacy boundaries and personalization elements, which are at the core of interior architecture. The lack of consideration of interior space in disaster policies is a clear indication that there is an urgent need to incorporate the discipline into the disaster policy process. Second, the need for the development of similar culturally adapted measurement tools is the most urgent methodological need, as seen in the APAS scale adaptation by Gültekin and Bulut (2025). Third, the literature that has been produced following the 2023 earthquakes in Kahramanmaraş, Türkiye, offers a unique opportunity for longitudinal post-occupancy evaluation (POE) studies in the next decade. The study has some methodological limitations. Studies (33.8%) without country names in the title were underrepresented in the thematic and geographic coding of the core corpus,

which was based on bibliographic records. In addition, the search was limited to the Scopus database, which may have excluded relevant literature, and the addition of Web of Science, PsycINFO, or Avery Index could expand the scope of interior architecture publications. Lastly, the 2026 records (22.8%) are for an incomplete calendar year and should be interpreted with caution for the most recent trends. Multi-database and full-text designs can be used in future research to overcome these limitations. Finally, this review provides an analytical framework that moves disaster architecture beyond engineering and logistics and reads it through the lens of belonging, privacy and Genius Loci. In seismic geographies, reconstruction must withstand not only earthquakes, but also the erosion of memory, identity and belonging. This is only possible through interdisciplinary cooperation between engineering, architecture, interior architecture and the social sciences.

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CHAPTER III

FURNITURE-RELATED SPATIAL RISKS IN EARTHQUAKE-RESILIENT INTERIOR DESIGN: LAYOUT, ANCHORING, AND SAFE CIRCULATION

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1. Introduction

Earthquake safety at the building scale is generally discussed in relation to the performance of the structural system. However, safety inside a building also depends on the behavior of nonstructural components during seismic shaking. Furniture, fixtures, equipment, and other interior components are not structural elements, yet their movement can affect users and interrupt the normal use of a space. FEMA (2012) classifies furniture, fixtures, equipment, and building contents as nonstructural components and describes measures for reducing the risks associated with them. For interior design, this means that earthquake safety needs to be considered not only at the structural level but also through the relationship between users and the fixed or movable elements around them.

Furniture does not react to earthquake shaking in the same manner; the way that freestanding or poorly secured furniture moves may depend on its size, how its weight is distributed, the degree of mobility it has, its position, and the way it contacts the floor. AFAD (2011) makes a similar connection between the

displacement of nonstructural elements and factors such as size, weight, the presence of wheels, and location. Further variables are included in experimental studies, such as the seismic input, the friction at the point of contact, and the furniture's configuration. For example, Isobe et al. (2018) noted rocking, translation, sliding and overturning in their examination of office furniture.

Evidence from field studies carried out in Türkiye shows how these risks manifest in homes. Açık (2025) examined 219 participants who had experienced at least one of the earthquakes that took place in Kahramanmaraş in 2023 while they were at home and found that furniture had been knocked over, objects had fallen from shelves, and considerable displacement of furniture had occurred, especially with wardrobes and bookcases. Of the participants, 16.5% said that furniture had been overturned, 22.9% reported that objects had fallen from shelves, and 14.7% stated that some furniture had been moved by more than 30 cm. Kitchens, the entrance areas and hallways were also found to be relatively high-risk areas. The results indicate that the risk associated with furniture depends on where the furniture is positioned and on how the surrounding space is used, as well as on the characteristics of the furniture itself.

In the field of interior architecture, it is important to consider what happens to the surrounding space when furniture starts to move. If furniture tips over, slides around, or spills its contents, it can go beyond its initial position, hinder movement, and alter the area available for circulation. Isobe et al. (2018), drawing on their observations of past earthquakes, pointed out that overturned furniture and scattered belongings could render evacuation routes unusable. Another similar problem was seen in the dynamic interior simulation carried out by Chu et al. (2022), in which damaged nonstructural elements blocked the evacuation routes and changes in the environment influenced the occupants' choice of route. Furthermore, moving objects would fall and come into contact with other items, causing further obstructions. The results of these studies indicate that the movement of furniture can modify the spatial conditions that people encounter during an earthquake.

Furniture location and anchoring need to be considered together. Anchoring can reduce the possibility of overturning or uncontrolled movement, but the consequences of any movement also depend on where the furniture is placed in relation to doors, passageways, and circulation routes. In their analysis of residential interiors, Garip et al. (2023) identified the obstruction of escape routes through overturning, breakage, and falling as major risks associated with fixed furniture and described anchoring and the securing of stored contents as

risk-reduction strategies. The study also identified the overturning of movable furniture, inappropriate placement, the scattering of stored objects, and the obstruction of escape routes as risks that may restrict user movement. Therefore, assessing furniture safety solely in terms of physical stability may overlook the spatial dimension of risk.

Previous studies involving residential occupants reveal considerable gaps between technically established anchoring and placement measures and their implementation in practice. Uzun et al. (2015), in a study involving 79 university staff members in Simav and Düzce, found that 81% of living-room furniture and 76.9% of sitting-room and bedroom furniture were not anchored to walls, while 77.2% of kitchen cabinets lacked door latches. Ulay and Bekiroğlu (2016), who examined residential occupants who had experienced the Van earthquakes, similarly found that furniture-related precautions remained limited. Participants who had taken measures adopted different strategies, including anchoring furniture, modifying furniture dimensions, and relocating furniture. In the Tosya case, 85% of participants had taken no precautions against a potential earthquake (Karamanoğlu and Ulay, 2017). Findings obtained at different times and in different locations suggest that awareness of earthquake hazards or previous earthquake experience alone may not be sufficient to promote the adoption of risk-reduction measures in interior spaces.

User habits and the culture of spatial use should also be considered in the assessment of furniture-related risk. In comparing residential interiors in Türkiye and Japan in terms of nonstructural earthquake hazards, Demirarslan (2016) draws attention to the relationship between furniture and fixture use, cultural patterns, living habits, and spatial organization. The study associates the use of fewer, lighter, functional, and multipurpose pieces of furniture in Japanese dwellings with a reduction in nonstructural risks. This comparative assessment allows furniture-related risk to be considered not only in terms of anchoring but also through furniture density, scale, function, and spatial placement.

Recent research on post-earthquake evacuation highlights the importance of considering architectural layout decisions together with nonstructural components. Hassanpour et al. (2024) developed an agent-based simulation approach linking architectural layout and the selection of nonstructural elements to post-earthquake evacuation performance. The study examined the relationships between corridor and exit widths, the selection of nonstructural elements, evacuation time, and injury outcomes, with furniture included among the nonstructural component groups considered in the simulation. Accordingly,

earthquake-resilient interiors should be considered not only in terms of the fixed spatial arrangement before an earthquake but also in relation to the changing spatial conditions that may emerge after seismic shaking.

The spatial consequences of risk may also vary according to the function of the building. In their on-site investigations of schools in Kaynaşlı, Bayraktar et al. (2019) demonstrated that placing nonstructural elements without considering potential disaster effects could create additional risks and emphasized that these elements should be evaluated from the design stage onward. In a recent field study conducted in healthcare facilities, 110 nonstructural hazards were identified across 12 hospital units, and interventions included preventing materials from falling from open shelves, securing cabinet doors, anchoring desktop devices, and securing wheeled equipment (Çırak and Ateş, 2026). In the hospital context, the functional importance of equipment and the continuity of healthcare services were considered in addition to the number of identified risks. Although furniture- and fixture-related spatial risks may arise from similar physical movements in residential, educational, and healthcare buildings, their consequences may differ according to the user profile and the function of the space.

Taken together, different types of research indicate that furniture-related earthquake risk can be considered at three interrelated levels: the physical behavior of furniture under seismic shaking, the spatial effects resulting from its movement, and the consequences of these effects within a specific context of use. Experimental and simulation-based studies explain how movement may occur, while field studies conducted in Türkiye provide evidence on the implementation of anchoring and placement measures in actual settings of use. Studies conducted in schools and hospitals further demonstrate that the same risk component may produce different consequences for different user groups and functions. Such an approach moves furniture beyond its consideration as an isolated product and positions it within the broader system of interior space use.

The available studies offer data at various scales concerning the physical behavior of furniture, anchoring, nonstructural risks, and evacuation performance. In the field of interior architecture, the main question is how this body of knowledge can be incorporated into design choices. The possibility of furniture moving during an earthquake cannot be examined without taking its location into account; similarly, appropriate placement alone is not enough to achieve sufficient risk reduction if the physical stability of the furniture is not guaranteed. The impact of the same physical behavior on user safety may also depend on the function of the space, the number of occupants, and the paths of

movement. In this study, the physical behavior of the furniture, the spatial area that could be affected by its movement, the anchoring requirements, the context of use, and the continuity of safe circulation are treated as complementary design elements.

The aim of this study is to examine the spatial risks which could result from furniture during an earthquake by considering the connection between how furniture is placed, how it is anchored, and safe circulation, and to determine the interior design choices needed to reduce earthquake risk by examining the interaction between the physical behavior of the furniture and its position in the interior. The study was carried out using document analysis within a qualitative research approach. The materials reviewed consisted of academic studies based on experiments and simulations, field studies that involved residents, risk assessments carried out in various types of buildings, comparative studies of interior environments, and technical documents issued by AFAD and FEMA. The analysis concentrated on the circumstances in which physical risks might turn into spatial problems, the relationship between placement and anchoring decisions and user safety, and the design choices that are especially important for ensuring safe circulation. By bringing together the findings from different contexts of use, the study investigates the relationship between the physical behavior of the furniture and its spatial consequences within a comprehensive interior architecture framework.

2. Furniture-Related Spatial Risks During Earthquakes

Furniture is generally treated as part of a fixed interior layout before an earthquake. During seismic shaking, however, its position and behavior may change. Furniture-related earthquake risk therefore involves more than damage to the furniture itself or the possibility of overturning. How a piece of furniture moves, where it is located, and what part of the surrounding space it may affect are also relevant to interior safety. AFAD (2011) and FEMA (2012) identify tall storage units, bookcases, cabinets, and wheeled elements among the items that may slide, overturn, or change position during an earthquake.

The spatial consequences of furniture movement cannot be explained by physical behavior alone. According to Isobe et al. (2018), seismic input, friction at the contact surface, and furniture configuration can affect how furniture moves. Their study showed that individual items may overturn after rocking or translational motion, while stacked cabinets can display more complex behavior and wheeled furniture can move across the floor. Wittich and Hutchinson (2015)

also showed experimentally that geometric asymmetry affects the rocking, sliding, and overturning behavior of freestanding rigid elements. Their study does not establish design criteria specifically for furniture, but it provides technical evidence for the relationship between geometry and seismic motion. For this reason, geometry, weight distribution, mobility, and use characteristics all need to be considered when the spatial effects of furniture movement are assessed.

The area affected by furniture movement is also important when physical risk is considered in spatial terms. Two items with similar height and weight may have very different consequences depending on where they are placed. Furniture positioned along a wall and away from circulation, for example, does not create the same spatial condition as furniture located next to a door or passageway. Physical risk and spatial risk therefore refer to related but different aspects of the same problem. The first concerns how furniture may move, whereas the second concerns how that movement may affect users and the surrounding space.

2.1. Physical Behavior and Anchoring of Furniture

Furniture movement during an earthquake may create risks beyond damage to the furniture itself. Overturning or displacement can injure users and may also obstruct doors and passageways. For tall storage furniture, proportions and weight distribution are especially relevant because they affect overturning behavior. FEMA (2012) reports that tall shelving may slide, overturn, or collapse, creating risks for occupants and nearby exits. AFAD (2011) likewise points to top-heavy items, elements that are tall in relation to their base dimensions, and wheeled furniture as more prone to movement.

Risk can also come from stored contents even when the furniture remains upright. Cabinet doors may open, objects may fall from shelves, and stored contents may spread into the surrounding area. In the Kahramanmaraş sample reported by Açık (2025), kitchen cabinets themselves fell relatively infrequently, while 31.7% of participants reported that objects inside cabinets had fallen. Storage furniture should therefore be assessed in terms of shelf arrangement, door control, and stored contents as well as the stability of the furniture body.

Anchoring is a basic measure for reducing the physical risks associated with furniture, but the connection itself is only one part of the problem. AFAD (2011) recommends examining the position of the furniture before deciding how it should be anchored. The type of wall, the relationship between the furniture and the wall, and proximity to windows are among the factors to be considered. The guideline illustrates this point with a display cabinet placed diagonally in

a corner. Before anchoring, the cabinet should be repositioned so that a more suitable connection with the wall can be established. The example makes clear that placement is part of the anchoring decision.

FEMA E-74 advises that bookcases and shelving units be connected to suitable load-bearing surfaces rather than to finish materials that cannot resist structural loads (FEMA, 2012). Some cases may also require engineering review. Whether an anchoring solution is adequate depends on the weight and geometry of the furniture, what it stores, and the building element receiving the connection. The connection detail therefore cannot be considered by itself; the furniture must also be placed where any remaining movement will not create an additional spatial hazard.

The two guidelines point to three issues that need to be considered when furniture is anchored: how the furniture may move, whether the connection surface is suitable, and where the furniture is located within the room. A technically sound connection cannot prevent stored objects from falling and cannot compensate for a location that conflicts with circulation. For interior design, these issues need to be addressed together.

Fixed storage units and furniture designed to move serve different functions and should not be approached in the same way. Earthquake safety for each item depends on its form, mobility, intended use, stored contents, and location. The design question is therefore specific to the item: how might it move during shaking, and what would that movement mean for the surrounding space?

For wheeled furniture and items that are routinely repositioned, permanent anchoring may not be compatible with their intended use. The design task is instead to preserve the required mobility while reducing uncontrolled movement during an earthquake. The likely movement of these items should also be checked against user areas and escape routes. Functional requirements and earthquake safety therefore need to be resolved together from the beginning of the design process.

2.2. Spatial Placement and Safe Circulation

Furniture placement becomes an earthquake-safety issue when the area reached after movement differs from the area occupied during normal use. A piece of furniture may leave circulation clear before an earthquake yet obstruct a doorway, corridor, or passageway after sliding or overturning. Safe circulation therefore depends on both the initial layout and the area that furniture could occupy after movement.

Evidence for this relationship comes from both earthquake observations and simulation studies. Isobe et al. (2018) mention the observations from the 1995 Great Hanshin-Awaji Earthquake, in which furniture was overturned and its contents scattered, thus rendering some evacuation routes unusable. In the simulation carried out by Chu et al. (2022), moving objects fell, interacted with other objects and created obstructions that could affect the occupants' choice of route. Xu et al. (2019) modeled the movement of movable furniture after damage in a physics-based virtual environment. Their approach was not intended to measure evacuation performance directly, but rather to show how the movement of furniture can become part of the changing interior conditions after an earthquake.

FEMA's (2012) approach to this matter is based on practical considerations. Furniture such as shelves and bookcases which have the potential to fall across an exit should not be placed right next to doors or exits, and unsecured furniture should be arranged in such a way that it does not obstruct circulation through sliding or toppling. Hence, physical stability by itself is not enough; it is also necessary to take into account the areas that are likely to be affected by movement.

Garip et al. (2023) came to a comparable conclusion in the case of residential interiors. Furniture that was fixed could block escape routes, whereas furniture that could be moved might hinder the movement of the occupants. Furniture placement is therefore directly related to safety. What matters is not only whether the furniture may move, but also where it is located in relation to doors, corridors, and occupied areas.

Passage width before an earthquake provides only part of the picture. Access also has to remain possible after furniture moves. For this reason, placement decisions should account for the normal-use area of furniture and the additional area that may be occupied if it overturns, slides, or releases stored contents. In this study, circulation is considered not as a fixed feature of the floor plan but as a dynamic safety component that may change according to spatial conditions during seismic shaking.

From the perspective of interior design, this approach requires furniture to be considered in relation to a broader potential impact area extending beyond its boundaries in the existing layout. The direction of overturning, the possibility of sliding, and the area over which stored contents may spread can be considered as part of a preliminary design-stage assessment without requiring a detailed mechanical analysis. This is particularly important in areas where circulation

should remain uninterrupted, such as spaces in front of doors, corridor intersections, and passages leading to stairs or exits. Evaluating the normal-use boundary of furniture together with its potential movement area may help identify spatial risks at the placement stage.

Such an approach requires circulation safety to be assessed beyond pre-earthquake passage width by also considering potential obstructions that may emerge after seismic shaking. Furniture may create different forms of obstruction within the same space by overturning, sliding, or scattering its contents onto circulation areas. Consequently, safe circulation should be evaluated by anticipating how furniture movement may alter the circulation system after seismic shaking, rather than by considering only its pre-earthquake position.

2.3. Context of Use and Variation in Spatial Risk

Although the physical behavior of furniture may be similar, the significance of the resulting risk is not the same in every interior environment. The overturning of a storage unit may affect an area frequently occupied by users in a dwelling, student movement in a school, or a critical service area in a hospital. Therefore, the assessment of furniture-related spatial risk should consider not only the physical characteristics and location of the furniture but also the function of the space, user profile, intensity of use, and the need to maintain uninterrupted circulation.

Research into residential settings in Türkiye indicates that the practice of anchoring, the way in which furniture is placed, and measures taken to prepare for earthquakes have not been consistent in various cases. Uzun et al. (2015) noted deficiencies in furniture anchoring and the layout of interior spaces in their study of Simav and Düzce. Ulay and Bekiroğlu (2016) drew the same conclusion in the case of residents who had experienced the Van earthquake, stating that precautions related to furniture were still limited. In Tosya, Karamanoğlu and Ulay (2017) also found a lack of preparedness regarding a possible earthquake. Açık (2025), on the other hand, recorded instances of furniture toppling over, objects being displaced, and stored items falling in the Kahramanmaraş area. Thus, these studies demonstrate that the level of residential risk is closely tied to how furniture is positioned, secured, and used for storage.

Educational buildings raise a separate issue since a large number of people might have to go through the building at the same time. In their field study of schools in Kaynaşlı, Bayraktar et al. (2019) found that there were unsecured cabinets in the classrooms and libraries, that some cabinets were placed near

exit doors, and that the desks and chairs were arranged in a dense manner which could hinder movement. In one instance, altering the use of the area in front of an emergency exit reduced the available width to about 50 cm. In another school, the tall unsecured cabinets close to an exit could act as obstacles if they toppled over. These examples demonstrate that the way furniture is positioned in schools is concerned not only with the safety of the individual items but also with the movement of large groups and with evacuation.

In healthcare environments there is an additional issue: the continuous operation of essential functions. Çırak and Ateş (2026) examined 12 departments in a training and research hospital and found 110 nonstructural hazards. The measures they took involved securing materials on open shelves, locking the doors of cabinets, anchoring desk equipment, and fastening wheeled equipment. Although intensive care units had fewer hazards than a number of the other departments, reducing these risks was still considered important because of the vital functions of the equipment. This result demonstrates that the significance of a risk is not solely determined by the number of hazardous items; it is also necessary to take into account the function which could be affected.

When residential, educational, and healthcare buildings are considered together, furniture-related spatial risk can produce different consequences depending on the context of use. In residential settings, individual exposure and everyday conditions of use become prominent; in educational buildings, intensive occupant movement and evacuation are key considerations; and in healthcare environments, the continuity of critical functions becomes important in addition to user safety. Similar physical behaviors may therefore lead to different design priorities depending on how the space is used.

From the perspective of interior architecture, these differences indicate that a uniform approach to furniture placement for earthquake safety would be insufficient. Design decisions should consider not only the movement potential of furniture but also which users, spatial areas, circulation routes, and functions may be affected by such movement. Considering physical behavior, spatial location, and context of use together may allow furniture-related risks to be identified earlier and more comprehensively in the design process.

3. Research Method

The study was conducted using document analysis within a qualitative research approach. Document analysis is a method based on the systematic examination, evaluation, and interpretation of printed and electronic documents

and involves the selection, interpretation, and synthesis of data relevant to the research problem (Bowen, 2009). This method was selected because it allows academic and technical documents concerning furniture-related earthquake risks to be evaluated together in accordance with the aim of the study.

The document corpus comprised peer-reviewed academic studies directly related to furniture-related earthquake risks and technical guidelines published by official institutions. Document selection was guided by several topics directly related to the study: the physical behavior of furniture during earthquakes, overturning and sliding, anchoring, spatial placement, nonstructural elements, and safe circulation and evacuation. The reviewed literature included experimental and simulation studies, questionnaire surveys with residential occupants, field investigations in educational and healthcare buildings, comparative studies of interior environments, and design- and prototyping-based research. Only peer-reviewed studies available in full text and Turkish- or English-language technical documents published by AFAD and FEMA were included. Relevance to the general topic was not sufficient for inclusion; the documents also needed to address the aim of the study and provide specific information on the risk areas examined. Studies indirectly related to furniture or interior spaces were included only when they provided direct evidence concerning physical behavior, spatial placement, anchoring, circulation, or context of use.

During the analysis, sections relevant to the research topic were first identified, after which the selected content was reread comparatively. Data obtained from the documents were evaluated in relation to the physical behavior of furniture, spatial placement, anchoring, and safe circulation. Context of use was also included as an analytical dimension, and findings from residential, educational, and healthcare buildings were interpreted in relation to the function of the space and user characteristics. Findings that recurred across sources, supported one another, or differed were compared. Results from experimental studies, simulation-based research, survey-based field studies, on-site risk assessments, comparative studies, and design- and prototyping-based research were interpreted within their respective methodological boundaries. Practice-oriented recommendations presented in technical guidelines were also evaluated separately from the findings of academic studies.

Data obtained from different types of research were neither directly compared quantitatively nor combined into a uniform dataset. Percentages reported in survey studies were interpreted within the sample and local context of each study. Experimental and simulation-based findings were used to explain

physical behavior, whereas field investigations were used to identify risks observed in actual use environments. Design- and prototyping-based studies were not treated as evidence of safety performance validated in practice, but as approaches that broaden the potential design roles of furniture in relation to earthquake safety. This approach allowed the methodological characteristics and limitations of the different source types to be preserved during interpretation.

In the final stage of the analysis, findings from different documents were brought together from the perspective of interior design to examine the conditions under which furniture-related physical risks may develop into spatial problems. The relationships among spatial placement, anchoring, and continuity of circulation were synthesized, and common points that could inform interior design decisions aimed at reducing earthquake risk were identified. The potential spatial effects arising from physical behavior were considered together with consequences associated with the context of use. The findings were then interpreted through the relationships among physical behavior, spatial impact, context of use, circulation outcomes, and design decisions. Rather than merely listing information from the reviewed sources, the analysis focused on relating findings from different types of research to one another in accordance with the aim of the study.

4. Findings and Evaluation of Design Decisions

The collective evaluation of the documents indicates that furniture-related earthquake risk does not depend on a single physical characteristic. While movement potential represents the physical starting point of risk, its consequences for user safety depend on the spatial location of the furniture and its relationship with the surrounding areas of use. The experimental findings of Isobe et al. (2018) and Wittich and Hutchinson (2015) demonstrate that geometry, contact conditions, and configuration may influence the movement of freestanding elements. The modeling of post-earthquake furniture movement within a dynamic environment by Xu et al. (2019) also provides a technical basis for the assumption that the initial position of furniture may change after an earthquake. From this perspective, physical behavior should not be considered in isolation but as a component that must be evaluated together with spatial placement and circulation decisions.

Field studies conducted in Türkiye show how furniture-related physical risks manifest in actual use environments across different samples. Açık (2025) identified furniture overturning and displacement, as well as the falling of stored

contents, in the Kahramanmaraş sample. Uzun et al. (2015), Ulay and Bekiroğlu (2016), and Karamanoğlu and Ulay (2017) showed that measures related to anchoring and interior arrangements may remain inadequate or limited in different locations. Although differences in the samples and periods covered by these studies do not allow direct quantitative comparison, their converging findings indicate that furniture-related risk should be considered together with physical movement potential during the design stage.

The relationship between anchoring and spatial placement constitutes the second major area of evaluation emerging from the analysis. AFAD (2011) considers the relocation of objects, in addition to anchoring, as a risk-reduction measure for nonstructural hazards. The recommendations provided by FEMA (2012) and Garip et al. (2023) similarly emphasize the relationship between anchoring furniture and positioning it in relation to doors, exits, and areas of use. Anchoring a piece of furniture does not necessarily mean that it is appropriately positioned; similarly, appropriate placement alone is insufficient when its movement potential has not been controlled. The simultaneous consideration of spatial placement and anchoring therefore provides a more comprehensive approach to risk reduction in interior design.

Field studies also demonstrate the limitations of treating anchoring as an independent intervention carried out after a space is already in use. Bayraktar et al. (2019) identified deficiencies in placement and anchoring in educational buildings that could create risks for occupant circulation and evacuation. Çırak and Ateş (2026) implemented different safety interventions in healthcare buildings involving open shelving, unsecured devices, and movable equipment. These findings suggest that risk-reduction decisions should be integrated into the design, implementation, and use processes rather than being left to individual interventions after occupancy.

When the residential studies of Açık (2025), Uzun et al. (2015), Ulay and Bekiroğlu (2016), and Karamanoğlu and Ulay (2017) are considered together, a direct relationship between earthquake experience or risk awareness and the physical precautions taken cannot be established in every case. This shared finding suggests that relying on user awareness alone may be insufficient in earthquake-resilient interior design. Incorporating the safe positioning of furniture, identifying anchoring requirements during the design stage, and integrating solutions for controlling stored contents into product and spatial decisions from the outset may reduce reliance on precautions expected to be taken during use.

The relationship between the potential movement area of furniture and safe circulation constitutes the third area of evaluation. Isobe et al. (2018) and Garip et al. (2023) provide findings indicating that escape routes may become obstructed as a result of furniture overturning or movement. Dynamic simulations conducted by Chu et al. (2022) demonstrate that obstacles created on the floor may alter occupants' movement routes. Hassanpour et al. (2024) further show that architectural layout, corridor and exit widths, and the selection of nonstructural elements can be evaluated in relation to post-earthquake evacuation performance. Although these studies employ different methods, they collectively indicate that circulation should not be assessed solely on the basis of the fixed pre-earthquake geometry of the floor plan. Continuity of access in the presence of obstacles that may emerge after seismic shaking should also be considered.

The on-site investigations conducted in schools by Bayraktar et al. (2019) provide a concrete illustration of the relationship between circulation safety and design practice. The study identified tall unsecured cabinets located near exits, dense furniture arrangements, and uses that reduced the width of emergency exit areas. The significance of these findings extends beyond the likelihood that individual objects may overturn, as the objects were positioned in locations where they could affect collective evacuation. The relationship between furniture and circulation should therefore be evaluated not only in terms of the area occupied during normal use but also in terms of the obstruction that furniture may create after overturning or displacement.

Context of use emerges as a distinct layer in evaluating the relationship between physical behavior and spatial consequences. The same event, such as overturning, sliding, or the scattering of stored contents, may affect an individual occupant in a dwelling, intensive student movement in a school, or, in a hospital, both user safety and the continuity of critical services. In the hospital study by Çırak and Ateş (2026), although fewer hazards were identified in intensive care units than in some other departments, mitigating these risks was considered critical because of the vital functions of the equipment involved. This finding demonstrates that the number of hazardous elements alone is insufficient for assessing spatial risk. The users, functions, and circulation relationships that may be affected should also be taken into account.

Demirarslan (2016) compared residential interiors in Türkiye and Japan and highlighted the impact of everyday patterns of use on earthquake risk. The study indicates that the number and size of furniture items, the way they are used

multifunctionally, and the manner in which the interiors are arranged can affect the conditions under which nonstructural risks occur. Earthquake safety relating to furniture therefore depends not only on the characteristics of the individual items but also on the density of the furniture and the patterns of its use.

The documents in question also indicate that furniture could have a part to play in earthquake safety apart from being a source of risk. In order to investigate this possibility, Kurtuluş and Muş Özmen (2025) put forward some proposals for transformable furniture within a design education setting. Their study examines how an item which is used in daily life might assume a protective role during or after an earthquake. The designs suggested, though, were not offered as field-validated safety solutions suitable for real-world use or as products ready for manufacturing. Instead, the study is presented as an exploration of design concepts which might serve as a foundation for further research. Taking this limitation into consideration, the study shows that the role of furniture in earthquake safety should be looked at not just in terms of reducing risk but also in relation to possible protective functions.

Taken together, four main outcome areas emerge from the documents examined: controlling physical movement potential, relating the potential movement area of furniture to spatial placement, evaluating consequences according to the context of use, and integrating risk-reduction decisions into the design process at an early stage. These areas are closely related. Furniture movement creates the initial spatial effect, placement influences which part of the space may be affected, and the context of use determines the importance of the consequences for users and functions.

The analysis therefore considered several aspects of furniture-related earthquake risk together. These included physical behavior, the potential movement area, spatial exposure, context of use, and possible effects on circulation or function. The purpose was not to develop a numerical risk calculation or scoring system. Instead, these relationships provide a conceptual basis for examining furniture-related earthquake risks within interior architecture.

Table 1: Relating Findings on Furniture-Related Spatial Risks to Design Decisions

Evaluation Dimension	**Potential Spatial Consequence**	**Interior Design Decision**
Sliding/overturning potential associated with furniture geometry and weight distribution	Movement beyond the initial position, affecting surrounding areas of use	Evaluating geometry, proportions, weight distribution, and movement potential before placement
Unanchored or inadequately anchored storage furniture	Risk to users and obstruction of passageways due to overturning or scattered contents	Evaluating anchoring in relation to furniture weight, the connection surface, and conditions of use
Furniture positioned near doors, corridors, or exits	Narrowing or blockage of passageways due to overturning or sliding	Preventing the potential movement area from overlapping with circulation and exit routes
Wheeled furniture or furniture intended to remain movable	Movement beyond the intended area of use due to uncontrolled displacement	Reducing potential effects on circulation while preserving the mobility required for use
Potential for stored contents to fall or scatter	New obstacles on the floor and reduced passage safety	Considering the weight of stored contents, storage height, and the potential for contents to fall or scatter as part of furniture design
Failure to consider context of use in risk assessment	Overlooking the different consequences of similar physical movements for different users and functions	Including the function of the space, user profile, intensity of use, and functional continuity requirements in the assessment
Fragmented evaluation of physical behavior, spatial placement, anchoring, and context of use	Individual measures may be insufficient to adequately reduce spatial risk	Integrating spatial placement, anchoring, context of use, and safe circulation decisions

Source: Developed by the authors based on the findings of the document analysis.

Table 1 relates risks arising from the physical characteristics and spatial location of furniture to corresponding interior design decisions. Table 2 compares design priorities across residential, educational, and healthcare buildings according to the context of use.

Table 2: Design-Oriented Evaluation of Furniture-Related Spatial Risks in Different Contexts of Use

Context of Use	**Risk Conditions Highlighted in the Sources**	**Spatial / Functional Consequence**	**Interior Design Priority**	**Key Sources**
Residential buildings	Overturning or displacement of furniture, falling of stored contents, and limited anchoring and earthquake-preparedness measures	Occupant exposure to furniture and falling objects; effects on passageways and areas of use	Evaluating furniture placement together with anchoring requirements; securing stored contents; relating the potential movement area to circulation	Açık (2025); Karamanoğlu and Ulay (2017); Ulay and Bekiroğlu (2016); Uzun et al. (2015)
Educational buildings	Unsecured tall cabinets, storage units near exits, and dense furniture arrangements	Narrowing or obstruction of passageways and adverse effects on collective evacuation	Anchoring storage furniture; keeping potential overturning areas away from exits and circulation routes; arranging furniture to support collective movement	Bayraktar et al. (2019)
Healthcare buildings	Materials on open shelves, unsecured devices and furniture, and wheeled equipment prone to uncontrolled movement	Risks to user safety and disruption to the continuity of critical healthcare services	Evaluating anchoring and securing stored contents together with the functional importance of equipment, mobility requirements, and continuity of service	Çırak and Ateş (2026)

Source: Developed by the authors based on the findings of the document analysis.

Table 2 was prepared not to provide context-independent safety recommendations for different building types, but to demonstrate that similar

physical risks may produce different spatial and functional consequences depending on the context of use. Accordingly, rather than standardizing design decisions according to furniture type, the relationship between the potential behavior of furniture and the user profile, circulation pattern, and functional requirements of the space should be considered.

Furniture-related earthquake risk needs to be considered as part of the way an interior is planned. Furniture may be fixed or movable in normal use, but during an earthquake it can change the spatial conditions around it. Physical stability, placement, and continuity of circulation are therefore closely connected. Their importance also changes with the function of the space and the characteristics of its users. Earthquake-resilient interior design should address both the possibility of furniture overturning and the effects that possible movement may have on users, passageways, and exits.

The findings also show that furniture safety cannot be addressed only through product selection or anchoring after installation. Decisions about the layout, furniture type, mobility, connection surfaces, storage, and critical circulation areas are made at different points within the same design process. Addressing these issues early can reduce the need for corrective measures after the interior has already been completed. For this reason, earthquake safety should be included among the safety criteria considered during the early stages of interior architecture and furniture design.

5. Conclusions

This study examined furniture-related spatial risks in earthquake-resilient interiors by focusing on physical behavior, spatial placement, anchoring, and safe circulation. The document review showed that risk does not end when a piece of furniture overturns or changes position. Once movement reaches areas used by occupants, passageways, or exits, it becomes a spatial safety issue. For this reason, furniture behavior during an earthquake needs to be considered together with its location and the way the surrounding space is used. Findings from residential, educational, and healthcare settings also show that the consequences of similar movements vary with user profile, intensity of use, evacuation needs, and the function carried out in the space. Furniture-related risk therefore needs to be assessed through the combined consideration of physical behavior, spatial location, and context of use.

The way furniture behaves during seismic shaking is affected by its shape, how the weight is distributed, the degree of mobility it has, and the items it

is storing. Whether or not this behavior leads to a hazard in the space mainly depends on where the furniture is situated in relation to doors, corridors, and other circulation areas. Both anchoring and placement deal with different aspects of the same issue: anchoring helps to prevent uncontrolled movement, while placement reduces the effects if any movement does take place. With furniture that is used for storage, care must also be taken regarding doors and the items stored, as doors might open and the objects could fall or spread into adjacent areas. In the case of furniture that is movable or on wheels, the design problem is to keep the necessary mobility without allowing uncontrolled displacement during seismic shaking. Appropriate safety decisions must therefore take into account the characteristics of the furniture, its use, and the role it plays in the space rather than applying a single anchoring solution to all items.

Residential studies also point to a gap between awareness and action. Across different locations and periods, shortcomings in anchoring, placement, and storage safety remained evident even where earthquake risk was familiar or had been experienced directly. This suggests that user awareness alone cannot be relied on to secure the interior. Addressing anchoring needs, suitable connection surfaces, likely movement areas, and critical circulation zones during design can reduce the number of precautions left to users after occupancy. Earthquake safety should therefore be treated not as an additional measure introduced after occupancy, but as a safety criterion incorporated into the early decision-making stages of interior and furniture design.

In evaluating furniture placement from the perspective of earthquake safety, it is important to distinguish between the area occupied by furniture during normal use and the area it may affect as a result of seismic shaking. Reducing the overlap between potential sliding, overturning, or displacement areas and areas occupied by users, circulation routes, and exits may contribute to maintaining continuity of circulation. Circulation safety can thus be assessed not only in terms of pre-earthquake corridor or passage widths but also in terms of maintaining access in the presence of obstacles that may emerge after seismic shaking.

Including context of use in the assessment also demonstrates that a single placement or anchoring approach will not produce the same outcome across all interior types. In residential settings, everyday habits and furniture density influence the conditions of exposure. In educational buildings, the main concern is the movement of large numbers of occupants during evacuation. In healthcare settings, continuity of critical services needs to be protected alongside user safety. The significance of a physical hazard therefore cannot be judged only

by the number of items that overturn or move. A similar event can have very different consequences depending on the user affected or the function disrupted. From the perspective of interior architecture, the assessment should therefore consider not only the movement potential of furniture but also the users, spatial areas, circulation routes, and functions that may be affected by such movement.

A holistic evaluation of the findings indicates that furniture-related risks can be linked to design decisions through physical behavior, potential movement area, spatial exposure, context of use, and consequences for circulation or function. This relationship is addressed not as a quantitative risk model or scoring system, but as a conceptual framework for evaluating furniture-related earthquake risks from the perspective of interior architecture. Such an approach allows the physical behavior of furniture during an earthquake to be considered together with its spatial location and the surrounding conditions of use.

The role of furniture in earthquake safety need not be limited to risk-reduction measures. The design studies reviewed indicate conceptual possibilities for adapting everyday objects to different functions during or after a disaster. However, such design proposals should not be regarded as safety solutions validated under field conditions and require further testing in terms of load-bearing capacity, accessibility, rapid usability, manufacturability, and performance under actual earthquake conditions. Such approaches may broaden the contribution of furniture design to earthquake safety beyond anchoring and placement measures and extend it into a wider field of design research.

From a methodological perspective, the reliance of this study on document analysis means that the design decisions proposed are limited to the scope of the academic studies and technical guidelines reviewed. Because the sources employ different methods, including experiments, simulations, surveys, field investigations, comparative assessments, and design studies, no direct quantitative comparison was made among the findings. Methodological diversity makes direct comparison difficult, but it also allows the problem to be viewed from physical, user-related, and functional perspectives. Future work could map likely furniture movement on actual floor plans from residential, educational, healthcare, and other interior settings. Alternative placement and anchoring strategies could then be compared, and physics-based or agent-based simulations could be used to examine circulation after an earthquake. Experimental testing would provide a further way to assess the design decisions proposed here. Studies that examine furniture density, user profile, storage arrangement, and spatial exposure together could also clarify how these relationships change across contexts of use.

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CHAPTER IV

COMPARING HUMAN AND ARTIFICIAL INTELLIGENCE DECISION-MAKERS IN THE BIOPHILIC INTERIOR PERFORMANCE ASSESSMENT OF POST-DISASTER EDUCATIONAL BUILDINGS: A FUZZY TOPSIS APPROACH

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1. Introduction

The advancements of AI technology are changing ways for designing models creation, visualizations, analytics on data and decisions making within architectural projects and interiors designs. Also, recently there are studies on how artificial intelligence can be used for simulation purposes when comparing different types of spaces based upon environmental factors, performance criteria and experience (Aytatlı et al., 2025). Generative AI systems based on large language models have evolved beyond tools for information retrieval. They can interpret criteria within a defined problem, evaluate alternatives, and generate reasoned decisions. While this development expands the role of AI in design disciplines, it also raises new questions about the relationship between human expertise and algorithmic decision-making.

Decision-making in architecture and interior architecture does not rely solely on technical data. Assessing spatial performance requires the joint interpretation of physical characteristics, user needs, spatial perception, comfort, sense of belonging, behavior, and psychological responses. Experts therefore

bring not only theoretical knowledge to design and evaluation processes but also professional experience, spatial interpretation, and user-centered judgment. Expert groups in multi-criteria decision-making (MCDM) methods serve a similar function. They assess complex decision problems through both measurable attributes and qualitative variables that are meaningful within the context of the problem. The growing number of performance criteria considered in building and design processes has further increased the need for systematic decision-support approaches. Çelebi and Arpacıoğlu (2026), for example, emphasize the integration of multi-criteria evaluation approaches with decision-support mechanisms in complex decision processes in the construction sector.

This issue becomes particularly relevant when AI systems are positioned as decision-makers. Large language models can draw on extensive knowledge bases, establish relationships among predefined criteria, and produce systematic evaluations. Nonetheless, they don't have a physical sense of space. It also raises issues regarding embodiment of perception by professionals' experiences and empathy towards customers during evaluation process. The potential differences between human experts and AI therefore cannot be reduced to whether a decision is simply "correct" or "incorrect." A more fundamental question concerns which components of interior architecture expertise can be represented through structured knowledge and where human expert judgment diverges from AI-based evaluation.

This research problem becomes more critical in post-disaster educational environments, where users' physical and psychological needs are particularly pronounced. Disasters affect not only the physical safety of educational buildings but also children's relationship with space and their recovery processes. The performance of educational buildings in post-disaster settings therefore cannot be assessed through structural safety alone. Interior components, furnishings, and other spatial elements that directly interact with users also contribute to risk reduction and safety (Polat et al., 2024). Within interior architecture, earthquake safety should likewise address non-structural elements, while knowledge of their associated hazards, risks, and mitigation measures constitutes an important component of professional awareness and expertise (Ertaş Beşir et al., 2023; Ertaş Beşir & Dereci, 2021).

Schools that remain in use after disasters should therefore provide not only safe environments but also spatial qualities that support student well-being. Biophilic design offers one such approach by integrating the human–nature relationship into the built environment through daylight, vegetation,

natural materials, airflow, views, and visual or sensory connections with nature. Within this framework, daylight also functions as an architectural component that strengthens the relationship between interior and exterior space; skylights can operate as permeable interfaces through which daylight becomes an active element of spatial design (Durmuş Öztürk & İsmailoğlu, 2017). Like this research does so for other studies on it, there is an emphasis here about how important biophilia would be in terms of helping kids recover from disasters physically and mentally after they happen.

Biophilic design in educational environments cannot be reduced to a single physical attribute. Assessing its spatial performance requires the simultaneous consideration of multiple criteria. Daylight, fresh air, vegetation, natural materials, visual connections with nature, spatial organization, and related components may differ both in importance and in how they are represented within a given environment. The presence of different biophilic design classifications for educational buildings in the literature further reflects this multidimensional structure (Lee & Park, 2018; Sayed & Nagy, 2020; Mustapa et al., 2024). Biophilic spatial performance therefore provides a suitable interior architecture problem for expert judgment-based multi-criteria evaluation.

This study builds on previous research that evaluated the biophilic spatial performance of primary and secondary schools that remained in use after the earthquake in Hatay through the Fuzzy TOPSIS method (Tarakçı, 2026a). In that study, a pool of biophilic criteria derived from the literature was presented to domain experts. The criteria were first evaluated according to their level of importance, after which the performance of the school alternatives was assessed against the selected criteria using expert judgments. These evaluations were analyzed through Fuzzy TOPSIS, and the schools were prioritized according to their need for improvement. This methodological structure provides a controlled basis for comparing decision processes generated by human experts and AI-based decision-makers using the same candidate criteria and spatial alternatives.

The main scientific rationale of the present study is the limited understanding of how human experts and generative AI systems differ or converge when they prioritize criteria and evaluate alternatives within the same candidate criterion pool, alternative set, and decision-making method. In a spatial assessment grounded in professional knowledge and experience, it remains unclear which criteria AI-based decision-makers will prioritize, how they will evaluate the same spatial alternatives, and where their final decision structure will align with or diverge from an expert-based model. Such a comparison is more useful for examining the

structure of expert judgment in interior architecture and the potential decision-support role of AI than for testing whether AI can replace experts.

Accordingly, this study aims to compare the decision structures produced by human experts and generative AI systems when evaluating the biophilic spatial performance of post-disaster educational buildings. The 18 candidate criteria, four school alternatives, and Fuzzy TOPSIS procedure used in the reference study were retained, while the criterion-prioritization and alternative-evaluation stages were repeated using three generative AI systems. Human- and AI-based decision processes were then compared in terms of criterion selection, criterion evaluations, and the final ranking of alternatives.

Originality is about treating artificial intelligence rather than just being an instrument to generate design ideas or perform calculations on TOPSIS models; it should be considered as a decision maker inside an architectural context. Therefore, this study is more concerned about interpreting and ranking space rather than computing power of an artificial intelligence system. Keeping the candidate criterion pool, alternative set, and methodological procedure constant allows the decision structures produced by the two groups to be compared directly. Particular attention is given to potential differences between physically identifiable biophilic attributes and criteria associated with user experience and spatial perception, as these differences may provide insight into the structure of professional judgment in interior architecture.

The study addresses the following research questions:

- To what extent do the criterion priorities of human experts and AI-based decision-makers overlap when they are presented with the same pool of biophilic criteria?
- For which biophilic spatial criteria are similarities and differences between expert and AI evaluations most pronounced?
- To what extent are the importance weights assigned to criteria prioritized by both decision-maker groups similar or different?
- To what extent does the ranking of alternatives generated through the AI-based decision process align with the ranking produced by the expert-based reference model?
- How can the observed agreements and divergences be interpreted in terms of the potential use of AI as a decision-support tool for multi-criteria spatial evaluation in interior architecture?

The main contribution of the study is its comparison of human and AI decision-making across the full decision process rather than through the final ranking of alternatives alone. By examining criterion prioritization together with alternative evaluation, the study identifies which components of expert judgment can be closely represented through structured knowledge and where experiential and contextual differences become more evident.

2. Theoretical Framework

Biophilia refers to an evolutionarily rooted human tendency to connect with nature, and the transfer of this tendency into the built environment forms the theoretical basis of biophilic design. Physical features and layout to school buildings are closely related. Learning process of students, motivation, and physical and cognitive development (İsmailoğlu & Zorlu, 2018). A systematic review of research papers about schools showed that biophilic elements are associated with better student achievement and psychological well-being according to Fisher (Fisher, 2024). These effects, however, depend on the interaction of multiple design components rather than on any single feature. Similarly, Lanzaro and Ucci (2024), in their study of primary schools in England, found that teachers and parents perceived stronger spatial preferences among children in schools with higher levels of biophilic design and reported that these preferences were also reflected in the learning process. Ghaziani (2025) found that children's biophilic preferences may be different than those of adults' evaluations, so there is a need for an evaluation framework which takes into consideration age and experience level of users. A systematic review of Chinese kindergartens by Huizi et al. (2024) likewise found that, despite the potential of biophilic design to support children's physiological and psychological needs, this potential is rarely realized to its full extent in practice. The result here relates directly to this issue of prioritizing criteria as discussed above since it shows how important a biological factor may be but not always practical for use.

The post-disaster building is an important setting to apply biophilia principles. Atmodiwirjo et al. (2023), in a mixed-method study of schools reconstructed after earthquakes in Indonesia and Thailand, found that reconstruction processes often prioritized speed of construction, although connections with nature played an important role in supporting children's post-disaster well-being. Being with people is important for us; safety matters too while we spend some time relaxing at peaceful places due to these factors of nature related designs. The clinical study of children who were affected by the

earthquake that occurred on February 6th, 2023 in Türkiye is relevant to this topic. According to Temelturk et al. (2025), there was a significant increase in acute stress disorder and PTSD incidence among preschoolers who were victims of earthquakes compared to those who had been exposed to other types of traumatic events. Tarakçı (2026a), meanwhile, addressed the question: "What are the spatial performance levels of primary and secondary schools in earthquake-affected Hatay according to biophilic design principles, and how can these schools be prioritized for architectural improvement using a scientific approach?" The study identified natural light, spatial openness, and vegetation as important factors in post-disaster learning environments and developed broader recommendations for post-disaster schools based on the findings from the examined cases. Khan et al. (2023) also emphasized the need for urgent and sustainable mental health support for children and adolescents following the Türkiye–Syria earthquake.

Evaluating the built environment in earthquake contexts cannot be reduced to a single dimension of performance. It requires the combined consideration of architectural, technical, and environmental criteria. Çelebi and Arpacıoğlu (2024, 2025) similarly argue that building decisions under seismic conditions should integrate earthquake performance with other dimensions of building performance. Taken together, these findings indicate that schools that remain in use after disasters should be evaluated not only in terms of physical safety but also through a spatial framework that accounts for users' psychological recovery.

The multidimensional nature of biophilic spatial performance, which includes both qualitative and quantitative criteria, makes multi-criteria decision-making methods particularly suitable for its assessment. Fuzzy TOPSIS incorporates subjective judgments into the decision model through linguistic variables and triangular fuzzy numbers and ranks alternatives according to their relative closeness to the ideal solution (Chen, 2000). This feature makes the method especially useful for decision problems in disciplines such as interior architecture, where spatial evaluation often depends on experiential judgment.

The use of large language models as decision-makers or criterion-weighting agents in multi-criteria decision-making has recently become a rapidly growing area of research in decision science. Svoboda and Lande (2024) integrated GPT-4 with the Analytic Hierarchy Process to generate automated decision support and reported that the model could establish internally consistent relationships among criteria, although its judgments did not fully correspond with those of human experts. Memduhoğlu et al. (2026) compared the AHP-based criterion-

weighting performance of large language models with that of human experts in a solar power plant site-selection problem. The models showed high consistency for criteria that were clearly defined in the literature and had explicit quantitative counterparts but diverged more strongly from expert judgment for context-specific criteria that depended on field experience. These findings suggest that the decision-support performance of large language models may vary according to the extent to which a criterion can be represented through structured knowledge.

Within this framework, expert judgment in interior architecture includes not only theoretical knowledge but also tacit knowledge derived from direct spatial experience, embodied perception, and empathic engagement with users. Large language models lack this experiential dimension. The contrast between structured knowledge and embodied professional experience therefore provides the central theoretical axis for examining both the potential and the limits of AI-based decision support in this study.

3. Method

This study used the Fuzzy TOPSIS method to compare decisions made by human experts and generative AI systems regarding the biophilic spatial performance of post-disaster educational buildings. The method incorporates uncertain and subjective evaluations into the model through fuzzy logic and ranks alternatives according to their relative closeness to the ideal solution (Chen, 2000). The methodological design was based on Tarakçı's (2026a) study, which evaluated the biophilic spatial performance of four schools that remained in use after the earthquake in Hatay using Fuzzy TOPSIS. The present study retained the 18-candidate-criterion pool, four school alternatives, evaluation scales, and Fuzzy TOPSIS procedure used in the reference study. The criterion-prioritization and alternative-evaluation stages were then repeated using generative AI systems. The overall research design is presented in Figure 1.

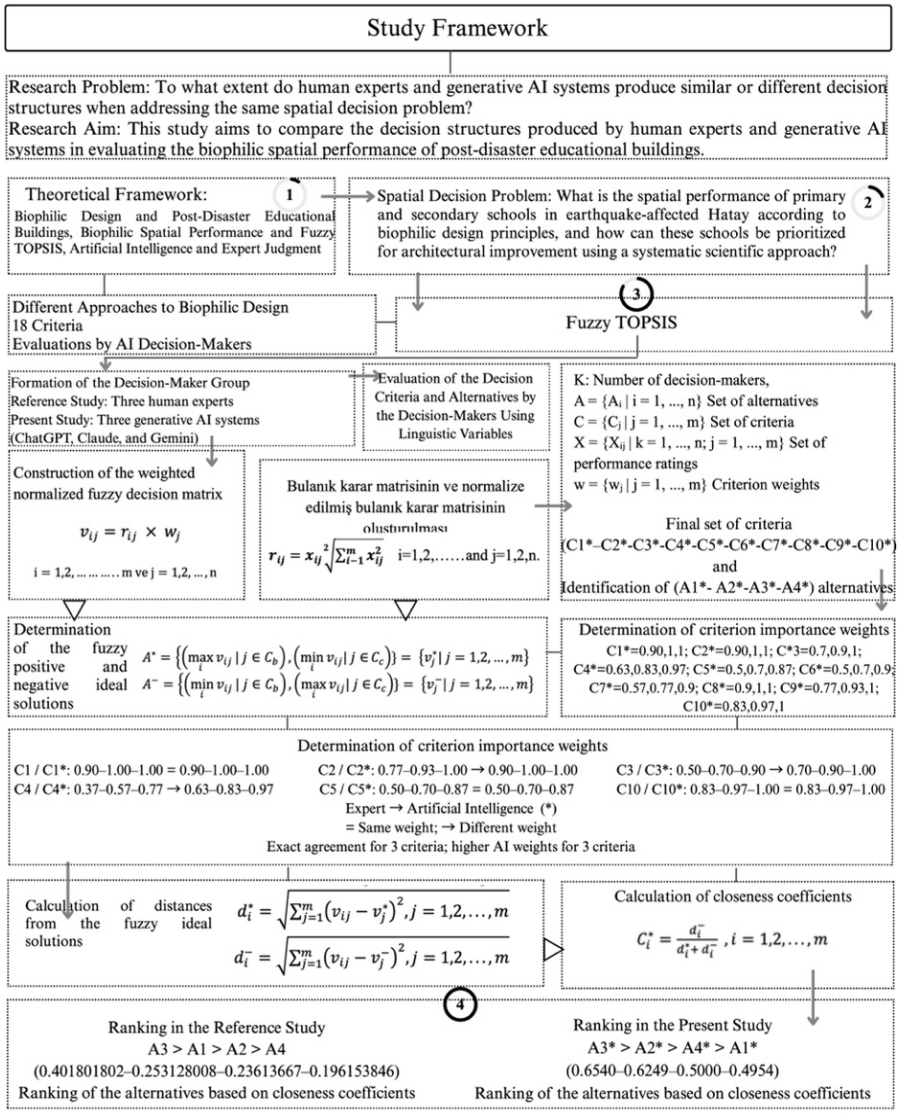


Figure 1. Schematic representation of the study

Fuzzy TOPSIS was selected because biophilic spatial performance involves both qualitative and quantitative criteria and because spatial assessments inherently include subjective judgments. The method enables criteria with different importance weights and evaluations involving uncertainty to be incorporated within a common analytical framework (Tarakçı, 2026b). The human expert evaluations were not reproduced in the present study. Instead,

the results reported by Tarakçı (2026a) were used as the reference data for comparison. The original data generated in this study consisted of independent assessments conducted by ChatGPT, Claude, and Gemini using the same criterion pool, alternatives, and evaluation scales. The aim was therefore not to reproduce the findings of the previous study, but to compare the decision structure established by human experts with that generated by AI-based decision-makers and to examine similarities and divergences associated with the type of decision-maker.

3.1. Formation of the Decision-Maker Groups

In the reference study, the decision-making group consisted of three human experts. Expert selection considered familiarity with the disaster context, professional expertise relevant to the research problem, and academic or professional experience. The group included an educational administrator with more than 31 years of managerial experience in Hatay and two interior architecture academics with more than 10 and 30 years of academic experience, respectively. The use of three decision-makers was supported by previous TOPSIS studies indicating that three-member decision committees can provide an adequate balance between diversity of judgment and consistency of evaluation (Ploskas & Papathanasiou, 2019; Tarakçı, 2026b; Tarakçı, 2026c; Chabok et al., 2025).

To preserve the three-member decision structure of the reference study, ChatGPT, Claude, and Gemini were used as independent AI decision-makers. The number of decision-makers was therefore kept equal across the human and AI groups. Each AI system completed the assessments independently, without access to the responses generated by the other systems or to the evaluations previously produced by the human experts. Input conditions were standardized by providing all systems with the same problem definition, criterion descriptions, visual and textual information on the alternatives, and evaluation scales. The assessments were conducted through the web-based user interfaces of ChatGPT, developed by OpenAI; Claude, developed by Anthropic; and Gemini, developed by Google. ChatGPT assessments were performed through the ChatGPT web interface (chatgpt.com), Claude assessments through the Claude web interface (claude.ai), and Gemini assessments through the Gemini web interface (gemini.google.com). On September 11th, 2026 all three AI models were tested out. Prompts and output models are logged for tracking purposes during this study. Since generative AI systems and their underlying models can change over time, we have recorded the interface used at that point in time as well as when it

was accessed. The report is written for reducing issues related to reproducibility due to changes in artificial intelligence technologies as well as improving transparency on how this evaluation works.

3.2. Identification of Biophilic Design Criteria

There is no new criteria pool to be used in this research paper. However, these same 18 biophilic design criteria identified by this research are kept unchanged. It made sure both humans who make decisions as well as artificial intelligence are evaluated under a common model of decision-making process. According to their level of importance, the three experts evaluated these criteria in this paper (Figure 2).

No	Biophilic Design Criterion	References									
		Mustapa et al. (2024)	Sayed & Nagy (2020)	Malek et al. (2024)	Yaseen & Mustafa (2023)	Siham (2023)	Lee & Park (2018)	Chabok et al. (2025)	Ghaziani et al. (2021)	Ghaziani (2025)	Lanzaro & Ucci (2024)	Terblanche & Khumalo (2025)
1	**Visual Connection with Nature** (Views, natural scenery, natural landscapes, ecosystem views)	●	●	●	●	●	●	●	●	●	●	○
2	**Non-Visual Connection with Nature** (Sensory contact through smell, sound, touch, and related stimuli)	●	○	●	○	○	○	○	●	●	○	○
3	**Non-Rhythmic Sensory Stimuli** (Natural sounds, wind movement, and other nature-related sounds)	●	○	○	○	○	○	○	●	●	○	○
4	**Thermal and Airflow Variability** (Natural ventilation, air movement, and temperature variation)	●	●	○	○	●	●	●	●	●	●	○
5	**Presence of Water** (Visual or auditory water features, access to water, and representations of water)	●	○	●	○	●	●	●	●	●	●	●
6	**Dynamic and Diffuse Light / Daylight** (Natural light, variation in light, and integration of daylight into the interior)	●	●	●	○	●	●	●	●	●	●	●
7	**Connection with Natural Systems** (Ecosystems, weather conditions, seasonality, and natural processes)	●	●	○	○	●	●	○	●	●	○	●
8	**Biomorphic Forms and Patterns** (Nature-inspired shapes, natural geometries, and organic forms)	●	●	○	●	●	●	●	●	●	●	●
9	**Material Connection with Nature** (Wood, stone, natural fibers, natural textures, and natural color palettes)	●	●	○	○	●	●	○	●	●	●	○
10	**Complexity and Order / Organized Complexity** (Nature-based rhythm, hierarchy, information richness, and pattern coherence)	●	○	○	●	○	○	○	●	●	○	○
11	**Plants and Green Elements** (Live plants, indoor planting, and green areas)	○	●	○	○	●	●	●	○	○	●	○
12	**Elements Related to Animals or Natural Life** (Animal presence, birdsong, traces of wildlife, and ecological interaction)	○	○	○	○	●	○	●	○	○	●	○
13	**Color and Texture** (Natural colors, earth tones, and nature-based textures)	○	●	○	○	●	○	●	○	○	●	●
14	**Shapes and Forms** (Spatial forms, curves, and organic lines that evoke nature)	○	●	○	○	●	○	●	○	○	●	●
15	**Mobility and Wayfinding / Spatial Organization** (Clear sightlines, orientation, sense of movement, and accessibility)	○	●	○	●	●	○	○	○	○	○	○
16	**Prospect and Refuge** (A balance between open views and safe, protected spaces)	○	○	○	●	●	●	○	○	○	○	○
17	**Transitional Spaces and Spatial Belonging** (Indoor–outdoor connections, thresholds, and sense of belonging to place)	○	○	○	○	●	●	○	○	○	○	○
18	**Traces of Time, Age, and Change** (Observation of seasonal change)	○	○	○	○	●	○	○	○	○	○	○

● The criterion is included in the corresponding source. ○ The criterion is not included in the corresponding source.

Figure 2. Biophilic design criteria identified from the literature

During the initial phase of this research project, each of these 18 biophilic design criteria was given to ChatGPT, Claude, and Gemini for evaluation on a three-point Likert scale as used by the previous paper, 3 = very important, 2 = moderately important, 1 = slightly important. The all three models had identical prompts; however, their experts' ratings, selection of parameters for evaluation purposes (to be used in this paper), and TOPSIS outcome values are not provided here. The process allowed for independent evaluation by an artificial intelligence system to generate its own results.

Scores of all three AI decision makers are summed up so that we can find out how important they are as a whole and on average per criterion. The

10 criteria with the highest mean scores were included in the AI-based Fuzzy TOPSIS analysis. The results are presented in Figure 3.

Criterion No	Criterion Name	ChatGPT Score	Claude Score	Gemini Score	Result
1	Visual Connection with Nature	3	3	3	3
2	Non-Visual Connection with Nature	3	2	3	2.6
3	Non-Rhythmic Sensory Stimuli	2	2	2	2
4	Thermal and Airflow Variability	3	2	3	2.6
5	Presence of Water	2	1	2	1.6
6	Dynamic and Diffuse Light / Daylight	3	3	3	3
7	Connection with Natural Systems	3	2	2	2.33
8	Biomorphic Forms and Patterns	2	2	2	2
9	Material Connection with Nature	3	2	3	2.6
10	Complexity and Order / Organized Complexity	2	2	2	2
11	Plants and Green Elements	3	3	3	3
12	Elements Related to Animals or Natural Life	1	1	1	1
13	Color and Texture	3	2	3	2.6
14	Shapes and Forms	2	2	2	2
15	Mobility and Wayfinding / Spatial Organization	3	3	3	3
16	Prospect and Refuge	3	3	3	3
17	Transitional Spaces and Spatial Belonging	3	3	3	3
18	Traces of Time, Age, and Change	2	1	1	1.33

Figure 3. Likert-scale ratings of the three AI decision-makers

The 10 criteria identified by the AI systems were compared with the 10 criteria prioritized by the human experts in the reference study to examine similarities and differences in the prioritization structures of the two decision-maker groups (Figure 4).

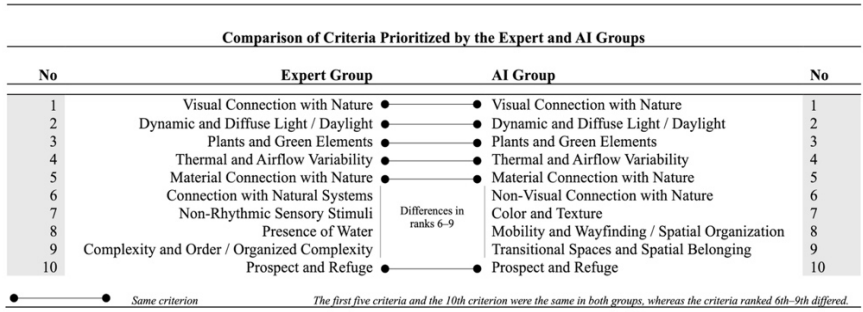


Figure 4. Comparison of prioritized criteria

In the reference study, 10 criteria were included in the decision model based on expert prioritization. Comparison with the AI-based criterion set showed that six criteria overlapped, corresponding to 60% agreement between the two groups. The expert group prioritized Connection with Natural Systems, Non-Rhythmic Sensory Stimuli, Presence of Water, and Complexity and Order, whereas the AI group included Non-Visual Connection with Nature, Color and

Texture, Mobility and Wayfinding/Spatial Organization, and Transitional Spaces and Spatial Belonging among its top 10 criteria.

3.3. Identification of Alternatives and Fuzzy TOPSIS Analysis

The set of alternatives was kept identical to that of the reference study and included four educational buildings in Hatay, one of the provinces severely affected by the February 6, 2023 earthquakes. Nuri Üysen Secondary School (A1), Erzin Gökdere Secondary School (A2), İskenderun Primary School (A3), and Selahattin Alanya Primary School (A4) were compared using the same spatial sample. Information on the schools is presented in Figure 5.

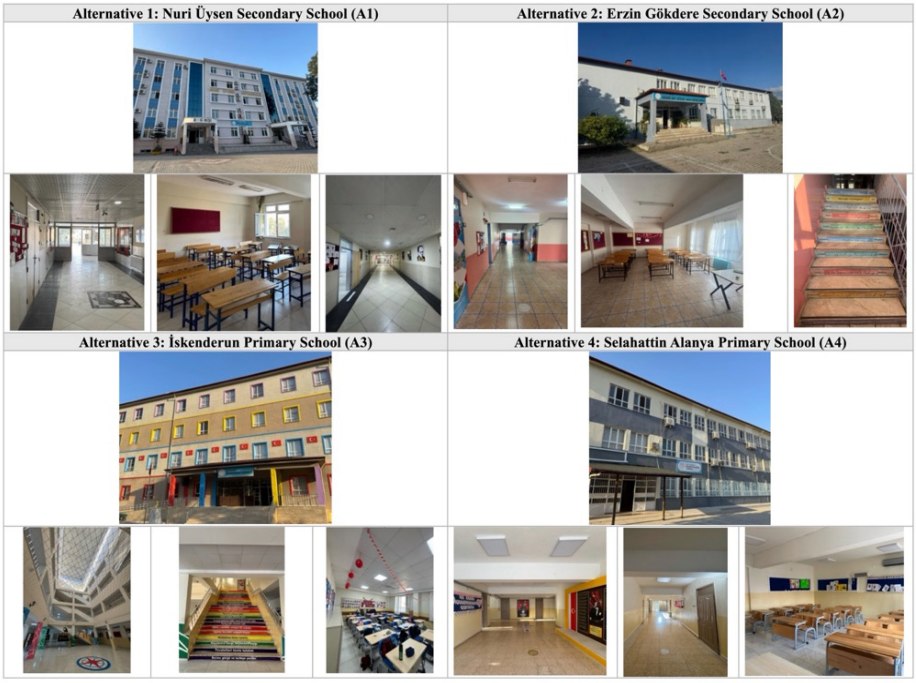


Figure 5. Alternative set examined in both studies (Tarakçı, 2026a)

Following criterion prioritization, the four schools were evaluated against the 10 criteria identified by the AI group. ChatGPT, Claude, and Gemini were provided with the same visual and textual data and the same evaluation instructions. The linguistic assessments were converted into triangular fuzzy numbers using the linguistic scale presented in Figure 6 and were subsequently aggregated to construct the fuzzy group decision matrix.

Linguistic Variables for the Importance Weights of the Decision Criteria		Linguistic Variables Used to Evaluate the Alternatives	
Linguistic Variable	Triangular Fuzzy Numbers	Linguistic Variable	Triangular Fuzzy Numbers
Very Low (VL)	(0.0, 0.0, 0.1)	Very Poor (VP)	(0, 0, 1)
Low (L)	(0.0, 0.1, 0.3)	Poor (P)	(0, 1, 3)
Slightly Low (SL)	(0.1, 0.3, 0.5)	Slightly Poor (SP)	(1, 3, 5)
Medium (M)	(0.3, 0.5, 0.7)	Medium (M)	(3, 5, 7)
Slightly High (SH)	(0.5, 0.7, 0.9)	Slightly Good (SG)	(5, 7, 9)
High (H)	(0.7, 0.9, 1.0)	Good (G)	(7, 9, 10)
Very High (VH)	(0.9, 1.0, 1.0)	Very Good (VG)	(9, 10, 10)

Figure 6. Linguistic variables and their corresponding triangular fuzzy numbers

The fuzzy importance weights of the criteria were then calculated, the decision matrix was normalized, and the weighted fuzzy decision matrix was obtained. After determining the fuzzy positive ideal solution and fuzzy negative ideal solution, the distance of each alternative from these ideal solutions was calculated, followed by the corresponding closeness coefficients. Four schools' rankings are based on a distance measure for obtaining an AI-based fuzzy TOPSIS score of each option.

The evaluation model for this paper is like that used in a previous research project where it was developed through aggregation of ratings given by three people and then weighted according to those ratings. Prior to conducting an evaluation by experts on this project's objectives, range, and methods for assessing it. Like that of ChatGPT, Claude and Gemini were given standard data regarding purpose to study; scope for this project; evaluation process prior to testing it out.

4. Findings

In the reference study, the 10 criteria identified through the evaluations of the expert group were defined as C1*–C10*, and the four school alternatives were assessed using Fuzzy TOPSIS. The present study retained the same decision structure, while criterion selection was based on the evaluations of the three AI systems.

The 10 criteria with the highest mean scores in the AI group were Visual Connection with Nature (C1*), Dynamic and Diffuse Light/Daylight (C2*), Plants and Green Elements (C3*), Thermal and Airflow Variability (C4*), Material Connection with Nature (C5*), Non-Visual Connection with Nature (C6*), Color and Texture (C7*), Mobility and Wayfinding/Spatial Organization (C8*), Transitional Spaces and Spatial Belonging (C9*), and Prospect and Refuge (C10*). The same four school alternatives used in the reference study

were retained: Nuri Üysen Secondary School (A1*), Erzin Gökdere Secondary School (A2*), İskenderun Primary School (A3*), and Selahattin Alanya Primary School (A4*). As the first step, the hierarchical structure of the AI-based decision problem was established (Figure 7).

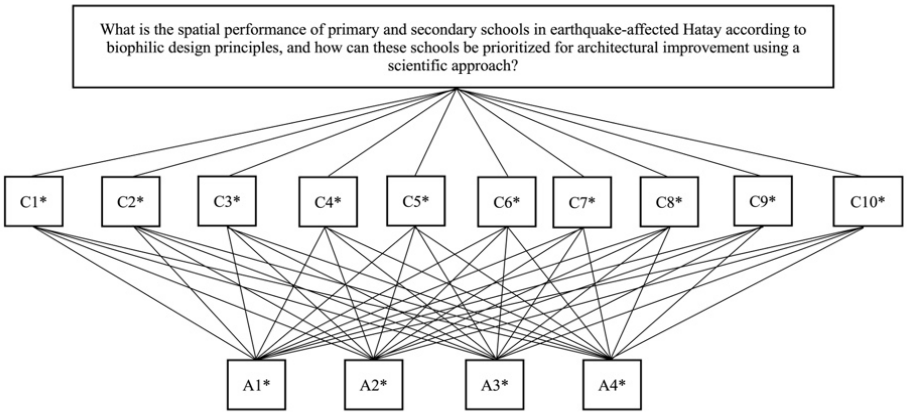


Figure 7. Hierarchical structure of the AI-based decision problem

In the second step, the importance levels of the selected criteria and the performance of the school alternatives against these criteria were evaluated using linguistic variables. Screenshots of the evaluation process are presented in Figure 8.

	Decision-Makers		
Criteria	**DM_{1*}**	**DM_{2*}**	**DM_{3*}**
C1*	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)
C2*	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)
C3*	(0.7, 0.9, 1.0)	(0.7, 0.9, 1.0)	(0.7, 0.9, 1.0)
C4*	(0.7, 0.9, 1.0)	(0.5, 0.7, 0.9)	(0.7, 0.9, 1.0)
C5*	(0.5, 0.7, 0.9)	(0.3, 0.5, 0.7)	(0.7, 0.9, 1.0)
C6*	(0.5, 0.7, 0.9)	(0.5, 0.7, 0.9)	(0.5, 0.7, 0.9)
C7*	(0.7, 0.9, 1.0)	(0.3, 0.5, 0.7)	(0.7, 0.9, 1.0)
C8*	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)	(0.9, 1.0, 1.0)
C9*	(0.7, 0.9, 1.0)	(0.7, 0.9, 1.0)	(0.9, 1.0, 1.0)
C10*	(0.9, 1.0, 1.0)	(0.7, 0.9, 1.0)	(0.9, 1.0, 1.0)

Figure 8. Criterion evaluations of the AI decision-makers

The decision-makers' evaluations of the alternatives using linguistic variables are presented in figure 9.

Criteria	Alternatives	AI Decision-Makers			Criteria	Alternatives	AI Decision-Makers		
		DM_{1}*	DM_{2}*	DM_{3}*			DM_{1}*	DM_{2}*	DM_{3}*
C1*	A1*	(5, 7, 9)	(0, 1, 3)	(3, 5, 7)	C6*	A1*	(1, 3, 5)	(1, 3, 5)	(3, 5, 7)
	A2*	(7, 9, 10)	(5, 7, 9)	(7, 9, 10)		A2*	(1, 3, 5)	(3, 5, 7)	(7, 9, 10)
	A3*	(5, 7, 9)	(7, 9, 10)	(1, 3, 5)		A3*	(0, 0, 1	(3, 5, 7)	(1, 3, 5)
	A4*	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)		A4*	(0, 0, 1)	(1, 3, 5)	(3, 5, 7)
C2*	A1*	(7, 9, 10)	(0, 1, 3)	(7, 9, 10)	C7*	A1*	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)
	A2*	(7, 9, 10)	(7, 9, 10)	(7, 9, 10)		A2*	(7, 9, 10)	(7, 9, 10)	(5, 7, 9)
	A3*	(9, 10, 10)	(9, 10, 10)	(9, 10, 10)		A3*	(9, 10, 10)	(9, 10, 10)	(9, 10, 10)
	A4*	(7, 9, 10)	(3, 5, 7)	(3, 5, 7)		A4*	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
C3*	A1*	(1, 3, 5)	(0, 0, 1)	(1, 3, 5)	C8*	A1*	(7, 9, 10)	(3, 5, 7)	(7, 9, 10)
	A2*	(3, 5, 7)	(0, 0, 1)	(7, 9, 10)		A2*	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
	A3*	(7, 9, 10)	(0, 1, 3)	(0, 1, 3)		A3*	(9, 10, 10)	(7, 9, 10)	(9, 10, 10)
	A4*	(0, 0, 1)	(0, 0, 1)	(0, 1, 3)		A4*	(7, 9, 10)	(5, 7, 9)	(7, 9, 10)
C4*	A1*	(5, 7, 9)	(1, 3, 5)	(3, 5, 7)	C9*	A1*	(5, 7, 9)	(0, 1, 3)	(5, 7, 9)
	A2*	(5, 7, 9)	(3, 5, 7)	(7, 9, 10)		A2*	(7, 9, 10)	(3, 5, 7)	(7, 9, 10)
	A3*	(7, 9, 10)	(5, 7, 9)	(7, 9, 10)		A3*	(9, 10, 10)	(7, 9, 10)	(9, 10, 10)
	A4*	(5, 7, 9)	(1, 3, 5)	(3, 5, 7)		A4*	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)
C5*	A1*	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	C10*	A1*	(7, 9, 10)	(1, 3, 5)	(7, 9, 10)
	A2*	(5, 7, 9)	(3, 5, 7)	(7, 9, 10)		A2*	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
	A3*	(1, 3, 5)	(1, 3, 5)	(3, 5, 7)		A3*	(7, 9, 10)	(7, 9, 10)	(9, 10, 10)
	A4*	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)		A4*	(5, 7, 9)	(1, 3, 5)	(7, 9, 10)

Figure 9. Alternative evaluations of the AI decision-makers

Step 3 involved determining the importance weights of the criteria using the AI decision-maker group. The fuzzy weights representing the importance of the decision criteria are presented in Figure 10.

Criteria	Weights
C1	(0.90, 1, 1)
C2	(0.90, 1, 1)
C3	(0.7, 0.9, 1)
C4	(0.63, 0.83, 0.97)
C5	(0.5, 0.7, 0.87)
C6	(0.5, 0.7, 0.9)
C7	(0.57, 0.77, 0.9)
C8	(0.9, 1, 1)
C9	(0.77, 0.93, 1)
C10	(0.83, 0.97, 1)

Figure 10. Importance weights of the decision criteria

Step 4 involved constructing the decision matrix and the normalized decision matrix. At this stage, the evaluations of the school alternatives provided by ChatGPT, Claude, and Gemini were aggregated to obtain fuzzy values for each alternative. The mean evaluations of the three AI systems were used to construct the decision matrix in the form of triangular fuzzy numbers, after which the matrix was normalized (Figure 11).

Criteria	A1*	A2*	A3*	A4*
C1*	(2,67; 4,33; 6,33)	(6,33; 8,33; 9,67)	(4,33; 6,33; 8,00)	(3,00; 5,00; 7,00)
C2*	(4,67; 6,33; 7,67)	(7,00; 9,00; 10,00)	(9,00; 10,00; 10,00)	(4,33; 6,33; 8,00)
C3*	(0,67; 2,00; 3,67)	(3,33; 4,67; 6,00)	(2,33; 3,67; 5,33)	(0,00; 0,33; 1,67)
C4*	(3,00; 5,00; 7,00)	(5,00; 7,00; 8,67)	(6,33; 8,33; 9,67)	(3,00; 5,00; 7,00)
C5*	(4,33; 6,33; 8,33)	(5,00; 7,00; 8,67)	(1,67; 3,67; 5,67)	(4,33; 6,33; 8,33)
C6*	(1,67; 3,67; 5,67)	(3,67; 5,67; 7,33)	(1,33; 2,67; 4,33)	(1,33; 2,67; 4,33)
C7*	(2,33; 4,33; 6,33)	(6,33; 8,33; 9,67)	(9,00; 10,00; 10,00)	(5,00; 7,00; 9,00)
C8*	(5,67; 7,67; 9,00)	(3,67; 5,67; 7,67)	(8,33; 9,67; 10,00)	(6,33; 8,33; 9,67)
C9*	(3,33; 5,00; 7,00)	(5,67; 7,67; 9,00)	(8,33; 9,67; 10,00)	(4,33; 6,33; 8,33)
C10*	(5,00; 7,00; 8,33)	(3,67; 5,67; 7,67)	(7,67; 9,33; 10,00)	(4,33; 6,33; 8,00)

Figure 11. Fuzzy decision matrix

Step 5 involved constructing the normalized fuzzy decision matrix. The fuzzy decision matrix derived from the evaluations of the AI decision-makers was normalized to place all criteria on a common comparison scale. For benefit criteria, the components of the triangular fuzzy numbers were scaled using the highest upper bound for the corresponding criterion (c_j^*). For cost criteria, normalization was based on the lowest lower bound for each criterion (a_j^-) (Figure 12).

Criteria	A1*	A2*	A3*	A4*
C1*	(0,276; 0,448; 0,655)	(0,655; 0,861; 1,000)	(0,448; 0,655; 0,827)	(0,310; 0,517; 0,724)
C2*	(0,467; 0,633; 0,767)	(0,700; 0,900; 1,000)	(0,900; 1,000; 1,000)	(0,433; 0,633; 0,800)
C3*	(0,112; 0,333; 0,612)	(0,555; 0,778; 1,000)	(0,388; 0,612; 0,888)	(0,000; 0,055; 0,278)
C4*	(0,310; 0,517; 0,724)	(0,517; 0,724; 0,897)	(0,655; 0,861; 1,000)	(0,310; 0,517; 0,724)
C5*	(0,499; 0,730; 0,961)	(0,577; 0,807; 1,000)	(0,193; 0,423; 0,654)	(0,499; 0,730; 0,961)
C6*	(0,228; 0,501; 0,774)	(0,501; 0,774; 1,000)	(0,181; 0,364; 0,591)	(0,181; 0,364; 0,591)
C7*	(0,233; 0,433; 0,633)	(0,633; 0,833; 0,967)	(0,900; 1,000; 1,000)	(0,500; 0,700; 0,900)
C8*	(0,567; 0,767; 0,900)	(0,367; 0,567; 0,767)	(0,833; 0,967; 1,000)	(0,633; 0,833; 0,967)
C9*	(0,333; 0,500; 0,700)	(0,567; 0,767; 0,900)	(0,833; 0,967; 1,000)	(0,433; 0,633; 0,833)
C10*	(0,500; 0,700; 0,833)	(0,367; 0,567; 0,767)	(0,767; 0,933; 1,000)	(0,433; 0,633; 0,800)

Figure 12. Normalized fuzzy decision matrix

Step 6 involved constructing the weighted normalized fuzzy decision matrix. The normalized fuzzy decision matrix was weighted by multiplying it by the criterion weights derived from the AI decision-makers. The resulting matrix is presented in Figure 13.

Criteria	A1*	A2*	A3*	A4*
C1*	(0,248; 0,448; 0,655)	(0,590; 0,862; 1,000)	(0,403; 0,655; 0,828)	(0,279; 0,517; 0,724)
C2*	(0,420; 0,633; 0,767)	(0,630; 0,900; 1,000)	(0,810; 1,000; 1,000)	(0,390; 0,633; 0,800)
C3*	(0,078; 0,300; 0,611)	(0,389; 0,700; 1,000)	(0,272; 0,550; 0,889)	(0,000; 0,050; 0,278)
C4*	(0,197; 0,431; 0,700)	(0,328; 0,603; 0,867)	(0,415; 0,718; 0,967)	(0,197; 0,431; 0,700)
C5*	(0,250; 0,512; 0,833)	(0,288; 0,565; 0,867)	(0,096; 0,296; 0,567)	(0,250; 0,512; 0,833)
C6*	(0,114; 0,350; 0,695)	(0,250; 0,541; 0,900)	(0,091; 0,255; 0,532)	(0,091; 0,255; 0,532)
C7*	(0,132; 0,332; 0,570)	(0,359; 0,639; 0,870)	(0,510; 0,767; 0,900)	(0,283; 0,537; 0,810)
C8*	(0,510; 0,767; 0,900)	(0,330; 0,567; 0,767)	(0,750; 0,967; 1,000)	(0,570; 0,833; 0,967)
C9*	(0,256; 0,467; 0,700)	(0,434; 0,716; 0,900)	(0,639; 0,902; 1,000)	(0,332; 0,591; 0,833)
C10*	(0,417; 0,677; 0,833)	(0,306; 0,548; 0,767)	(0,639; 0,902; 1,000)	(0,361; 0,612; 0,800)

Figure 13. Weighted normalized fuzzy decision matrix

Step 7 involved determining the fuzzy positive and negative ideal solutions. Based on Chen's (2000) model and considering the number of criteria (n), the fuzzy positive and negative ideal solutions were determined using Equations (3) and (4). For benefit criteria, the maximum values represented the ideal solution, whereas for cost criteria, the minimum values were taken as ideal.

$A^* = [(1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1)]$

$A^- = [(0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0)]$

Step 8 involved calculating the distances from the fuzzy ideal solutions. For the 10 criteria and four alternatives, the Vertex method was used to calculate the distance of each alternative from the Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS). The distance values for the positive and negative ideal solutions are presented in Figures 14 and 15, respectively.

Criteria	d(A1*, A+)	d(A2*, A+)	d(A3*, A+)	d(A4*, A+)
C1*	0,57	0,25	0,41	0,53
C2*	0,42	0,22	0,11	0,43
C3*	0,71	0,39	0,50	0,90
C4*	0,59	0,46	0,38	0,59
C5*	0,53	0,49	0,71	0,53
C6*	0,66	0,51	0,73	0,73
C7*	0,68	0,43	0,32	0,50
C8*	0,32	0,48	0,15	0,27
C9*	0,56	0,37	0,22	0,46
C10*	0,40	0,50	0,22	0,45
di+	**5,43**	**4,10**	**3,73**	**5,38**

Figure 14. Distances from the positive ideal solution

Criteria	d(A1*, A−)	d(A2*, A−)	d(A3*, A−)	d(A4*, A−)
C1*	0,48	0,83	0,65	0,54
C2*	0,62	0,86	0,94	0,63
C3*	0,40	0,74	0,62	0,16
C4*	0,49	0,64	0,74	0,49
C5*	0,58	0,62	0,37	0,58
C6*	0,45	0,62	0,34	0,34
C7*	0,39	0,66	0,74	0,58
C8*	0,74	0,58	0,91	0,81
C9*	0,51	0,71	0,86	0,62
C10*	0,66	0,57	0,86	0,62
di−	**5,33**	**6,83**	**7,05**	**5,38**

Figure 15. Distances from the negative ideal solution

Step 9 involved calculating the closeness coefficients. Using the distances from the fuzzy positive and negative ideal solutions obtained from the AI decision-makers' evaluations, the closeness coefficient (C*) was calculated for each alternative. This value indicates the relative closeness of each alternative to the positive ideal solution.

Step 10 involved ranking the alternatives. The calculated C_i values were ordered from highest to lowest to determine the final priority ranking of the school alternatives. C_i value closer to 1 indicates that the corresponding alternative is closer to the positive ideal solution (Figure 16).

Alternatives	d_i^+	d_i^-	CC_i	Arrangement
A1*	5,43	5,33	0,4954	**4**
A2*	4,10	6,83	0,6249	**2**
A3*	3,73	7,05	0,6540	**1**
A4*	5,38	5,38	0,5000	**3**

Figure 16. Closeness coefficients and ranking of the AI-based alternatives

Accordingly, the final ranking obtained from the AI-based Fuzzy TOPSIS analysis was A3* > A2* > A4* > A1*. A3*, İskenderun Primary School, had the highest closeness coefficient and was therefore identified as the most favorable alternative in terms of biophilic spatial performance.

5. Discussion

The purpose of this paper was to find out where there are similarities and differences between decisions made by humans through an expert system versus those generated by artificial intelligence models without changing any

parameters such as criteria pools, alternatives sets or fuzzy TOPSIS method. Findings indicate there are three aspects to consider when comparing them - criteria priority, criteria composition and final rankings for options available.

There was a 60% overlap among the top ten criteria chosen by experts and AI groups, showing some level of agreement between them. Overlapping Criteria - Visual Connection to Nature, Dynamic and Diffuse Light / Daylight, Plant/green Elementality; Temperature Fluctuation and Air Flow variability; Material connection with nature; Prospect and refuge are some of those that have been discussed most often by researchers as being part or aspect of Biophilia Architecture theory today. They are all observable through direct observation, measurement, and association with material properties like color of substances to brightness levels for example purposes.

In contrast, Connection with Natural Systems, Non-Rhythmic Sensory Stimuli, Presence of Water, and Complexity and Order were prioritized by the expert group but did not appear among the AI group's top 10 criteria. They include a sense of time for space, an embodiment/ sensory involvement to it, or some kind of indirect way that we interpret spaces through them. The higher priority given by experts might suggest that professional experience and field practice pay more attention to aspects not explicitly stated in texts but still have an impact on spatial perception. Non-visual connection to nature (Color and texture), mobility/way finding/ spatial organization, transitional spaces and spatial belonging are similarly clearly defined as a set of concepts that can be expressed categorically and described relative standardization within research papers. The model shows that AI based criteria prioritization is affected by how clearly and structurally an item of information can be expressed as part of text.

Differences were also evident in the importance weights assigned to the six criteria shared by both groups. Visual Connection with Nature, Material Connection with Nature, and Prospect and Refuge received the same fuzzy importance weights from the expert and AI groups. In contrast, Dynamic and Diffuse Light/Daylight, Plants and Green Elements, and Thermal and Airflow Variability received higher weights from the AI group. The largest difference was observed for Thermal and Airflow Variability.

These findings show that divergence between human experts and AI systems is not limited to which criteria are included in the decision model. Differences can also emerge in the relative importance assigned to criteria that both groups consider relevant. In other words, agreement on the inclusion of a criterion does

not necessarily imply agreement on its influence within the decision model. Previous research has similarly shown that changes in the relative importance assigned to criteria can alter the final positioning of alternatives in multi-criteria architectural decision models. In Tarakçı's (2026c) AHP–TOPSIS assessment of temporary shelter systems, changes in decision-maker priorities affected the relative performance of the alternative systems. Human–AI comparisons should therefore address not only criterion selection but also the relative weighting structure assigned to those criteria (Figure 17).

Criteria	Expert Group Weight	AI Group Weight	Status
Visual Connection with Nature	(0.90, 1.00, 1.00)	(0.90, 1.00, 1.00)	Shared – Same Weight
Dynamic and Diffuse Light / Daylight	(0.77, 0.93, 1.00)	(0.90, 1.00, 1.00)	Shared – Higher AI Weight
Plants and Green Elements	(0.50, 0.70, 0.90)	(0.70, 0.90, 1.00)	Shared – Higher AI Weight
Thermal and Airflow Variability	(0.37, 0.57, 0.77)	(0.63, 0.83, 0.97)	Shared – Higher AI Weight
Material Connection with Nature	(0.50, 0.70, 0.87)	(0.50, 0.70, 0.87)	Shared – Same Weight
Prospect and Refuge	(0.83, 0.97, 1.00)	(0.83, 0.97, 1.00)	Shared – Same Weight
Connection with Natural Systems	(0.50, 0.70, 0.87)	—	Expert Group Only
Non-Rhythmic Sensory Stimuli	(0.10, 0.30, 0.50)	—	Expert Group Only
Presence of Water	(0.30, 0.50, 0.70)	—	Expert Group Only
Complexity and Order	(0.70, 0.87, 0.97)	—	Expert Group Only
Non-Visual Connection with Nature	—	(0.50, 0.70, 0.90)	AI Group Only
Color and Texture	—	(0.57, 0.77, 0.90)	AI Group Only
Mobility and Wayfinding / Spatial Organization	—	(0.90, 1.00, 1.00)	AI Group Only
Transitional Spaces and Spatial Belonging	—	(0.77, 0.93, 1.00)	AI Group Only

Figure 17. Comparison of the fuzzy importance weights of the selected criteria between the human expert and AI groups

The findings suggest that the differences between human experts and AI-based decision-makers should not be interpreted as a simple distinction between "correct" and "incorrect" judgments, but rather as differences associated with the nature of the criteria. Strong convergence was observed for criteria that are physically identifiable, frequently discussed in the literature, and clearly expressed in linguistic terms, such as lighting, vegetation, materials, and thermal comfort. By contrast, divergence was more pronounced for criteria related to user experience, temporally evolving perception, sensory variability, and psychological or emotional relationships with space.

The relevance of such experiential dimensions in post-disaster environments is also supported by studies showing that users' sense of belonging and appropriation of space can contribute to psychological, social, and physical recovery (Tarakçı & Kavut, 2024). This finding is consistent with the theoretical framework of the present study: expert judgment in interior architecture considers not only whether a criterion is present, but also the type of spatial experience it produces. In post-disaster spatial assessment, integrating literature-based knowledge with user experience and expert judgment allows

the decision process to account not only for technical criteria but also for experiential spatial needs (Tarakçı & Kavut, 2026). Because AI-based decision-makers do not physically experience space, reproducing the relative importance of tacit and embodied criteria solely from structured textual knowledge remains more difficult.

The findings indicate that generative AI systems can produce a systematic and internally coherent evaluation structure in a multi-criteria interior architecture problem, but they do not represent all components of human expert judgment to the same extent. The 60% overlap at the criterion level suggests that AI systems were able to prioritize many of the well-defined and physically explicit components of biophilic design in a manner similar to that of human experts. This pattern indicates that AI may have a supporting role in stages such as preliminary screening of criterion pools, identification of measurable performance criteria, and large-scale comparative assessments. However, the divergence observed in criteria associated with spatial belonging, sensory variability, and user experience indicates that professional experience derived from direct engagement with space, together with embodied and empathic forms of assessment, is not fully reproduced by current AI systems. This supports the position introduced earlier in the study that AI is more appropriately considered a decision-support mechanism than a substitute for professional expertise. The findings of this study are based on responses generated by three generative AI systems at a specific point in time and through specific versions and interfaces. Because these systems are continuously updated, temporal changes in model behavior may limit the reproducibility of the findings. In addition, the AI systems evaluated the school alternatives using visual and textual information rather than direct spatial experience. Their information basis therefore differs fundamentally from that of human experts, and this difference may partly explain the divergence observed for experience-dependent criteria.

At the same time, applying the same decision structure to both human experts and AI systems made it possible to identify which components of interior architecture judgment can be represented through structured information and which remain more strongly dependent on professional experience and direct spatial engagement. In this respect, the study provides a basis for future research on AI-supported multi-criteria decision-making in interior architecture, particularly regarding the representation of tacit criteria such as user experience, spatial belonging, and embodied spatial perception.

6. Conclusions and Recommendations

The purpose of this research was to find out how much there are similarities between experts' decisions made by fuzzy TOPSIS models and those made by artificial intelligence based on their own data whereas they have identical criteria sets, alternatives among them and methodology used here. Findings indicate there is no straightforward difference between convergence and divergence for human knowledge vs machine learning models' performance. At the criterion-prioritization level, 60% of the top 10 criteria independently selected by the two decision-maker groups overlap. The convergence is primarily concerned with criteria that have a direct relationship to nature such as lighting conditions for plants, temperature levels of buildings etc. along with material properties like color reflectance index values or texture indices. On the other hand, there is a greater difference between these factors like "Connection to Nature", "Non-rhythmic sensory stimuli", "Presence of water," and "Complexity and order" that are related more closely with time-dependent multi-sensory/tacit aspects of space perception.

For alternative evaluation and final ranking purposes, an AI-based fuzzy TOPSIS model ranked İskenderun Primary School (A3*) at the top due to its proximity score. The result is more related to a school's relative performance against those that are easily recognizable by sight or definition. In general terms, these results show how generative artificial intelligence models are able to create an organized and consistent framework for evaluating multiple criteria within space planning tasks inside buildings; however, it doesn't capture everything about experts' opinions on them. Within the scope of this study, generative AI appears more suitable as a complementary decision-support tool for prioritizing structured criteria and conducting preliminary evaluations of alternatives than as a substitute for human expert judgment. In this sense, AI can help reveal which components of professional judgment can be represented through structured knowledge and which remain more strongly dependent on experiential and contextual expertise. Several practical, methodological, and theoretical recommendations follow from these findings. In practice, AI-based systems may support the evaluation of biophilic performance in post-disaster educational buildings, particularly during the preliminary screening of large numbers of alternatives, rapid comparisons based on measurable criteria, and the systematic processing of large datasets. However, human expert judgment should remain central to final-stage decisions involving user experience, spatial belonging, sensory comfort, and other experience-dependent criteria. AI-based

assessments may therefore be strengthened through site visits, expert validation, or other forms of direct spatial assessment. A hybrid decision model that combines AI-supported analysis with expert-based evaluation may offer a more effective balance between analytical efficiency and professional validity.

Methodologically, future studies could examine whether richer forms of input improve agreement between experts and AI systems. School alternatives could, for example, be evaluated using 360-degree imagery, video recordings, or other multimodal spatial data rather than relying solely on written descriptions and static images. Longitudinal studies could also assess the consistency of large language models as their underlying systems and interfaces are updated over time. Increasing the number of AI decision-makers and comparing different large language models, model versions, and prompt designs would further help assess the robustness and generalizability of AI-supported multi-criteria decision-making. From an academic perspective, this paper identifies criteria-based divergences as a foundation to understand interior design skills by means of two main aspects such as formalized information and informal/tacit experience. Future studies may classify biophilia-based architecture on these two parameters and devise various decision support models accordingly. Structured criteria can be assessed by an artificial intelligence-based pre-assessment while tacit knowledge dependent ones may require a more qualitative approach such as participant involvement or expertise evaluation methods. This would help to improve theory behind human-AI collaboration for interior design decisions.

In conclusion, results of this study on post-disaster education facilities need to be validated through testing at various locations for diverse users' needs. Expanding this analysis beyond current settings will provide more clarity on when artificial intelligence is most effective at supporting experts' judgments while still being necessary for direct human expertise and experience.

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CHAPTER V

RISKS AND DISASTERS IN URBAN PLANNING EDUCATION: A COMPARATIVE STUDY OF TURKISH PLANNING CURRICULA

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1. INTRODUCTION

Disasters cause extensive natural, economic, and social damage in the geographical areas where they occur. In 2025, the EM-DAT database recorded 358 reported disasters worldwide. These events resulted in 16,607 deaths and affected 110.2 million people Centre for Research on the Epidemiology of Disasters [CRED], 2026. Natural events such as earthquakes, volcanic eruptions, landslides, and avalanches affect human settlements and create growing risks (Bull-Kamanga et al., 2003). Their adverse effects are particularly severe in areas with large and densely concentrated populations.

Among atmospheric events, tropical cyclones, hurricanes, hailstorms, and severe ice and snow events are becoming more severe due to rising temperatures and changing weather conditions associated with climate change. Hydrological disasters, including river floods, coastal floods, and droughts, are also influenced by urbanization and environmental change (Dilley et al., 2005). In the case of biological disasters, epidemics are among the events that most strongly affect urban areas (Drake et al., 2023), while fires have also become more prominent due to the combined effects of climate change and human activities" now reads "… while wildfires are also increasingly discussed in relation to climate change and human activities. Hydrogeological disasters such as floods and landslides may

result in loss of life, property damage, and the disruption of livelihoods (Cazabat, 2022). Climate-related and geophysical hazards, including earthquakes, floods, and fires, have significant consequences for communities (Matthews & Thorsen, 2020). Storms and floods are also among the most common events leading to population displacement (Cazabat, 2022).

Communities affected by disasters may be required to live in overcrowded temporary or permanent accommodation. During such periods, interruptions in access to safe water and sanitation, together with inadequate healthcare services, increase the risk of infectious disease outbreaks, which can be regarded as secondary consequences of disasters (Watson et al., 2007).

From a technological perspective, transport accidents, industrial disasters, explosions and fires, as well as the leakage of toxic or radioactive substances, continue to pose serious risks to people and other living beings in urban areas. In rapidly growing cities in particular, unsafe buildings and facilities increase the risk of structural collapse and fire (Huq et al., 2007). The storage, transportation, and improper handling of hazardous materials also create potential risks that may interact with natural hazards.

Finally, transboundary air pollution, climate change, and sea-level rise, all of which are associated with global environmental change, pose serious threats to the balance and sustainability of ecosystems worldwide. Environmental degradation caused by desertification, the depletion of natural resources, and intensive urbanization is also among the risks experienced at the global scale (Wamsler, 2014).

Risks and disasters are unavoidable concerns of planning because of the many social, economic, and environmental problems associated with urbanization. Accordingly, many countries develop policies to improve preparedness for disasters and risks, while measures are taken at both spatial and institutional levels. Numerous national and regional action plans and policies include regulations addressing disasters and risks ((Afet ve Acil Durum Yönetimi Başkanlığı [AFAD], 2022; T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2023). In addition, relevant public institutions and organizations seek to raise awareness of disasters and risks, particularly through universities (van Ginkel, 2004). Urban and regional planning is one of the disciplines actively involved in comprehensive and interdisciplinary work, especially during the pre-disaster stages of risk assessment and measurement, including hazard identification, database development, vulnerability assessment, damage assessment, and loss estimation and risk mitigation through land-use planning.

The planning profession is not merely a complementary discipline that becomes involved during disaster response and recovery. It also has a decisive role in preventing risks from turning into disasters by shaping the spatial conditions through which such risks are produced. Planning is responsible for integrating disaster risk reduction activities into the planning, design, construction, and operation of the built environment (Chmutina et al., 2014). It also contributes actively to disaster prevention and recovery by involving different actors and stakeholders in risk-reduction processes and defining their rights and responsibilities (Chmutina et al., 2014). In this respect, urban planners not only reduce post-disaster risks but also help prevent future disasters by creating safer and more resilient places. Planning education should therefore be structured to cover the fields in which future planners will work and to provide the technical, theoretical, and practical skills these fields require (Frank et al., 2014).

The foundations of urban and regional planning education in Türkiye began to take shape at the Sanayi-i Nefise Mektebi (Academy of Fine Arts), particularly through urban planning courses and seminars introduced there from the 1920s onwards. Urbanism education gained greater importance through the courses delivered by Celal Esat Arseven at intervals from the early 1920s until 1941. It developed further when the political uncertainty and wartime conditions in Europe led many European scholars to continue their academic work and contribute to higher education in Türkiye. In the second half of the twentieth century, the establishment of urban planning departments enabled the discipline to develop its own academic staff. As planning programs expanded across different cities, they provided comprehensive education and contributed to the growth of a professional planning community in the country.

Educational reforms associated with Türkiye's EU accession process and the Bologna Process have encouraged efforts to make curricula more comparable across higher education institutions. Frank et al. (2014) argued that the growing diversity and pluralism of planning education models in Europe could create difficulties for international professional recognition and the establishment of common standards. They also noted that planning education in Europe has been influenced by changes in planning practice paradigms and the profession, European integration policies, the Bologna Process, and wider transformations in the higher education sector.

These changing global agendas increasingly affect the content of curricula in educational institutions. For example, there is broad agreement on the importance of educating urban planners who can develop effective responses to

climate change and managing and protecting natural resources. In this context, courses addressing climate change have increasingly been incorporated into planning curricula in recent years (Infield et al., 2023; Laurian & Göçmen, 2025; Preston-Jones, 2020).

How urban and regional planning schools prepare future planners is a critical question in Türkiye, where the devastating effects of disasters are experienced intensely. This study thus aims to identify how risks and disasters are addressed in the undergraduate curricula of higher education institutions in Urban and Regional Planning programs in Türkiye and to comparatively examine the changes made following the earthquakes of 6 February 2023. For this purpose, the undergraduate course information packages of the universities identified through the Council of Higher Education Undergraduate Atlas (YÖK Atlas) were reviewed in two periods: between July and October 2023 following the earthquakes, and between March and July 2026 using the same criteria. The identified courses were then examined by using content and descriptive analysis. In this way, the study discusses the extent to which planning education updated its agenda in this field following a major disaster and develops a framework for future curriculum development.

2. METHOD

Qualitative research methods and techniques were used in this study. Qualitative research can be defined as a process that uses data collection methods such as qualitative observation, interviews, and document analysis to present findings in a holistic manner (Yıldırım & Şimşek, 2018). In this study, document review was used for data collection, while content analysis was applied to analyze the data (Bailey, 2008; Büyüköztürk et al., 2013; Krippendorff, 2013).

In line with the purpose of the study, course information packages were examined as written materials that provide detailed information about the scope of courses related to disasters and risks. A course information package covers the course aim, content, notes, and teaching methods (Kalite Yönetim Birimi, 2023). The course aim states what students are expected to gain, while the course content lists the subjects to be covered throughout the semester. Course notes provide any additional information that needs to be communicated beyond the stated content, whereas teaching methods explain how the course will be delivered and which skills it is intended to develop. These packages are useful both for informing students about the course and for guiding instructors in its planning and delivery.

Course information packages were selected as the documents for this study because they provide the most comprehensive and comparable information about the content and delivery of a course. The document review was conducted in four stages: (1) accessing the documents, (2) checking their authenticity, (3) understanding the documents, and (4) analyzing the data (Forster, 1994). Data were collected in two different periods. The first review was conducted between July and October 2023, in the months following the earthquakes of 6 February 2023, which affected 11 provinces in Türkiye. The curricula examined during this period largely reflected programs designed before the earthquakes. The second review was conducted at the same institutions between March and July 2026, based on the curricula in effect during the spring semester of the 2025–2026 academic year. This review aimed to determine whether the heightened institutional and public awareness of disasters following this destructive event had been reflected in the curricula. The same sampling criteria were applied in both reviews.

In the first stage, which involved accessing the documents, the universities with active undergraduate programs in Urban and Regional Planning were identified through the continuously updated YÖK Atlas website (YÖK Atlas, n.d.) in both review periods. An active program was defined as one in which students were currently enrolled. The number of active programs was 35 in the first review conducted in 2023 and 37 in the second review conducted in 2026. The newly established programs at Niğde Ömer Halisdemir University and Bolu Abant İzzet Baysal University had not yet become operational across all four years or produced graduates. Their curricula therefore did not cover the full duration of undergraduate education. As disaster- and risk-related courses taught in the later years may not yet have been introduced in these programs, the comparative analysis was conducted using the 35 programs included in both review periods. The two newly established programs were evaluated separately (Figure 1).

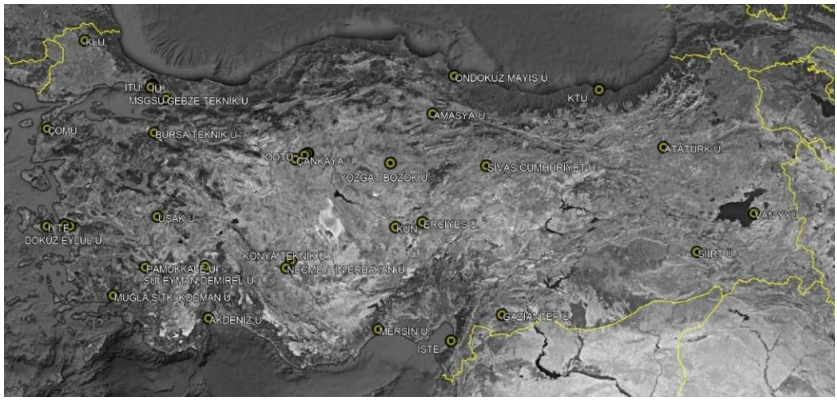


Figure 1. Universities with undergraduate program in Urban and Regional Planning in Türkiye (Source: By the author using Google Earth Pro, 2025).

In the second stage, the authenticity and completeness of the data were checked. For this purpose, the following information included in each course form was examined:

- course profile, including the semester in which it was offered, its status as compulsory or elective, and its credits;
- curriculum design, including the course title, aim, content, subjects, and competencies/learning outcomes; and
- assessment and evaluation methods, including assignments, seminars, practical work, presentations, projects, and examinations.

Courses lacking one or more of these components were excluded.

In the third stage, which involved understanding the documents, the collected data were systematized according to the purpose of the study before the analysis. For this purpose, the course information packages were searched for the words “disaster” and “risk.”

In the fourth stage, the sample was determined before the data were analyzed. As the study focuses on risks and disasters, the identified courses were screened for their relevance to these subjects. To be included in the sample, the concepts of “disaster” and/or “risk,” including the commonly used synonym “catastrophe,” had to appear either in the course title or in at least one of the four fields of the course information package: aim, content, subjects, or competencies/learning outcomes. Courses whose information packages were not publicly accessible or contained no information (including the relevant courses at Mersin and Siirt

universities and individual courses at Amasya and Atatürk universities), as well as courses not offered during the period reviewed (including an individual course at Pamukkale University), were excluded from the sample.

The 31 courses that met these criteria and were available during the 2023 review constituted the first sample. The 28 new courses added to the curricula between 2023 and 2026 formed the second sample. The course information packages included in these samples were examined through document and content analysis in relation to the research questions.

The courses in the sample were classified as directly or indirectly related according to the extent of their connection with the planning discipline. Courses were coded as directly related when the concept of disaster or risk appeared in the course title, or when it was addressed in at least 40% of the weekly subjects and was also included in the course aim or content. Courses in which disaster or risk was mentioned only as a single subtopic or covered for one week were coded as indirectly related. The courses were also coded according to how they were offered: departmental elective (DE), university elective or taken from outside the department (UE), and departmental compulsory (DC).

The data were examined using content analysis. At this stage, the collected information was reviewed, organized under specific themes, and grouped into defined categories (Patton, 2002). Descriptive names or codes were assigned to sections that formed meaningful units in themselves. After all the data had been coded, a code list was compiled. This list served as a coding key for reviewing and organizing the data and was used by both the researcher and the other coders. The coding process covered the course titles, aims, contents, subjects, and learning outcomes.

To ensure coding reliability, three researchers participated as coders and independently coded the raw data. Intercoder agreement was calculated as follows. For example, in the coding of course aims, the first coder identified 18 codes, the second identified 20, and the third identified 17. The codes were then marked according to whether they converged or differed (Table 1). Miles and Huberman (1994, p. 64) refer to converging codes as “agreements” and differing codes as “disagreements.” Intercoder reliability was calculated by dividing the number of agreements by the total number of agreements and disagreements and multiplying the result by 100. The results are presented in Table 1.

Table 1. Intercoder reliability results for the coding of course aim in undergraduate programs concerning risks and disasters

Coder comparison	2023 coding	2026 coding
I–II	89%	85%
I–III	94%	84%
II–III	94%	88%
All three coders	Approximately 81%	84%

As shown in Table 1, the level of agreement in the 2023 coding was 89% between Coders I and II, 94% between Coders I and III, 94% between Coders II and III, and approximately 81% across all three coders. According to the Miles and Huberman reliability formula, an initial agreement level of at least 70% is considered acceptable (Miles & Huberman, 1994).

The content analysis was repeated using the same procedure for the new courses included in the sample during the 2026 review. The same three coders independently coded these courses using the 2023 coding key. In this round, agreement ranged from 84% to 88% between coder pairs and was calculated as 84% across all three coders (Table 1). The course information packages belonging to the 2023 sample were also reviewed again in 2026. As no changes were identified in their content, the codes assigned in 2023 were retained.

3. FINDINGS

The findings are organized into three main sections in line with the research questions (Table 2).

Table 2. Research questions and classification of the findings

Research question	Scope of the findings
(1) What is the status of courses concerning risks and disasters in Urban and Regional Planning programs in Türkiye?	Identification of courses directly and indirectly related to risks and disasters; course status (compulsory or elective), level, and credits.
(2) Which teaching, assessment, and evaluation methods are used in courses concerning risks and disasters in Urban and Regional Planning programs in Türkiye?	Teaching methods and course delivery; assessment and evaluation methods.
(3) Which concepts are addressed in the aims, contents, subjects, and learning outcomes of courses concerning risks and disasters in Urban and Regional Planning programs in Türkiye?	Content analysis of course aims, contents, subjects, and competencies/learning outcomes.

3.1. Courses on Risks and Disasters in Urban and Regional Planning Curricula

This section presents the courses in undergraduate Urban and Regional Planning programs that were identified as directly or indirectly related to risks and disasters. It also examines the titles under which these subjects are addressed at different universities and whether the courses are offered as electives (E) or compulsory courses (C). The 2023 review showed that 22 of the 35 universities offering Urban and Regional Planning education in Türkiye had at least one course directly or indirectly related to risks and disasters. The relevant courses at Mersin and Siirt universities were excluded from the analysis because their course information packages were empty. In total, 31 relevant courses were identified, of which 23 were elective (74%) and eight were compulsory (26%). The programs at Çanakkale Onsekiz Mart University (four courses), Akdeniz University (three courses), and and Amasya, Dokuz Eylül, Gazi, and Istanbul Technical universities (two courses each) included more than one course related to the subject (Table 3).

Table 3. Courses on Risks and Disasters in Undergraduate Urban and Regional Planning Programs[1]

University Name	Course Name	Direct	Indirect	2023	2026
Akdeniz U.	European Union Environmental, Nature and Landscape Policy (DE)		✓	✓	
	Fire Protection in Buildings (UE)		✓	✓	
	Volunteering Studies (UE)		✓	✓	
	Natural Disasters in Urban and Built Environments (DE)	✓			✓
Amasya U.	Environment and Ecology (DE)		✓	✓	
	Urban Analysis Techniques (DC)		✓	✓	
	Urban Coastal Planning and Design (DE)		✓		✓
	Climate Change, City and Planning (DE)		✓		✓
Atatürk U.	Analysis and Evaluation Techniques in Planning (DC)		✓	✓	
	Contemporary Approaches to Planning (DE)		✓		✓
Bursa Tech. U.	Regeneration of Obsolete Areas (DE)		✓	✓	
	Urban Sociology (DE)		✓		✓
Çanakkale Onsekiz Mart U.	Disaster Risk Reduction in the Built Environment (DE)	✓		✓	
	Disaster Risk Management and Planning (DE)	✓		✓	
	Remote Sensing and Geographic Information Systems in Disaster Risk Management (DE)	✓		✓	
	Climate Science and Change (DE)		✓	✓	
	Urban Climate (DE)		✓		✓
Çankaya U.	Nature, Risk and Mitigation Planning (DC), removed by 2026	✓		✓	
	Current Issues in Urban and Regional Planning (DE)		✓		✓
	New Political Debates in Planning (DE)		✓		✓

1 A check mark indicates the classification of each course and the review period in which it entered the sample. “2026” includes only courses introduced after the 2023 review. DE: departmental elective; UE: university elective; DC: departmental compulsory. Official English course titles were retained where available; where they were unavailable, the original Turkish titles were translated into English by the author.

Dokuz Eylül U.	Risk Management and Mitigation Planning for Natural Disasters (DE)	✓		✓	
	Urban Infrastructure (DC)		✓	✓	
Erciyes U.	Disaster Management and Mitigation Planning (DE)	✓		✓	
Gazi U.	Resilient Cities (DE)	✓		✓	
	Conservation of Cultural Heritage Areas at Risk (DE)		✓	✓	
	Urban Geology and Planning (DC)		✓		✓
Gaziantep U.	Disaster Mitigation in Urban Planning (DE)	✓			✓
	Urban Environment and Sustainability (DC)		✓		✓
Gebze Tech. U.	Current Issues in Planning (DC)		✓	✓	
İskenderun Tech. U.	Disaster and Risk Management (DE)	✓		✓	
Istanbul Tech. U.	Disaster Mitigation in Urban Planning (DE)	✓		✓	
	Natural Hazards and Urban Safety (DE)	✓		✓	
	Healthy Cities (DE)		✓		✓
Istanbul University	Disaster Management and Planning (DC)	✓		✓	
Kapadokya U.	Urban Geology and Planning (DE), removed by 2026		✓	✓	
	Climate Crisis and Urbanization (DE)	✓			✓
	Natural Hazards and Urbanization (DE)	✓			✓
	Planning in Areas at Risk of Disaster (DE)	✓			✓
Karadeniz Tech. U.	Natural Disasters and Planning (DE)		✓	✓	
	Vulnerability and Resilience in Planning (DE)	✓			✓
Kırklareli U.	Disaster Risk Management and Urban Planning (DE)	✓			✓
Konya Tech. U.	Planning and Geology (DC)		✓	✓	
Mimar Sinan Fine Arts U.	Urban Regeneration Projects in Türkiye (DE)		✓		✓
	Urban Information Systems (DE)		✓		✓
Muğla Sıtkı Koçman U.	Disaster and Risk Management in Planning (DE)	✓		✓	
Necmettin Erbakan U.	Urban Geology and Planning (TS-3) (DE)		✓	✓	

Ondokuz Mayıs U.	Ecological Approaches to Urban Planning (DE)		✓		✓
Pamukkale U.	Disaster Planning (DE)	✓		✓	
	Global Climate Change and Biology (UE)		✓		✓
Sivas Cumhuriyet U.	Urban Geology, Natural Disasters and Planning (DC)	✓		✓	
Süleyman Demirel U.	Planning and Design in Disaster-Affected Areas (DE)	✓		✓	
Van Yüzüncü Yıl U.	Disaster Management (UE)	✓			✓
	Geological and Geotechnical Principles in Land-Suitability Assessments (DE)	✓			✓
	Disaster and Risk Management (UE)	✓			✓
Yıldız Tech. U.	Disaster Prevention and Disaster Risk Reduction in Planning (DE)	✓		✓	
	Disaster Knowledge and Awareness (UE)	✓			✓
Yozgat Bozok U.	Natural Disasters (UE)	✓			✓
	Disaster Management (UE)	✓			✓
	Epidemics in Disasters (UE)	✓			✓

The courses were classified as directly or indirectly related according to the prominence of risk and disaster concepts in their titles, aims, contents, and weekly subject schedules. Based on the course status and the departmental affiliation of the instructor, they were also coded as departmental electives (DE), university electives or courses taken from outside the department (UE), and departmental compulsory courses (DC). Of the 31 courses in the 2023 sample, 16 (52%) were directly and 15 (48%) indirectly related to risks and disasters. An examination of their titles shows that directly related courses generally focused on disaster and risk management, mitigation planning, disaster loss reduction, natural hazards and urban safety, and planning in disaster-affected areas. Indirectly related courses addressed subjects such as environment and ecology, urban analysis techniques, planning analysis, urban regeneration, geology and planning, climate science, and risks to cultural heritage (Table 3).

The 2026 review revealed a notable expansion in the provision of courses related to risks and disasters following the earthquakes of 6 February 2023.

Twenty-eight new courses had been added to the curricula by this period, comprising 14 directly and 14 indirectly related courses (Table 3, 2026 columns). Eighteen universities introduced at least one new course. Six programs that had included no relevant courses in 2023 at Gaziantep, Kırklareli, Mimar Sinan Fine Arts, Ondokuz Mayıs, Van Yüzüncü Yıl, and Yozgat Bozok universities listed such courses for the first time. Alongside disaster, climate change/crisis appeared in several titles, and vulnerability and resilience emerged for the first time.

Of the 14 newly identified directly related courses, six were disaster-awareness electives offered university-wide to students from all departments (UE). The number of new directly related courses added to the planning departments' own curricula was therefore eight. Of all 28 newly introduced courses, 26 were elective and only two were compulsory: *Urban Geology and Planning* at Gazi University and *Urban Environment and Sustainability* at Gaziantep University. Both compulsory courses were classified as indirectly related. In contrast, Çankaya University removed its directly related compulsory course, *Nature, Risk and Mitigation Planning*, from the curriculum. Some courses could not be included in the sample because their information packages were empty or they were not offered during the period examined. These included *Disaster-Resilient Planning and Design* at Atatürk University, whose title clearly indicates a direct connection with the subject.

The distribution of courses by year and status (Table 4) shows that, in both periods, they were predominantly offered as upper-year electives. In the 2023 sample, directly related courses were largely concentrated among fourth-year electives, with nine of the 16 courses offered at this level. By contrast, the directly related courses introduced by 2026 shifted towards second- and third-year electives, with five courses offered at each level. Neither period included a directly related first-year course, and directly related compulsory courses were very limited. No common pattern was found among universities regarding the semesters in which compulsory courses were taught.

In 2023, only three courses were both compulsory and directly related to risks and disasters: *Nature, Risk and Mitigation Planning* at Çankaya University, *Disaster Management and Planning* at Istanbul University, and *Urban Geology, Natural Disasters and Planning* at Sivas Cumhuriyet University. No new course combining these two characteristics was introduced by 2026. Moreover, Çankaya University removed its relevant compulsory course from the curriculum. Overall, most of the 59 courses identified across the two periods were elective and concentrated in the third and fourth years of undergraduate education.

Table 4. Levels of Compulsory (C) and Elective (E) Courses on Risks and Disasters (2023–2026)

Period/relationship	Year								Total
	1 C	1 E	2 C	2 E	3 C	3 E	4 C	4 E	
2023 Direct	–	–	1	2	1	2	1	9	16
2023 Indirect	1	1	3	–	1	3	–	6	15
2023 subtotal	**1**	**1**	**4**	**2**	**2**	**5**	**1**	**15**	**31**
2026 Direct	–	–	–	5	–	5	–	4	14
2026 Indirect	–	1	2	3	–	5	–	3	14
2026 subtotal	**–**	**1**	**2**	**8**	**–**	**10**	**–**	**7**	**28**
Overall total	**1**	**2**	**6**	**10**	**2**	**15**	**1**	**22**	**59**

When the two periods are considered together, the findings suggest that the heightened awareness created by the 2023 earthquakes was reflected in a quantitative expansion of course provision but did not produce a comparable structural change in the curricula. Although the increase in the number of courses is noteworthy, almost all the newly introduced courses were electives. Moreover, nearly half of the new directly related courses were university-wide awareness courses offered outside departmental curricula. There was no net increase in the number of courses that were both compulsory and directly related to risks and disasters; one such course at Çankaya University was instead removed from the curriculum. Thus, despite the experience of a major disaster, risks and disasters remain subjects addressed primarily through upper-year electives rather than being integrated into the compulsory core of planning education.

3.2. Teaching and Assessment Methods Used in the Courses

This section examines the teaching methods, modes of delivery, and assessment methods used in the 31 courses included in the 2023 sample after the screening process. Assignments, presentations, projects, and practical work were identified in the course information packages as semester activities, while face-to-face teaching, laboratory work, and technical visits were recorded as modes of course delivery.

As almost all the courses were theoretical, face-to-face lectures (n = 31, 100%) were specified as the mode of delivery in every course, while midterm or final examinations (n = 30, 97%) were used as an assessment method in nearly all of them. Assignments (n = 21, 68%) and presentations (n = 18, 58%) were also widely used. Practical work (n = 7, 23%) and projects (n = 5, 16%), however, were less common.

Active and practice-based forms of assessment, such as projects and practical work, were found mainly in directly related courses. Projects were included in five courses: *Remote Sensing and Geographic Information Systems in Disaster Risk Management*, *Climate Science and Change*, *Disaster Management and Mitigation Planning*, *Disaster and Risk Management in Planning*, and *Urban Geology, Natural Disasters and Planning*. Practical work was specified in seven courses. Laboratory work was included only in *Remote Sensing and Geographic Information Systems in Disaster Risk Management*, while technical visits or fieldwork were included in *Volunteering Studies* and *Planning and Geology*.

The assessment structures of the 28 new courses included in the 2026 sample showed a similar pattern. Face-to-face teaching (n = 27, 96%) and examinations (n = 27, 96%) remained the main methods in almost all the courses. Assignments were again common (n = 19, 68%), whereas the use of presentations declined considerably (n = 7, 25%). Practical work (n = 2, 7%) and projects (n = 1, 4%) had almost disappeared. Furthermore, the project, practical work, and technical visit activities identified in this period appeared only in two indirectly related courses, *Contemporary Approaches to Planning* and *Urban Sociology*. The newly introduced directly related courses, by contrast, relied primarily on face-to-face lectures and examinations (Table 5).

Table 5. Teaching and Assessment Methods Used in the Courses (2023–2026)

Method	2023 (n = 31)	Frequency (%)	2026 (n = 28)	Frequency (%)
Face-to-face teaching	31	100	27	96
Examination (midterm/final)	30	97	27	96
Assignment	21	68	19	68
Presentation	18	58	7	25
Practical work	7	23	2	7
Project	5	16	1	4
Technical visit/ fieldwork	2	6	2	7
Laboratory work	1	3	–	0

When the two periods are considered together, the teaching and assessment structures remained largely centered on theoretical instruction and examinations.

Practice-based assessment methods such as projects and practical work, which were present in directly related courses in 2023, were almost entirely absent from the directly related courses introduced by 2026. This suggests that although the number of courses addressing risks and disasters increased, the expansion was not accompanied by a shift towards practical and skill-oriented education. Disaster and risk education therefore continues to rely primarily on the transmission of theoretical knowledge.

3.3. Course Aims, Content, Subjects, and Learning Outcomes Related to Risks and Disasters

The findings concerning course content were derived from a content analysis of the 31 courses in the 2023 sample and the 28 new courses included in the 2026 sample. The analysis was organized under four components: course aims, content, subjects, and competencies/course learning outcomes. The resulting themes and categories are presented under these four components.

The findings from the content analysis of the **course aims** are presented in Table 6 for the 2023 sample and Table 7 for the 2026 sample. In 2023, the course aims were grouped under four themes: Disasters, Risks, Environment, and Planning.

Table 6. Aims of Undergraduate Courses Related to Risks and Disasters

Theme	Category
Disasters	Understanding and managing the social, cultural, and spatial effects of disasters; Emergency planning and crisis management; Types and effects of natural disasters
Risks	Ensuring building safety using geological data; Conducting risk analyses and developing risk-management strategies; Effects of technological threats on urban planning; Analyzing interactions between natural and technological hazards
Environment	Developing environmental awareness and promoting sustainability; Problems affecting the natural environment; Role of environmental effects in urban planning; Planning for sustainable living environments
Planning	Urban spatial analysis and planning; Developing strategies for the regeneration of urban areas; Urban infrastructure planning and management

Within the Disasters theme, the main areas of emphasis were understanding and managing the social, cultural, and spatial effects of disasters, emergency and crisis management, and the types of natural disasters. The Risks theme focused on ensuring building safety through geological data, risk analysis and management, and the examination of interactions between natural and technological hazards. The Environment and Planning themes complemented the disaster and risk focus more indirectly through environmental awareness, sustainability, urban spatial analysis, and urban regeneration. The aims of the new courses included in the 2026 sample were also examined under four themes (Table 7).

Table 7. Themes and Codes Identified in Course Aims (2026)

Theme	Codes
Disaster management and loss reduction	Disaster risk prevention and reduction; post-disaster recovery; disaster management cycle; crisis management and coordination; disaster awareness; institutional actors and disaster preparedness; disasters and public health, including epidemics; discussion of social, economic, and environmental effects
Hazard and risk analysis	Identifying natural hazards; analyzing and assessing disaster risks; using geological and geotechnical data; integrating risk data into planning processes and land-use decisions
Risk-sensitive planning and design	Development restrictions and building decisions; land-suitability assessment; strategies for critical infrastructure; disaster-resilient planning and design; vulnerability and resilience; connections between ecological systems and sustainability; climate change and urbanization
Climate change and urban risk	Climate change adaptation, mitigation, and policy development; developing a climate-sensitive planning perspective

As shown in Table 7, the aims of the new courses were concentrated around disaster management and loss reduction, hazard and risk analysis, risk-sensitive planning and design, and climate change and urban risk. Compared with 2023, the aims moved away from broader environmental and general planning concerns towards more focused and current concepts. These included the disaster management cycle, vulnerability and resilience, the integration of

risk data into land-use decisions, and the development of a climate-sensitive planning perspective. This shift suggests that, in terms of course aims, the new courses are more closely aligned with contemporary disaster-risk discourse.

The findings of the course content are presented in Table 8 for the 2023 sample and Table 9 for the 2026 sample. In 2023, course content was grouped under five themes: Sustainability and Environmental Policy, Disaster Management and Risk Reduction, Planning and Analysis, Geology and Earth Sciences, and Community Participation and Volunteering.

Table 8. Content analysis of Undergraduate Courses Related to Risks and Disasters

Theme	Category
Sustainability and environmental policy	Global climate change and environmental problems; European Union environmental policies and their areas of implementation; Development of landscape policies and the European Landscape Convention; Types of environmental pollution and environmental impact assessment processes; Sustainable living environments and renewable energy sources
Disaster management and risk reduction	Types of disasters and concepts of risk management; Urban regeneration and disaster management processes; Strategies and methods for reducing the effects of disasters
Planning and analysis	Urban analysis; planning processes; Planning urban areas from ecological and disaster-sensitive perspectives
Geology and earth sciences	Relationship between earth sciences and disaster management; Disaster sensitivity and site-selection criteria
Community participation and volunteering	Concept and management of volunteering; Role and participation of communities in disaster and environmental issues

The Sustainability and Environmental Policy theme covered European Union environmental and landscape policies, the European Landscape Convention, and environmental problems. The Disaster Management and Risk Reduction theme included types of disasters, risk-management concepts, and strategies for reducing disaster impacts. Urban analysis and ecological and disaster-sensitive planning were prominent within Planning and Analysis. The Geology and Earth Sciences theme addressed the relationship between earth sciences and disasters, together with site-selection criteria. Community Participation and Volunteering focused on volunteering and the role of

communities in disaster and environmental issues. This distribution indicates that the 2023 course content extended across a relatively broad and dispersed range of subjects, including not only disasters and risks but also environment, geology, and community participation. The content of the new courses included in the 2026 sample was grouped under four themes (Table 9).

Table 9. Themes and Codes Identified in the Content of Newly Introduced Courses

Theme	Codes
Disaster management and loss reduction	Concept of disaster and the disaster management cycle; multi-actor governance and institutional responsibilities; disaster awareness and community preparedness; crisis management and coordination; post-disaster recovery and return to normality; disasters, public health, and epidemic management; social and cultural effects of disasters
Hazard and risk analysis and land suitability	Types of hazards and their formation processes; risk components, vulnerability, and capacity; risk analysis and risk management; micro-zoning and land-suitability studies
Risk-sensitive planning, design, and legislation	Incorporating risk information into planning; land use, site selection, and development decisions; disaster-safe construction and urban design; critical infrastructure, logistics, and storage areas; legislative and policy frameworks; coastal and riverine cities and flood risk
Climate change, resilience, and sustainability	Scientific foundations of climate change; relationships among urbanization, climate, and disasters; climate adaptation, mitigation, and action plans; resilient and sustainable urban planning; urban ecology and environmental management

As shown in Table 9, the new course content was concentrated around disaster management and loss reduction; hazard and risk analysis and land suitability; risk-sensitive planning, design, and legislation; and climate change, resilience, and sustainability. Compared with the more dispersed themes identified in 2023, such as environmental policy, geology, and volunteering, the 2026 content showed a more integrated and direct focus on disasters and risks. Greater attention was given to the disaster management cycle, the incorporation of risk information into planning and legislation, vulnerability and resilience, and climate adaptation. At the level of course content, this indicates a shift

from a dispersed and indirect framework towards a more focused and current approach to disaster and risk education.

The findings of course subjects are presented in Table 10 for the 2023 sample and Table 11 for the 2026 sample. In 2023, course subjects were grouped under four themes: European Union Environmental Legislation and Policies, Urban Planning and Analysis, Disaster Management and Urban Resilience, and Climate Change and Sustainable Development.

Table 10. Themes and Codes Identified in the Subjects (2023)

Theme	Codes
European Union (EU) environmental legislation and policies	EU Environmental Action Programs; Environmental and nature conservation directives; Integration of EU environmental policies into other fields; Legal and institutional instruments; Nature conservation programs and databases
Urban planning and analysis	Emergency planning; Urban analysis techniques and tools; Urban technical infrastructure and planning; Infrastructure services and planning; Urban infrastructure problems and management policies
Disaster management and urban resilience	Concept and management of disasters; Types and effects of natural disasters; Stages of disaster management and its legal framework; Risk analysis and disaster-prevention strategies; Disaster loss reduction and risk-reduction activities; Urban resilience and post-disaster reconstruction
Climate change and sustainable development	Climate change and its effects; Indicators of global warming and climate change; Effects of climate change on disasters and adaptation strategies; Sustainable Development Goals; Natural disasters and urban areas; Resource use and pollution; Biodiversity and soil conservation

The European Union Environmental Legislation and Policies theme covered EU environmental action programs, nature conservation directives and databases, and legal and institutional instruments. Urban Planning and Analysis included emergency planning, urban analysis techniques, and issues related to technical infrastructure. The Disaster Management and Urban Resilience theme addressed the concept and management of disasters, types of natural disasters, risk analysis, disaster-prevention strategies, and urban resilience.

Climate Change and Sustainable Development covered global warming, the effects of climate change on disasters, adaptation strategies, and the Sustainable Development Goals. Thus, alongside disaster- and risk-related subjects, the 2023 courses included relatively indirect areas such as EU environmental legislation and general urban infrastructure. The subjects covered by the new courses in the 2026 sample were grouped under four themes (Table 11).

Table 11. Themes and Codes Identified in the Subjects (2026)

Theme	Codes
Disaster management, governance, and community resilience	Concept and cycle of disasters; prevention and preparedness; crisis management; recovery and reconstruction; policies and practices; multi-actor governance; community awareness; social impacts and vulnerability; public health and quality of life
Hazard and risk analysis and land suitability	Types of hazards; seismic and ground-related hazards; hydrometeorological hazards; landslides and mass movements; risk analysis and mapping; earth sciences and micro zoning; land suitability; urban analysis and digital tools
Risk-sensitive spatial planning, development control, and infrastructure	Incorporating risk into planning; risk-based land use; development and safe design; resilient infrastructure; emergency assembly areas and logistics; flood management and river rehabilitation; development in coastal and riverine areas
Climate change, sustainability, and urban resilience	Relationships among climate, cities, and disasters; adaptation and mitigation; low-carbon planning; urban resilience; ecology and nature-based solutions; pollution and circular resource management

As shown in Table 11, the subjects of the new courses were structured around disaster management, governance, and community resilience; hazard and risk analysis and land suitability; risk-sensitive spatial planning, development control, and infrastructure; and climate change, sustainability, and urban resilience. The EU environmental legislation and general infrastructure subjects prominent in 2023 were replaced in the 2026 sample by areas more directly related to disasters and risks. These included seismic and ground-related hazards, micro zoning and land suitability, the incorporation of risk into land-use decisions, flood management and river rehabilitation, and urban resilience.

The greater focus already observed in the course content was therefore also evident in the subjects covered. The new courses approached disasters and risks through more technical, spatial, and practice relevant topics.

The findings concerning **competencies and learning outcomes** are presented in Table 12 for the 2023 sample and Table 13 for the 2026 sample. In 2023, the intended learning outcomes were grouped under three themes: Disaster Management and Urban Planning, Environmental and Nature Conservation, and Geology and Earth Sciences.

Table 12. Competencies and Learning Outcomes of Undergraduate Courses Related to Risks and Disasters

Theme	Category
Disaster management and urban planning	Disaster risk management; Disaster risk reduction; Disaster and risk analysis; Use of remote sensing and GIS in disaster management; Meteorology and climate change; Effects of disasters on urban planning; Disasters and urban regeneration
Environmental and nature conservation	Definitions of environment, nature, and landscape; Requirements for and reasons behind environmental and nature conservation; Approaches to environmental and nature conservation policies; Environmental action programs; European Union environmental policies; Conservation of nature and biodiversity
Geology and earth sciences	Geological assessment of settlements and site selection

In the Disaster Management and Urban Planning theme, the main intended outcomes included disaster risk management and reduction, disaster and risk analysis, the use of remote sensing and GIS in disaster management, meteorology and climate change, and understanding the effects of disasters on urban planning and regeneration. Environmental and Nature Conservation covered definitions of environment, nature, and landscape; environmental protection policies; EU environmental policies; and biodiversity conservation. Geology and Earth Sciences focused the geological assessment of settlements and site selection. Thus, alongside competencies directly related to disasters and risks, the 2023 outcomes also included relatively indirect areas such as environmental protection and geology. The learning outcomes of the new courses included in the 2026 sample were grouped under four themes (Table 13).

Table 13. Themes and Codes Identified in Course Competencies and Learning Outcomes (2026)

Theme	Codes
Disaster management and governance	Concepts, types, and effects of disasters; strategies, policies, and practices; prevention, mitigation, and recovery; social effects and vulnerability; participation and risk communication; ethics and public interest; health and first aid in disasters
Hazard and risk analysis and land suitability	Risk identification and analysis; risk components and indicators; multi-scalar risk assessment; digital risk analysis; earth-science data; land-suitability analysis
Risk-sensitive spatial planning and decision-making	Relationship between disasters and planning; risk-based land use; disaster-sensitive planning decisions; climate-sensitive planning; planning and development in coastal and riverine areas; planning proposals and strategies; spatial and thematic analysis
Climate change, sustainability, and resilience	Effects of climate change; relationships among climate, urbanization, and disasters; adaptation and mitigation strategies; resilient urban planning; ecology and biodiversity

As shown in Table 13, the learning outcomes of the new courses were structured around disaster management and governance; hazard and risk analysis and land suitability; risk-sensitive spatial planning and decision-making; and climate change, sustainability, and resilience. The competencies dispersed across environmental conservation and geology in 2023 were replaced in the 2026 sample by more practice- and decision-oriented competencies. These included risk identification and digital risk analysis, risk-based land use and disaster-sensitive planning decisions, climate-sensitive planning, and risk communication.

The content analysis reveals a shift from the broad and dispersed thematic structure of 2023 towards a more integrated and disaster-risk-focused framework in 2026. However, this greater focus at the level of course aims and content has not yet been supported by a structural change in course status or level, such as the incorporation of these subjects into the compulsory core curriculum. The intended outcomes therefore remain largely confined to elective courses and mainly conventional learning methods.

4. DISCUSSION

The discussion provides a comparative evaluation of the findings from the 2023 and 2026 reviews. A summary of the comparison between the two periods is presented in Table 14.

Table 14. Comparison of Courses Related to Risks and Disasters, 2023–2026

Indicator	**2023**	**2026**
Courses included in the sample	31	28
Number of Programs	22	18, including 6 for the first time
Directly related	16 (16 D + 0 U)	14 (8 D + 6 U)
Indirectly related	15 (13 D + 2 U)	14 (13 D + 1 U)
Compulsory/elective	8/23	2/26
***D:** course included in the departmental curriculum; **U:** university-wide common elective. The 2026 column includes only courses added to the curricula after 2023.*		

The expansion observed between 2023 and 2026 indicates that curricular agendas developed in parallel with international discussions concerning climate change and resilience. However, the nature of this expansion differs when the source of the courses is considered. University-wide disaster-awareness electives are a positive indication that disaster awareness has become more widespread in higher education. Nevertheless, they do not provide the theoretical and technical depth specifically required for planning education and should not therefore be interpreted as evidence that disaster and risk education has become institutionalized within planning curricula.

The main themes identified in 2023 remained present across all four analytical components. Disaster management, hazard and risk analysis, and risk-sensitive planning continued to form the conceptual foundation of the newly introduced courses. Three areas that had received limited attention in 2023, however, became considerably more prominent: climate change, including adaptation, mitigation, and climate action plans; vulnerability and resilience, including their concepts, types, and measurement methods; and the incorporation of risk information into development-control instruments, including development restrictions, safe construction, critical infrastructure, and micro zoning.

Across the four analytical components, disaster management, hazard and risk analysis, and risk-sensitive planning continued to form the main conceptual structure of the courses. However, climate change, vulnerability

and resilience, and the incorporation of risk information into development-control instruments became considerably more prominent in the new courses. Two previously unrepresented areas which are, disasters and public health, and coastal, riverine, and flood risks also entered the curricula, although their coverage remained limited. Table 15 summarizes this thematic continuity and change between the two periods.

Table 15. Thematic Synthesis of the 2023 and 2026 Content Analyses

Theme cluster	2023	2026: new courses	Trend
Disaster management and loss reduction	Present	Continued, with greater emphasis on recovery, the disaster management cycle, and coordination	Continuity and greater depth
Hazard and risk analysis	Present	Continued, with more detailed coverage of risk components, micro zoning, and land suitability	Greater depth
Risk-sensitive planning, development control, and legislation	Secondary	Expanded through development-control instruments, safe construction, critical infrastructure, and legislation	Considerably strengthened
Climate change	Secondary	Addressed across all four analytical components through adaptation, mitigation, action plans, and low-carbon planning	Considerably strengthened
Vulnerability and resilience	Marginally represented	More clearly represented through concepts, types, indicators, and measurement methods	Emerging theme
Disasters and public health	Absent	Newly introduced, mainly through university-wide electives	New theme
Coastal, riverine, and flood risks	Absent	Newly introduced but represented in only one program	New but limited theme
Community participation and governance	Present, mainly through participation	Expanded to include risk communication, ethics, and public interest	Expanded

The findings may also be interpreted through the concept of institutional capacity, which is central to the disaster risk-management literature. The Sendai Framework for Disaster Risk Reduction identifies understanding disaster risk as its first priority and emphasizes the need to develop capacity at all levels (United Nations Office for Disaster Risk Reduction [UNDRR], 2015). Planning schools are among the principal institutions responsible for developing this capacity because they educate professionals who will undertake responsibilities during the pre-disaster stage (Wamsler, 2014). The number of programs with relevant courses increased from 22 of 35 in 2023 to 28 by 2026. Nevertheless, the absence of a common structure across schools in terms of compulsory course provision, course level, and content indicates that this capacity-building role has not yet become institutionalized or standardized.

5. CONCLUSIONS

This study comparatively examined courses related to disasters and risks in active undergraduate Urban and Regional Planning programs in Türkiye during two review periods, 2023 and 2026, following the earthquakes of 6 February 2023. The course information packages were analyzed across four components: aims, content, subjects, and learning outcomes. Establishing the current situation in this type of research requires the systematic transformation, classification, and measurement of data in accordance with the defined research purpose.

The content analysis showed that the courses were structured in relation to shared agendas such as sustainability and climate change. Themes related to disaster management and planning, urban resilience, sustainability and environmental policy, and climate change formed the main conceptual framework. The comparison of the two periods revealed that the relatively dispersed thematic structure identified in 2023, which covered environmental policy, geology, and volunteering, developed into a more focused and current framework in 2026. The new courses placed greater emphasis on disaster management, hazard and risk analysis, risk-sensitive planning, and climate change and resilience.

This curricular update at the level of content, however, was not accompanied by a structural transformation. The courses were concentrated mainly in the third and fourth years and were generally elective, while the number of compulsory courses directly related to the subject remained very limited. Although 28 new courses were introduced following the 2023 earthquakes and six programs included relevant courses for the first time, the number of directly related

compulsory courses within departmental curricula did not increase. It instead declined following the removal of one such course. The fact that a considerable proportion of the new directly related courses consisted of university-wide disaster-awareness electives also suggests that the expansion reflected a broader increase in awareness rather than the institutionalization of the subject specifically within planning curricula.

Almost all the courses were theoretical. Active learning activities such as projects and practical work remained limited and became even less common among the courses introduced by 2026. This suggests that undergraduate planning education does not sufficiently develop the practical skills required for planners' pre-disaster responsibilities, particularly risk assessment and mitigation planning.

Considering these results, disaster and risk-reduction principles should be incorporated into Urban and Regional Planning education more widely and systematically. Rather than remaining limited to elective specialist courses, the subject should be represented by at least one compulsory course within the core curriculum. Education in this area should also be strengthened through experiential learning components, including GIS-supported risk analysis, scenario-based studio work, and field-based exercises. These components would improve planning students' conceptual and technical competence and help them understand the complex relationships among risks, disasters, and climate change and translate this knowledge into professional practice. Such integration, however, requires the development of specialized course content and the allocation of qualified academic staff and adequate resources.

Integrating disaster and risk management into the curriculum may also increase students' awareness of the importance of disaster prevention and management. Participatory course content could further contribute to the development of a culture of disaster and risk management among students and within the wider community.

Finally, the absence of a shared national database for course information packages, together with incomplete or inaccessible packages in some programs, limits the scope of studies of this kind. The findings represent two temporal snapshots based on course information collected between July and October 2023 and between March and July 2026. They do not capture subsequent changes in the number of programs or courses. Limited access to course information is an obstacle not only for researchers but also for students seeking information about course content and delivery. Further research on this subject could contribute

to the field by supporting the development of different methods and enabling broader comparative studies.

NOTES

An earlier stage of this study was presented under the title "Risks and Disasters in Urban Planning Education" at the 9th KBAM Symposium, held at İzmir Institute of Technology on 15–17 December 2023, and was published as a conference abstract. This book chapter updates and extends that study using data from the 2026 review.

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CHAPTER VI

READING SPACE DURING AN EARTHQUAKE: VISIBILITY GRAPH ANALYSIS OF HOSPITAL EXIT LEGIBILITY AND ITS IMPLICATIONS FOR DESIGN EDUCATION AND DISASTER POLICY

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1. Introduction

On 6 February 2023, at 04:17 and again at 13:24 local time, two earthquakes of magnitude Mw 7.7 and Mw 7.6 struck the Pazarcık and Elbistan districts of Kahramanmaraş (Afet ve Acil Durum Yönetimi Başkanlığı, 2023). The sequence caused severe destruction in 11 provinces. More than 48,000 people lost their lives, over half a million buildings were damaged, and communication and energy infrastructure was disrupted. Hospitals were among the buildings that failed at the moment they were needed most. In the affected region, 42 hospital buildings were left with heavy or moderate damage: 27 belonging to the Ministry of Health, 6 to universities and 9 to the private sector (Strateji ve Bütçe Başkanlığı, 2023, p. 57). In Hatay, one of the province's main public hospitals was severely damaged just after the first shock, and its patients had to be transferred to city hospitals in Mersin and Adana (Şenol Balaban et al., 2025).

The United Nations Office for Disaster Risk Reduction (UNDRR, 2017) defines a disaster as "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity". A hospital is a dense case of this interaction. It brings together two user groups under one roof: health staff, and

patients, older people, disabled people and children, many of whom cannot move on their own. It is open 24 hours a day, its emergency department in particular. After an earthquake, the staff who will treat the injured are inside the same building. Past earthquakes have also shown that a hospital can stop working even when its structural frame survives. Damage to non-structural elements, equipment and utilities has repeatedly led to a loss of function (Achour et al., 2011). After the Kahramanmaraş earthquakes, non-structural systems performed poorly and were the leading cause of the partial closure of hospitals (Tapia-Hernández et al., 2025).

A building may provide the number of exits required by regulation and still be difficult for a first-time visitor to leave. Users do not read a hospital in the same way. A nurse or a technician who has worked in the building for years knows the main exits and the side routes, and authorised staff can open doors that are kept locked. A patient who arrived for an appointment an hour earlier may know little more than the door through which they entered. Research on evacuation in fires and in virtual settings shows that people tend to move toward the familiar (Sime, 1985), and that exit familiarity influences exit choice (Kinateder et al., 2018). After an earthquake, signs may fall, the power may fail, and corridors may be blocked. When these supports are weakened, the spatial configuration may become an important source of orientation information. Weisman (1981) identified plan configuration as one of the environmental features that make a building legible, that is, easy to understand and to find one's way in.

This question also concerns how designers are trained. In Türkiye, the number of universities offering disaster and earthquake related courses in architecture and interior architecture rose from 35 in 2022 to 97 in 2025, and the number of such courses from 40 to 140. Most of these courses, however, are elective (88–90%) and theoretical (88–95%) (Tarakçı et al., 2026). Structural safety and code compliance are taught, but there are few practice-oriented settings in which students can test on a real plan whether an exit can be seen and reached. Space syntax studies of hospitals have examined wayfinding in everyday use (Haq & Zimring, 2003; Bitik, 2024), and studies of emergency departments have examined visibility under crowding (Yuan & Zhou, 2025). Fewer studies compare, on the same hospital plan, how the depth to an exit changes when different sets of exits are taken as targets, and fewer still link such a comparison to design education.

The aim of this chapter is to examine how the plan organisation of a hospital ground floor affects visual and metric access to exit targets under different

assumptions about exit knowledge, and to show how this kind of analysis can be brought into design education and disaster policy. The case is the ground floor of a public hospital in Hatay, one of the provinces most affected by the earthquakes. The plan is analysed with visibility graph analysis (VGA) (Turner et al., 2001) in depthmapX. The chapter addresses three research questions:

RQ1: How does the representation of fixed interior elements change visual connectivity and visual integration on the ground floor?

RQ2: How do visual step depth and metric path length to the nearest target differ between a condition in which only two entrances are designated as targets and a condition in which 25 physical exit doors are designated as targets?

RQ3: In which parts of the floor does visual depth remain high even when the set of exit targets is extended, and what does this mean for design education?

The earthquake in the title refers to the context of the question, not to the moment of shaking. The study does not simulate the earthquake, the behaviour of people during shaking or an evacuation. It models neither structural damage nor crowd movement, and it does not measure what real users know. It compares two modelled conditions of exit knowledge on the same plan and shows where the depth to an exit target grows when only the entrances are taken as targets, and where it remains high even when all identified exit doors are. The contribution of the chapter lies in this spatial reading: it separates the areas where more exit targets reduce depth from the areas where depth comes from the configuration of the plan, and it proposes a studio sequence built on this distinction. The chapter first sets out the theoretical framework, then describes the method, presents the findings, and closes with a discussion of their meaning for design education and disaster policy.

2. Theoretical Framework

2.1. Health Buildings in Disaster Management

UNDRR (2017) describes a disaster as the outcome of hazardous events interacting with conditions of exposure, vulnerability and capacity. An earthquake becomes a disaster when it meets a building stock, a population and an institutional system that are unable to absorb it. The Sendai Framework for Disaster Risk Reduction 2015–2030 organises the response to this problem around four priorities: understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction for resilience, and enhancing preparedness for effective response (UNDRR, 2015). The same document places

disaster risk reduction across prevention, mitigation, preparedness, response, recovery and rehabilitation, and names hospitals among the critical facilities that require structural, non-structural and functional risk reduction measures (UNDRR, 2015, para. 30(c)). It also calls for health facilities to "remain safe, effective and operational during and after disasters" (UNDRR, 2015, para. 33(c)).

Hospitals hold a particular place in this framework. On an ordinary day they serve patients; after an earthquake they are expected to receive the injured while their own users are still inside. The Hospital Safety Index of the World Health Organization and the Pan American Health Organization (WHO & PAHO, 2015) assesses this double role through three modules: structural safety, non-structural safety, and emergency and disaster management capacity. In the index, non-structural elements cover the architectural elements, emergency access and exit routes, critical systems such as electricity, water and fire protection, and medical equipment (WHO & PAHO, 2015). Exit routes are therefore treated as part of what keeps a hospital working, alongside its generators and its imaging units.

The distinction between structure and function matters because a hospital can stand and still fail. Achour et al. (2011) examined 34 health facilities affected by nine earthquakes in seven countries between 1994 and 2004. They found that damage to utilities and equipment followed similar patterns across cases, that loss of utilities forced the evacuation of some facilities, and that unstable equipment could obstruct evacuation routes. After the 6 February 2023 earthquakes, Tapia-Hernández et al. (2025) inspected seven hospitals in the affected region. Newer hospitals generally showed limited structural damage, while some older ones partially or fully collapsed; across the sample, non-structural systems performed poorly and were the leading cause of partial hospital closures. Liu et al. (2026) describe hospital functions through physical, clinical and organisational dimensions, and argue that seismic resilience depends on structural, non-structural and organisational strategies taken together. Çoban et al. (2026), working on field hospitals set up after the same earthquakes, show that the spatial layout of a health facility, analysed through space syntax, affects how quickly needed units can be reached.

Hospitals also differ from other public buildings in who uses them. They bring together two groups under one roof. The first is health staff, who use the building every day. The second includes patients, older people, disabled people and children, many of whom depend on others to move. Hospitals are open around the clock, and their emergency departments receive people who have never been in the building before. A house is used by a few people who know it well; an office

or a school has a regular population and working hours. A hospital combines a large floor area, a constantly changing population and a high share of users with limited mobility. For this reason, a hospital's safety in an earthquake depends on its structure and its systems, and also on whether the people inside can understand where to go. On the ground floor, where entrances, outpatient clinics and the emergency department are usually located, this question links the functional continuity of the hospital to the movement of people who do not know the building.

2.2. Spatial Legibility and Wayfinding in Hospitals

Weisman (1981) defined legibility as the degree to which a building helps its users find their way within it. In a study of ten university buildings, he found that the judged simplicity of the floor plan configuration explained 56% of the variance in how often users reported being disoriented, while users' own familiarity with the buildings explained only 9% (Weisman, 1981). The plan, in other words, did more than personal experience to determine whether people got lost.

Hospitals are a demanding test of this finding. They combine departments with different access rules, long corridors, repeated room layouts and several entrances. Haq and Zimring (2003) asked 128 volunteers to explore and then search for destinations in three large hospitals. During first exploration, participants relied on local qualities, such as how many decision points could be seen from where they stood. As they learned the building, their movement was better predicted by global qualities measured through space syntax integration. Güç et al. (2013) reached a related result in a Turkish university hospital: when users felt lost, they moved toward areas with high connectivity and integration, and these same areas appeared in the sketch maps they drew. Bitik (2024) applied visibility graph analysis to the ground floor of Etlik City Hospital in Ankara, where the large shared ground floor connects the hospital towers, and showed that alternative plan arrangements changed connectivity and the wayfinding problems identified in the existing layout.

These studies suggest that the same hospital is read differently by different people. A nurse who has worked in one department for years may know the side corridors and the service exits nearby, and authorised staff can open doors that are kept locked. A specialist who spends most of the day in one unit may know little about the rest of the building. A patient who came for an appointment knows the entrance and the route to the clinic. Spatial knowledge varies with time spent in the building, role and personal ability, and no group can be assumed to know all the exits.

The difference between exits that exist and exits that are known is central to this chapter. Turkish regulation requires, unless otherwise stated, at least two protected exits in all buildings. The number of exits is derived from the occupant load calculated under Article 33; spaces with more than 50 occupants, or 25 in high-hazard spaces, need at least two exits, and at least three or four exits are required when the number of occupants exceeds 500 or 1000. Exits should be placed as far apart as possible, with minimum separation rules for undivided spaces and corridors (Binaların Yangından Korunması Hakkında Yönetmelik, 2007, Art. 39). Escape routes are further defined by occupancy class, occupant load, floor area, travel distance and exit capacity (Binaların Yangından Korunması Hakkında Yönetmelik, 2007, Art. 31). These provisions set the number, capacity and placement of exits. They do not address whether a first-time user can find them. Behavioural research shows why this gap matters. Most of this research comes from fires and controlled experiments rather than from hospitals after earthquakes, and it is used here as indirect evidence. Sime (1985), analysing a fire in a public building, described escape as movement toward familiar people and places. Kinateder et al. (2018) tested this in an ambulatory virtual museum: when an alarm sounded, participants were significantly more likely to leave through the door they had entered than through a second available exit, and this tendency grew when virtual neighbours did the same. The study was not set in a hospital or in an earthquake, so its results cannot be transferred directly. It does show that exit familiarity shapes exit choice. Kobes et al. (2010), reviewing the literature on human behaviour in fire, noted that measures required by law do not always give occupants the support they need, and that several assumptions behind current fire safety practice are not consistent with research findings. Their review also questions the common assumption that occupants behave irrationally in an emergency, which suggests that occupant behaviour is better understood through what people know and perceive.

Earthquakes add conditions that weaken the usual supports for wayfinding. The Hospital Safety Index asks evaluators to check whether signs inside and outside the hospital could fall (WHO & PAHO, 2015). Utilities may fail and equipment may block corridors (Achour et al., 2011). Lifts are not accepted as escape routes (Binaların Yangından Korunması Hakkında Yönetmelik, 2007, Art. 31). After the Kahramanmaraş earthquakes, communication and energy infrastructure was damaged across the region (Strateji ve Bütçe Başkanlığı, 2023), and Gül and Şeker (2026) point to the need for physical resilience in communication systems. When signs, lighting and phones cannot be relied on,

the information a user can draw from the plan itself, such as long sightlines, clear connections and distinct reference points, may become an important source of orientation. Yuan and Zhou (2025), studying emergency departments, found that simple layouts performed best for wayfinding regardless of crowd obstruction.

Four terms need to be kept apart in this discussion. An exit is known when a user has knowledge of it. It is visible when it lies in a user's field of view from a given position. A layout is legible when its configuration helps users understand where they are and where exits lie. An exit is accessible when it can be physically reached and used, which after an earthquake also depends on damage, debris and the state of the door. An exit may be known but not visible, visible but not reachable, or reachable but unknown. This chapter models visibility relations and graph distances directly, represents knowledge only through assumed sets of exit targets, and does not assess physical accessibility after an earthquake.

2.3. Space Syntax and Visibility Graph Analysis

Space syntax offers a way to measure the properties discussed above. Developed by Hillier and Hanson (1984), it describes buildings and cities as systems of connected spaces and analyses each space through its relations to all others. A space is considered integrated when it can be reached from the rest of the system in few steps, and segregated when reaching it requires passing through many intermediate spaces.

Visibility graph analysis (VGA) applies this logic to what can be seen. Turner et al. (2001) showed that a set of isovists can be used to build a graph of mutual visibility between locations, and that measures taken on this graph may relate to wayfinding, movement and space use. In VGA, the floor is divided into a grid of cells. Visual connectivity is the number of cells directly visible from a given cell. Visual integration expresses how close a cell is, in visual steps, to all other cells in the system. Visual step depth is the minimum number of graph steps, through visibility relations, that connect a cell to a designated target. Metric step shortest-path length is the corresponding graph-based metric length of the path to that target. Neither measure represents observed walking distance, actual turning behaviour or evacuation time.

Hillier (1996/2007) used the relation between these local and global measures to define intelligibility: the degree to which what can be seen from each space is a reliable guide to what cannot be seen, namely the integration of that space into the system as a whole. In an intelligible layout, well-connected spaces also tend to be well integrated, so a user's local view gives reliable clues

about the whole. Intelligibility is usually reported as the R^2 of the correlation between connectivity and integration, and it is commonly used in hospital wayfinding studies (Yuan & Zhou, 2025).

VGA has clear limits. It analyses the potential of a plan, not the behaviour of people in it. It does not measure evacuation time, does not model structural damage or crowd movement, and does not know what each user actually knows about the building. Yuan and Zhou (2025) showed that crowds in an emergency department change visibility relations, so the visibility offered by the plan and the visibility experienced in use can differ. A low depth value does not mean a space is safe, and a high one does not mean it is dangerous. The method is suited to comparing the same plan under different assumptions, for example, different sets of exits taken as targets. In this chapter such scenarios stand for assumed levels of exit knowledge; they are not measurements of what real users know.

2.4. Education, Awareness and Policy

The Sendai Framework calls for disaster risk knowledge to be included "in formal and non-formal education, as well as in civic education at all levels, as well as in professional education and training" (UNDRR, 2015, para. 24(l)). For architecture and interior architecture, this means teaching students to see disaster risk in design decisions as well as in structural calculations.

Tarakçı et al. (2026) examined disaster and earthquake related courses in architecture and interior architecture programmes in Türkiye between 2022 and 2025. The number of universities offering such courses rose from 35 to 97 and the number of courses from 40 to 140. Most of these courses, however, were elective (88–90%) and theoretical (88–95%), with limited compulsory or practice-oriented components. The authors call for more practice-based and compulsory structures that bring disaster risk reduction into design thinking and professional practice (Tarakçı et al., 2026).

Spatial analysis can serve this purpose in the studio. A student who runs a VGA on a hospital plan can see where exit depth increases when users rely only on the main entrances, which wings depend on a single corridor, and how a small change in the plan alters the result. Exit legibility then becomes something students can test on a plan, alongside exit counts and corridor widths. Interior architecture has a direct role here. Decisions on corridor continuity, openings to the outside, material and colour changes, and reference points are part of how a building tells users where they are. These decisions shape legibility and should be treated as part of disaster preparedness.

Awareness also concerns the people who use hospitals. Staff can be trained, through drills and briefings, to know alternative routes beyond their own departments. Patients and visitors cannot be trained in the same way, so for them environmental legibility and accessible wayfinding information become especially important. These two groups need different measures, and a hospital's preparedness plan should address both.

On the policy side, Türkiye has built a substantial legal and institutional structure for disaster management. Gül and Şeker (2026) note that the 2009 reform and the creation of AFAD (Disaster and Emergency Management Presidency) reduced confusion over authority, and that strategic documents such as TAMP and TARAP increased planning capacity. The 2023 earthquakes, however, revealed gaps between plans on paper and implementation in the field, especially in coordination between institutions, logistics and local capacity (Gül & Şeker, 2026). A similar gap can appear at the building scale, between the exits a plan provides and the exits a first-time user recognises. Analyses of plan legibility can help to narrow this gap, in design review, in hospital preparedness planning and in the curricula that train the designers of future hospitals. Whether such teaching improves design outcomes is a question for further empirical research in design education.

3. Method

3.1. Case Building and Plan Data

The study analyses the ground floor of a public hospital in Hatay that provides health services in the period after the 2023 earthquakes. The architectural floor plan was obtained from publicly accessible materials published on the hospital's official website. The plan was subsequently redrawn and simplified in AutoCAD for visibility graph analysis. During this step, annotations were removed and the walls and fixed partitions were redrawn by the author as continuous lines. To limit the disclosure of detailed spatial information concerning a healthcare facility, the original architectural drawings and direct download links are not reproduced. Only aggregated analytical visualisations are presented. The analysis maps are shown in 3 m blocks, without room names, functions or dimensions. This reduces detail but does not hide the general outline of the floor, which remains visible in the maps. All measures were calculated at the 0.75 m resolution of the analysis grid; the 3 m blocks are used only for presentation.

Only the ground floor was analysed, for two reasons. First, the study does not aim to document the whole building, and presenting all floors would disclose more layout information than the research questions require. Second, the ground floor is where first-time users are most likely to be: outpatient clinics, the emergency department and the main entrances are located there, while the upper floors mainly contain inpatient wards.

3.2. Modelling in depthmapX

The redrawn plan was imported into depthmapX 0.9.1 (SpaceGroupUCL, 2026), and a visibility graph was built on a 0.75 m grid following the procedure described by Turner et al. (2001). The model rests on three assumptions. All interior doors and patient curtains were taken as open, so that the analysis reflects the configuration of the plan rather than the state of individual doors at a given moment. External windows on the ground floor were taken as closed and drawn as part of the building boundary, so views to the outside through windows are not represented. Movable furniture was excluded.

Two models were prepared. Model A, the base spatial model, contains only walls and fixed partitions and has 36,333 analysis cells. Model B, the model with additional fixed interior obstructions, adds reception and information desks, MRI units, large counters and full-height cabinets, and has 35,917 cells, 416 fewer than Model A. depthmapX uses a single drawing layer as a barrier to both sight and movement. Every element added in Model B was therefore treated as a full obstruction, regardless of its height. This is reasonable for full-height cabinets and MRI rooms, but it overstates the visual effect of desks and counters, over which a standing person can usually see. Model B is therefore read as an upper bound of the effect of fixed elements, not as a measurement of it. Model A and Model B were compared on the 35,917 cells that exist in both models (matched cells). Because Model B also treats the areas behind desks and counters as unreachable, all exit scenarios were run on Model A.

3.3. Exit Target Conditions

The two scenarios represent assumed conditions of exit knowledge, not the measured knowledge of real users. Their basis is the finding that people in an emergency tend to move toward the familiar (Sime, 1985) and that exit familiarity influences exit choice (Kinateder et al., 2018). In depthmapX, a set of cells is selected and the depth from every other cell to the nearest selected cell is calculated. In this chapter the selected cells are called designated target

cells. Table 1 lists the door categories considered and the condition in which each was used.

Scenario A, the limited exit-knowledge condition, designates only the doors through which people enter the building: the main entrance and the walk-in entrance of the emergency department. The main entrance is a single entrance with two doors, so one target cell was placed at each door, giving three target cells. The condition can be illustrated by a first-time visitor, but it is a modelling assumption, not a description of how visitors behave. The ambulance entrance was not included, because patients who arrive by ambulance are accompanied by health staff and were not treated as independent users.

Scenario B, the extended exit-target condition, designates 25 physical doors identified on the plan as potential exit targets: the entrance doors of Scenario A, emergency exits, doors leading to fire escape routes, other doors opening directly to the outside, and staff entrances. One target cell was placed at each door. Service exits used for specific functions, namely the mortuary exit and the medical and domestic waste exits, were excluded. The condition can be illustrated by a staff member who knows the building well. Some of these doors may be kept locked in daily use, and the condition assumes that authorised staff can open them. The operational availability, emergency suitability and post-earthquake accessibility of the 25 doors were not independently verified. Their regulatory compliance was not assessed.

Table 1: Door Categories Designated as Exit Targets in Scenarios A and B

Door category	**Scenario A**	**Scenario B**
Main entrance (two doors)	Target (2 cells)	Target
Emergency department walk-in entrance	Target (1 cell)	Target
Emergency exits	–	Target
Doors leading to fire escape routes	–	Target
Other doors opening directly to the outside	–	Target
Staff entrances (assumed to be opened by authorised staff)	–	Target
Mortuary exit	–	Excluded
Medical and domestic waste exits	–	Excluded
Total target cells	3	25

Source: Prepared by the author.

The three target cells of Scenario A are among the 25 of Scenario B. Between the two conditions, both the number of targets and their distribution

across the floor change. The comparison therefore shows how depth responds to an extended and more widely distributed set of targets; it does not isolate the effect of knowledge as such.

3.4. Measures

Two groups of measures were used. The first describes the visual organisation of the floor as a whole. Visual connectivity is the number of cells directly visible from a cell. Visual integration (HH) expresses how close a cell is, in visual steps, to all other cells, normalised after Hillier and Hanson (1984). Intelligibility was calculated as the R^2 of the linear relation between connectivity and visual integration across all cells of a model (Hillier, 1996/2007).

The second group measures access to the designated targets. Visual step depth represents the minimum number of graph steps connecting a cell to the nearest designated target through visibility relations. Metric step shortest-path length, shortened in this chapter to metric path length, represents the corresponding graph-based metric length of the path, in metres. When several target cells are designated, depthmapX assigns each cell its depth to the nearest of them. These measures do not represent observed walking distance, actual turning behaviour or evacuation time.

The attribute tables of both scenarios were exported from depthmapX. For each scenario, the mean, median and maximum values and the distribution of cells by depth were calculated. The difference between the two scenarios was then calculated cell by cell, so that the analysis shows where on the plan depth changes, as well as by how much it changes on average.

3.5. Spatial Subarea Analysis

To examine where depth remains high in Scenario B, the floor was divided into two subareas. The central block was defined as the band between the two main corridors, including the corridors themselves. The corridors were located from the cells in the top 10% of visual integration, which concentrate in two parallel bands running the length of the floor, at about 60–66 m and 93–99 m from the western edge of the model. The central block was therefore defined as all cells with an x coordinate between 60 m and 99 m from the western edge (11,223 cells, 30.9% of the floor). All other cells form the rest of the floor (25,110 cells). For each subarea, mean depths in both scenarios and the number of cells at five or more visual steps in Scenario B were calculated from the cell-level data. To test whether the result depends on the exact boundaries, both limits were moved by 3 m inwards and outwards in all nine combinations.

3.6. Limitations

The study is not an evacuation simulation. It does not calculate evacuation time and does not model structural damage, fallen objects or crowd movement, which can change visibility relations in use (Yuan & Zhou, 2025). Adding targets to a scenario can only reduce or keep the depth to the nearest target; a lower average in Scenario B is therefore expected, and the more informative result is where the reduction occurs and where it does not. The analysis assumes a user who can walk and read the space unaided. Patients who cannot move on their own depend on staff, and for them exit legibility is first of all a matter of staff knowledge. The scenarios were not checked against the knowledge of real patients, visitors or staff. Finally, the model is based on published plans and was not checked against the current state of the building on site.

4. Findings

4.1. Visual Organisation of the Ground Floor

In Model A, the most integrated cells lie along the two main corridors that run the length of the floor, and the wings branch off from them. Across all 36,333 cells, mean visual connectivity is 220.0 cells, while the median is 141: a small number of open areas see a large part of the floor, while most rooms and corridors see much less. The R^2 between connectivity and visual integration is 0.353. What can be seen from a point therefore explains about a third of the variation in how that point is related to the floor as a whole, and the local view is only a partial guide to the global structure.

Table 2 compares the two models on the 35,917 matched cells. Adding the fixed interior obstructions of Model B reduced mean connectivity by 7.23% and mean visual integration by 1.48%. These changes follow from the assumption that every added element blocks sight completely; they are not a direct measurement of physical visibility in the building. The fixed elements changed local views more than the overall structure of the floor. R^2 is slightly higher in Model B (0.399). This difference is not read as an improvement in legibility, because Model B removes the cells behind the added elements and treats low desks and counters as full-height barriers (Section 3.2).

Table 2: Visibility Measures in Model A and Model B

Measure	Model A	Model B	Change (%)
Analysis cells	36,333	35,917	−1.14
Mean visual connectivity, matched cells	220.55	204.60	−7.23
Mean visual integration (HH), matched cells	2.778	2.737	−1.48
Intelligibility (R^2), all cells of each model	0.353	0.399	–

Source: Calculated by the author from the depthmapX attribute tables.

4.2. Depth to Exit Targets in the Two Conditions

Table 3 summarises the two conditions. In Scenario A, where only the main entrance and the emergency walk-in entrance are designated as targets, mean visual step depth is 3.84 and 7.0% of the floor lies six or more visual steps from the nearest target. Mean metric path length is 101.2 m, and more than half of the cells (53.1%) are over 100 m from the nearest target. In Scenario B, where 25 physical doors are designated as targets, mean visual step depth falls to 2.35 and mean metric path length to 27.3 m. No cell remains more than 100 m from a target.

Table 3: Depth to Exit Targets in Scenarios A and B

Measure	Scenario A	Scenario B
Target cells	3	25
Mean visual step depth	3.84	2.35
Median / maximum visual step depth	4 / 9	2 / 6
Cells at six or more visual steps (%)	7.0	0.2
Mean metric path length (m)	101.2	27.3
Maximum metric path length (m)	219.4	87.8
Cells more than 100 m from the nearest target (%)	53.1	0.0

Source: Calculated by the author from the depthmapX attribute tables.

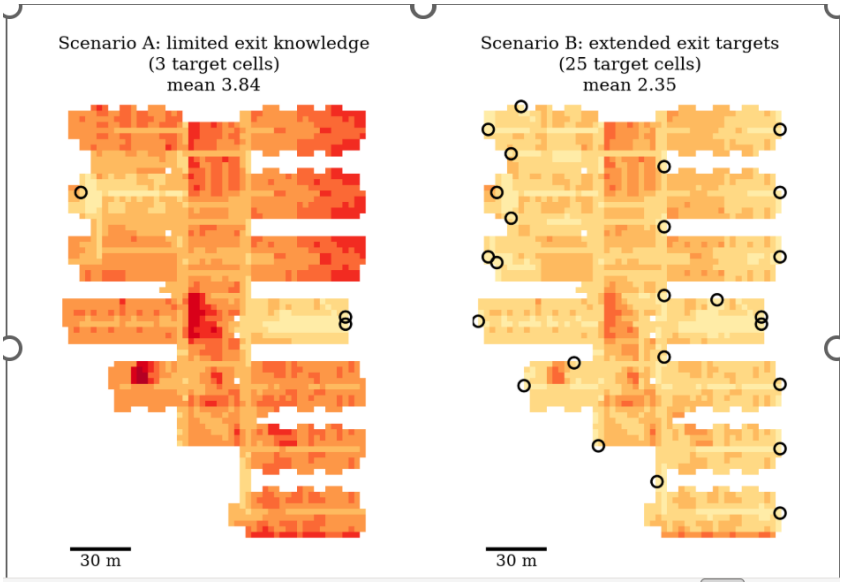
As noted in Sections 3.3 and 3.6, a reduction is expected when targets are added, and both the number and the distribution of targets change between the conditions. The size of the reduction shows how far the floor depends on the doors that are designated as targets. In the model, the 22 additional doors shorten graph distances only when they are designated as targets.

4.3. Where the Difference Occurs and Where Depth Remains

The difference between the conditions is not spread evenly across the floor (Figure 1, Figure 2). In 13.3% of the cells, mostly around the two entrances,

visual step depth is the same in both conditions. The largest differences occur at the ends of the wings farthest from the entrances, where metric path length falls by more than 150 m in 5.7% of the cells and by up to 208 m. In these wings, a door designated in Scenario B lies close by, while the nearest target in Scenario A is reached only through a long sequence of spaces.

Figure 1: Visual Step Depth to the Nearest Target in Scenarios A and B



Source: Produced by the author; visual step depth values were calculated in depthmapX 0.9.1 on a 0.75 m grid and aggregated into 3 m blocks (rounded block mean) for presentation in Python (matplotlib).

A second pattern appears in the central block between the two main corridors, defined in Section 3.5 (Table 4, Figure 3). In Scenario B, 1,050 cells remain five or more visual steps from the nearest target. Of these, 773 cells (73.6%) lie in the central block, although the block contains 30.9% of the floor's cells. Within the block, 6.9% of the cells remain at five or more steps, against 1.1% in the rest of the floor. Mean visual step depth falls by 29.0% in the central block and by 42.9% in the rest of the floor. When the block boundaries are moved by 3 m in either direction, the block holds 26.1–35.2% of the cells and 73.1–74.8% of the deep cells, so the result does not depend on the exact limits chosen. The doors at the ends of the wings reduce depth in the wings but have a smaller effect on the spaces between the corridors. In this block, depth appears

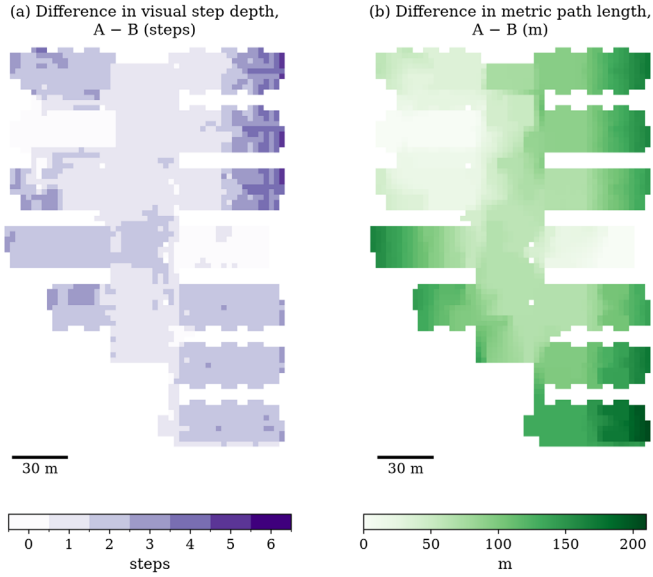
to come mainly from the configuration of the plan, and extending the set of exit targets reduces it only in part.

Table 4: Depth to Exit Targets in the Central Block and the Rest of the Floor

Measure	Central block	Rest of the floor	Whole floor
Cells (share of floor, %)	11,223 (30.9)	25,110 (69.1)	36,333 (100)
Mean visual step depth, Scenario A	3.79	3.86	3.84
Mean visual step depth, Scenario B	2.69	2.21	2.35
Reduction in mean visual step depth (%)	29.0	42.9	38.7
Mean metric path length, Scenario A (m)	95.2	103.8	101.2
Mean metric path length, Scenario B (m)	29.5	26.3	27.3
Cells at five or more visual steps, Scenario B (share of subarea, %)	773 (6.9)	277 (1.1)	1,050 (2.9)
Share of the 1,050 deep cells (%)	73.6	26.4	100

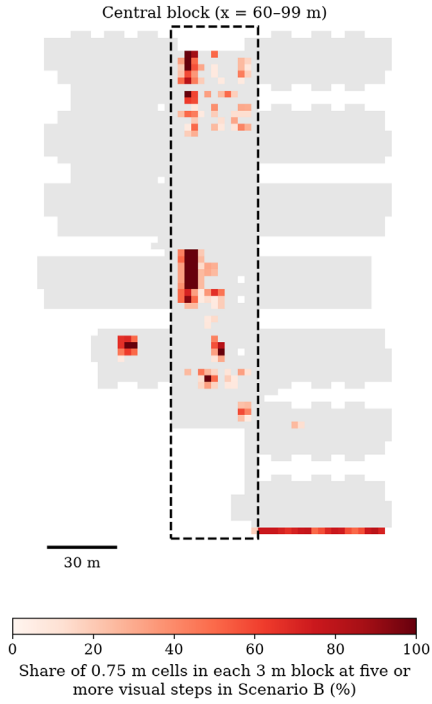
Source: Calculated by the author from the depthmapX attribute tables.

Figure 2: Difference in Visual Step Depth and Metric Path Length Between Scenarios A and B



Source: Produced by the author using depthmapX 0.9.1; values calculated on the 0.75 m grid and aggregated into 3 m blocks for presentation.

Figure 3: Share of Cells at Five or More Visual Steps in Scenario B by 3 m Block, with the Central Block



Source: Produced by the author using depthmapX 0.9.1. Each 3 m block is coloured by the percentage of its 0.75 m analysis cells that lie five or more visual steps from the nearest target in Scenario B; grey blocks contain no such cells.

5. Discussion: Design Education and Disaster Policy

5.1. An Exit on the Plan Is Not an Exit That Is Known

The findings are consistent with the starting point of this chapter: the exits drawn on a plan and the exits a user takes into account are not the same set. On the same ground floor, the condition in which only the entrances are targets and the condition in which all 25 identified doors are targets produce substantially different target-accessibility patterns. In the first, half of the floor is more than 100 m, in graph terms, from a designated target; in the second, no cell is. These are modelled conditions. The study did not measure what patients, visitors or staff know, and it did not verify that the 25 doors can be used after an earthquake. What the comparison shows is how strongly the depth of this floor depends on which doors are taken as targets.

For staff, the gap between existing and known exits can be narrowed through training. Drills and briefings that take staff beyond their own units can extend their knowledge to exits they rarely use. Patients and visitors cannot be trained in the same way. Research from fires and virtual experiments suggests that people tend to head for the door they came in through (Sime, 1985; Kinateder et al., 2018), although this evidence does not come from hospitals after earthquakes. For these users, environmental legibility and accessible wayfinding information become especially important. The central block adds a further point. Even when all 25 doors are targets, some areas remain deep, because their depth comes from the plan. Such areas may require spatial design interventions in addition to information-based measures.

5.2. Space Is Read as a Whole

A user does not read a building through the professions that produced it. Walls, openings, finishes, furniture, light and views reach the user at the same moment and are understood together. Weisman (1981) found that plan configuration explained far more of users' disorientation than their familiarity with the building, which suggests that legibility is formed by the space itself before any added information is read.

In practice, however, legibility is often treated as a problem to be solved after the plan is fixed. When a route proves hard to find, the usual response is to add a sign or a floor marking. These additions are useful in daily use, but they are vulnerable in an earthquake. Signs may fall (WHO & PAHO, 2015), the power may fail, and equipment may block corridors (Achour et al., 2011). Model B also suggests that elements added later act on the same visual field as the plan: under the full-obstruction assumption, fixed elements reduced mean connectivity by about 7% on the matched cells. This value is a result of the modelling assumption, not a measurement of visibility on site. In the author's view, exit legibility should therefore be considered from the first sketch, with architects and interior architects working on it together rather than in sequence. A space that explains itself through its corridors, openings, views and reference points depends less on added layers that may be lost.

5.3. Bringing Spatial Analysis into Design Education

The Sendai Framework calls for disaster risk knowledge to be part of professional education and training (UNDRR, 2015, para. 24(l)). In architecture and interior architecture programmes in Türkiye, disaster-related courses have

grown in number since 2023, but most remain elective and theoretical (Tarakçı et al., 2026). Exit legibility rarely appears in these courses as something students can test on their own designs.

The findings of this chapter suggest a studio sequence in four stages, built on the distinction between areas where more exit targets reduce depth and areas where depth persists. In the first stage, reading the space, students study a hospital plan, its circulation system and the exit knowledge that different users may have. In the second stage, analysing the visual system, they run connectivity and integration analyses and calculate depth to different sets of exit targets, as in Scenarios A and B. In the third stage, revising the design, they identify the areas where depth remains high even with all exits as targets, such as the central block in this case, and develop alternative layouts for them. In the fourth stage, testing the design decision, they compare the analysis maps before and after the change and check their claim of improvement against the results. This sequence has not yet been tested in a studio, and its effect on the plans students produce remains a question for empirical research.

For such teaching to reach every student, the use of these tools should not depend on an individual instructor's interest or on a designer's own initiative. In the author's view, evacuation and spatial legibility should be part of compulsory disaster-related courses in architecture and interior architecture programmes and should be linked to studio work. The software used in this study is open source and freely available, which makes such exercises possible without additional cost.

5.4. Implications for Disaster Policy

Regulation remains the basis of exit safety, and the findings do not argue against it. They point to what it does not address. Gül and Şeker (2026) describe a gap between plans on paper and their implementation in the field after the 2023 earthquakes. A similar gap may exist at the scale of a single building, between the exits a plan provides and the exits its users take into account. Three steps could help to narrow it. First, the design review of health buildings could include a check of exit legibility for first-time users alongside the count, capacity and spacing of exits. Second, hospital disaster preparedness plans, which the Hospital Safety Index assesses under emergency and disaster management (WHO & PAHO, 2015), could include training that gives staff knowledge of exits beyond their own units. Third, the author proposes that education policy make evacuation and spatial legibility a compulsory part of design curricula; the effect of such a requirement has not been tested. Regulation sets the minimum.

In the author's view, design decisions made early in the process, and the way designers think about disaster and evacuation from the start of a project, may significantly influence whether a building can be read when it is needed.

6. Conclusion

This chapter asked how the plan organisation of a hospital ground floor affects visual and metric access to exit targets under different assumptions about exit knowledge. On the ground floor of a public hospital in Hatay, the answer depends strongly on which doors are taken as targets. When 25 identified physical doors are targets, the nearest target is on average just over two visual steps and less than 30 m away in graph terms. When only the two entrances are targets, the same plan is much deeper: almost four steps and more than 100 m on average, and in the far ends of the wings the path to a target is up to 208 m longer. The exits were identified as physical targets; their regulatory compliance and post-earthquake usability were not assessed. Within these limits, the results show that the presence of exits on a plan says little about how deep the floor is for a user who takes only some of them into account.

The analysis also shows that extending the set of exit targets does not reduce depth everywhere. The central block between the two main corridors holds about three quarters of the cells that remain five or more visual steps from a target, although it contains less than a third of the floor. Here, depth appears to come mainly from the configuration of the plan. Such areas may require spatial design interventions, in the way spaces open onto one another and onto the corridors that already carry visual integration, in addition to signs and floor markings, which are added later and may be lost in an earthquake. In the author's view, this calls for architects and interior architects to work on legibility together from the first sketch.

For this reason the chapter has placed its findings within design education and disaster policy. Visibility graph analysis lets students test on their own plans whether an exit can be seen and reached in graph terms, and the four-stage studio sequence proposed in Section 5.3 links this test to design revision. The author proposes that such analyses become a compulsory part of disaster-related courses in architecture and interior architecture. Legibility could then be checked while the design is still being made rather than after the building is in use; whether this improves the plans students produce remains to be tested.

The study has limits. It examines a single floor, represents exit knowledge through assumed sets of targets, and models neither structural damage nor the

movement of people. Future studies could test the results on other floors and other hospitals, compare them with observations of how visitors and staff actually find exits, and examine in the studio whether students trained in these methods produce more legible plans. Regulation sets the minimum. Design decisions made early in the process may significantly influence whether a building can explain itself when it is needed.

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CHAPTER VII

A SPATIAL PLANNING MODEL FOR POST-DISASTER TEMPORARY COLLECTIVE SHELTERING IN SEMI-STRUCTURED PUBLIC SPACES: THE CASE OF TOROS COVERED NEIGHBORHOOD MARKET, ADANA*

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1. Introduction

Türkiye's recurrent seismicity makes post-disaster shelter planning a continuing component of disaster preparedness. Earthquakes can simultaneously damage housing, disrupt infrastructure, and displace large populations; shelter provision therefore extends beyond the replacement of damaged dwellings to questions of urban resilience, accessibility, safety, and preparedness (Karazincir, 2024; Uslu & Uzun, 2014; Yoloğlu & Zorlu, 2024). The 6 February 2023 Kahramanmaraş-centered earthquakes demonstrated the

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scale and urgency of this need and reinforced the importance of identifying urban spaces that can be rapidly activated for collective shelter.

On 6 February 2023, two major earthquakes (Mw 7.7 in Pazarcık and Mw 7.6 in Elbistan) caused extensive destruction across a broad region, damaging buildings and infrastructure and generating urgent shelter needs (AFAD, 2023; Tarakçı & Kavut, 2025). Continued seismic activity, including the Mw 6.4 Yayladağı earthquake on 20 February and prolonged aftershocks, further extended the social and spatial impacts of the disaster (AFAD, 2023; Tarakçı & Kavut, 2025).

These conditions highlight the value of existing public spaces that can be mobilized during emergencies. Covered neighborhood markets are widely distributed, accessible at the neighborhood scale, protected by large-span roof systems, and often connected to basic urban infrastructure. They may therefore complement conventional shelter solutions by providing rapidly usable, semi-structured environments for short-term collective accommodation.

Although the post-disaster shelter literature addresses tents, containers, sports halls, schools, exhibition centers, and open public spaces, covered neighborhood markets have received comparatively limited attention as a planned short-term collective shelter type. This study therefore assesses their suitability in relation to international humanitarian standards and develops an applicable spatial planning model. Its contribution lies in translating the spatial and infrastructural potential of an existing neighborhood market into explicit site-selection and design criteria for pre-disaster preparedness.

Within this framework, the study seeks to answer the following research questions:

1. Which spatial and functional criteria can be used to assess covered neighborhood markets for short-term collective shelter after a disaster?
2. What are the main characteristics that support the selection of Adana Toros Covered Neighborhood Market as the pilot study area?
3. According to which spatial design criteria can a short-term post-disaster collective shelter model be developed?
4. How can the proposed model be evaluated in relation to the minimum international humanitarian shelter standards?

In Adana, covered neighborhood markets in Çukurova District were considered because dense residential development creates a substantial

neighborhood-scale demand for accessible, roofed emergency space. The proposed model is positioned within the emergency-shelter phase. Drawing on FEMA's staged understanding of post-disaster sheltering as interpreted by Yılmaz (2021), it addresses the period beginning with the initial response and continuing until transition to longer-term temporary housing becomes feasible (Figure 1).

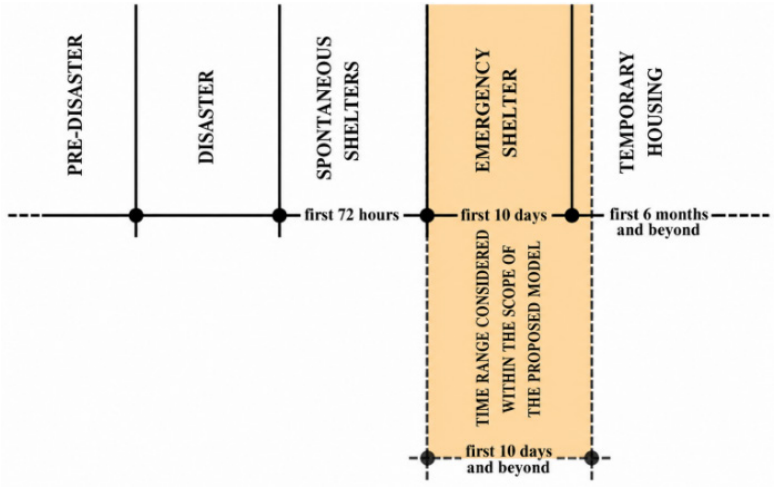


Figure 1: Project Proposal Timeframe Based on Housing Phases Defined by FEMA (Figure created by the authors.)

Accordingly, the model does not treat the first 10 days as a rigid cut-off. It recognizes that logistical, infrastructural, and installation constraints may prolong emergency sheltering and therefore emphasizes an adaptable spatial system capable of supporting users until temporary housing is available.

2. Post-Disaster Temporary Shelter and Semi-Open Public Spaces

2.1. Post-Disaster Temporary Shelter

Post-disaster sheltering is a multidimensional recovery process that contributes not only to the physical protection of affected populations but also to the restoration of social life (Sphere Association, 2018). Accordingly, shelter strategies should extend beyond the provision of temporary physical enclosure and support living environments that address safety, privacy, hygiene, accessibility, and access to essential services. The Sphere Standards (2018) further emphasize that shelter provision should be considered together with water supply, sanitation, energy access, community safety, and privacy.

Within international literature, post-disaster sheltering is generally structured through successive phases, including emergency shelter, temporary or transitional shelter, temporary housing, and permanent housing. Although these phases are typically sequential, they may overlap depending on local conditions and changing needs. The IOM Transitional Shelter Guidelines (2012) emphasize the importance of the transitional period between emergency shelter and temporary housing, during which shelter solutions should be rapidly deployable, adaptable to changing user needs, and capable of remaining in use for extended periods when necessary. In this context, modular systems offer particular advantages in post-disaster shelter design due to their portability, flexibility, adaptability, and potential for reconfiguration (Beyatlı, 2010).

Temporary post-disaster sheltering may be accommodated through a wide range of spatial solutions, including tents, container settlements, sports halls, schools, exhibition facilities, and open public spaces. Despite their differences, these environments share the need to accommodate large numbers of users within a short period while providing access to essential infrastructure and basic services. In this regard, the dual-purpose use of existing urban facilities has gained particular importance, as public buildings and spaces that serve everyday functions under normal conditions can be rapidly adapted for emergency response and temporary sheltering when required.

Covered neighborhood markets are particularly relevant within this framework because of their neighborhood-scale distribution, accessibility, integration with transportation networks, and potential to accommodate multiple functions. Their large-span roof systems can provide immediate protection from environmental conditions, while their semi-open spatial character may support natural ventilation. Hard-surfaced floors facilitate the rapid placement of modular shelter units, and existing electricity, water, and drainage infrastructure can support temporary settlement functions. In addition, open circulation areas can accommodate relief distribution, logistics, and emergency operations. Taking together, these characteristics indicate that covered neighborhood markets can function not only as shelter spaces but also as multipurpose components of post-disaster response. International examples further demonstrate the potential of existing large-span public structures to be repurposed for temporary sheltering after disasters.



Figure 2: Street Market, Onagawa (Japan) Temporary Housing Area (Özden & Açmaz Özden, 2023, s. 38).

Following the 2011 Great East Japan Earthquake and Tsunami, market areas in Onagawa were used to respond to temporary shelter needs (Figure 2) (Özden & Açmaz Özden, 2023, s. 38). This case demonstrates the potential of existing public spaces to be rapidly repurposed for post-disaster accommodation and integrated into emergency shelter strategies. Highlights the value of utilizing already accessible and serviced urban spaces to support a faster and more flexible response to short-term shelter demand.



Figure 3: Modular Tents Used in an Evacuation Center in Marikina City, Philippines, 2018. **Source:** Pablo (2018).

Following Typhoon Haiyan in the Philippines, multipurpose evacuation centers were developed to provide safe shelter during disasters while serving various community needs under normal conditions. In the Guiuan and Borongan examples in Eastern Samar, the buildings were designed with open-plan layouts and flexible use to accommodate both emergency and everyday functions (Figure 3). The use of lightweight partition elements when needed also allows privacy-

oriented spaces to be created, increasing the adaptability of the buildings to changing conditions (IOM & UNICEF, 2018).



Figure 4: February 6, 2023, Adana (Photo: Niyazi Sertkalaycı)

The figure 4, taken at a covered neighborhood market in Adana after the 6 February 2023 Kahramanmaraş earthquakes shows AFAD tents installed beneath the existing roof structure. This spontaneous use demonstrates the immediate shelter potential of covered neighborhood market areas; however, the absence of a predefined spatial organization limited the systematic arrangement of circulation, shared-use areas, and functional zones. The existing roof, large-span configuration, and infrastructure nevertheless provided a basic level of environmental protection during the initial response phase. This case highlights the importance of pre-disaster planning to improve shelter capacity, circulation, privacy, and service provision in such spaces. Accordingly, the proposed model seeks to transform spontaneous post-disaster use into a more systematic temporary collective shelter arrangement. Considered together, the international cases reveal several recurring principles, including the use of existing infrastructure, spatial flexibility, modular organization, environmental protection, and support for logistical functions. In Japan, large-span structures were combined with independent modular units; in the Philippines, market buildings were planned for dual use; and in Chile, market areas accommodated both shelter and logistical functions. These examples demonstrate the potential of existing public facilities to support multiple roles in post-disaster response. The Toros model therefore adapts these recurring principles to local spatial conditions and international humanitarian shelter standards.

Table 1: Examples of Post-Disaster Spatial Utilization and Their Implications for the Toros Covered Neighborhood Market (Prepared by the Authors)

Country	**Building Type Used**	**Post-Disaster Function**	**Implication for the Toros Model**
Japan	Marketplace, greenhouse, large-span structure	Evacuation and temporary shelter	Independent modular units beneath the roof structure
Philippines	Market, evacuation center	Multipurpose disaster center	Integrated planning for both daily and emergency use
Chile	Local market	Logistics, kitchen, and temporary shelter	Use of market areas as crisis management and aid distribution centers
Türkiye	Neighborhood Market	Assembly area for disasters and emergencies; market area	The building's central location, extensive covered area, and existing transportation and infrastructure facilities enhance its potential to provide safe assembly space and respond to temporary shelter needs after a disaster.

3. Minimum Shelter Standards and Design Criteria

International standards for post-disaster temporary sheltering conceptualize shelter not only as physical protection, but as a living environment that should safeguard human dignity, safety, privacy, and basic living conditions. Accordingly, key planning criteria include minimum living space, household organization, sanitation capacity, safe water access, energy and lighting, accessibility, fire safety, and the organization of pedestrian and service circulation. Although the *Sphere Handbook* (2018), the UNHCR *Emergency Handbook*, FEMA guidance, and ADA accessibility standards address these issues at different scales and levels of detail, they converge on the need to provide safe, healthy, and habitable temporary shelter environments. On this basis, the principal minimum shelter criteria defined by Sphere, UNHCR, FEMA, and ADA were comparatively reviewed and are presented in Table 2.

Table 2: Minimum Standards and Spatial Criteria for Temporary Shelter Areas (The table was created by the authors.)

Minimum Shelter Conditions				
	Sphere	UNHCR	FEMA	ADA
Living Space	3.5 m² / Person	3.5–4.5 m² / Person	7–10 m² / Person	-
Total Settlement Area	30–45 m² / Person	≥ 30 m² / Person	-	-
Clear Interior Height	≥ 2.0 m	≥ 2.0 m	Subject to Housing Standards	≥ 2.03 m
Toilet (WC) Ratio	1 WC / 20 Person	1 WC / 20 Person	In-Unit WC	Accessible WC Required
Shower / Bath Ratio	1 shower / 50 Person	1 shower / 50 Person	In-Unit Bath	Accessible Bath Required
Distance Between Toilet and Shelter Area	≤ 50 m	≤ 50 m	In-Unit	Ramp-Accessible, Barrier-Free Route
Water Supply	15–20 L / Person	15–20 L / Person	Housing Infrastructure Dependent	-
Energy and Lighting	Basic Lighting Required	Lighting and Energy Access	HVAC, Electricity, and Insulation	Lighting and Circulation
Privacy	Family-Based Units	Culturally and Gender Sensitive	Unit Privacy	-
Disability Access	Recommended	Strongly Applied	Housing Accessibility	Mandatory
Ramp Slope	-	-	-	Max. 1:12
Door Width	-	-	-	≥ 90 cm
Accessible WC Size	-	-	-	≈ 2.20 × 1.80 m
Minimum Distance Between Modules	≥ 2 m (fire safety)	2–3 m	Depending on housing layout	-

Fire Corridor / Emergency Route	≥ 4–5 m	≥ 4 m	≥ 6 m	≥ 1,2 m clear passage
Pedestrian Access Route	≥ 3 m	≥ 4 m	≥ 6 m	≥ 1,2 m clear passage
Main Service Road Width	≥ 6 m	≥ 6 m	≥ 6 m	-

Although international standards differ in some quantitative recommendations, they largely converge on a common set of humanitarian planning principles. According to the reviewed guidelines, adequate living space, privacy, hygiene, access to safe water, accessibility, secure circulation, fire safety, and essential infrastructure consistently emerge as core components of temporary shelter planning. These shared principles indicate that, despite institutional and contextual differences, minimum shelter standards are structured around comparable requirements for safety, dignity, health, and habitability.

Within this framework, living space per person constitutes a key parameter in determining overall shelter capacity, while the preservation of household integrity contributes to both individual and collective privacy. Adequate sanitation provision, appropriate distances between shelter and hygiene facilities, and sufficient water supply are also central to maintaining acceptable health conditions. Energy and lighting systems further support nighttime safety and the continued use of shared spaces.

Accessibility is another recurring priority across the reviewed standards. Barrier-free circulation, appropriate ramp gradients, accessible sanitary facilities, and adequate lighting are particularly important for older adults, persons with disabilities, families with children, and other users with specific needs. At the same time, unobstructed evacuation routes, fire-safety separation distances, and service access are essential both for user safety and for the effective operation of emergency response activities.

The design decisions of the proposed spatial model were derived from the common principles identified across the reviewed international standards. Accordingly, shelter capacity, modular layout, household organization, hygiene facilities, pedestrian and service circulation, accessibility, and fire-safety measures were treated as interrelated components of a single planning framework. Rather than applying the standards as isolated numerical requirements, the model translated them into spatial relationships and design decisions adapted to the

physical and infrastructural characteristics of the Toros Covered Neighborhood Market. In this way, the proposed model seeks to provide a user-oriented, flexible, and operationally applicable temporary collective shelter arrangement consistent with international humanitarian shelter principles.

4. Method

This study employed a systematic and iterative research process to develop a spatial model for post-disaster temporary collective sheltering. The process comprised problem definition, literature and standards review, pilot-site selection, field analysis, formulation of design criteria, model development, evaluation against international standards, and final revision (Figure 5). Findings generated at each stage informed subsequent design decisions, allowing the research and design phases to develop in an integrated manner.

The theoretical framework was established through a review of national and international studies, guidelines, standards, and practical examples concerning temporary post-disaster sheltering and the adaptive reuse of existing public structures. Attention was given to living space, accessibility, privacy, hygiene, safety, shared-use areas, circulation, and sustainability, as well as to the spatial and operational advantages of using existing buildings and infrastructure.

Covered neighborhood markets included in AFAD's 2022 Emergency Areas list were then assessed according to predefined site-selection criteria, including spatial capacity, plan geometry, roof and structural characteristics, technical infrastructure, surrounding residential density, pedestrian and vehicular accessibility, and adaptability for post-disaster use. Based on the weighted suitability assessment, Toros Covered Neighborhood Market was selected as the pilot study area.

Fieldwork at the selected site included documentation of its physical condition, structural system, existing infrastructure, entrances and exits, current use, and relationship with the surrounding urban context. Plan and section data were prepared, spatial measurements were conducted, and the site was documented photographically. The surrounding road network, pedestrian and vehicular connections, nearby residential fabric, and logistical accessibility were also examined. These findings were used to adapt the general criteria derived from the literature to the specific spatial and infrastructural conditions of the site.

Based on the literature, standards, and field findings, the principal design criteria were defined and translated into an integrated spatial program comprising shelter units, health and safety areas, dining and social spaces, sanitary facilities,

technical and service units, and circulation systems. The design process progressed from conceptual relationship diagrams to increasingly defined spatial configurations and the final layout. A modular and scalable approach was adopted to support flexibility, safe circulation, privacy, access to essential services, and efficient use of existing infrastructure.

The resulting model was evaluated against the criteria derived from Sphere, UNHCR, FEMA, and ADA, with particular emphasis on living space, accessibility, privacy, hygiene, safety, circulation, and access to essential services. Evaluation and revision were embedded throughout the design process rather than treated as a final-stage check. This iterative procedure produced a temporary collective shelter model adapted to the physical and infrastructural capacities of Toros Covered Neighborhood Market while remaining flexible and scalable for comparable settings.

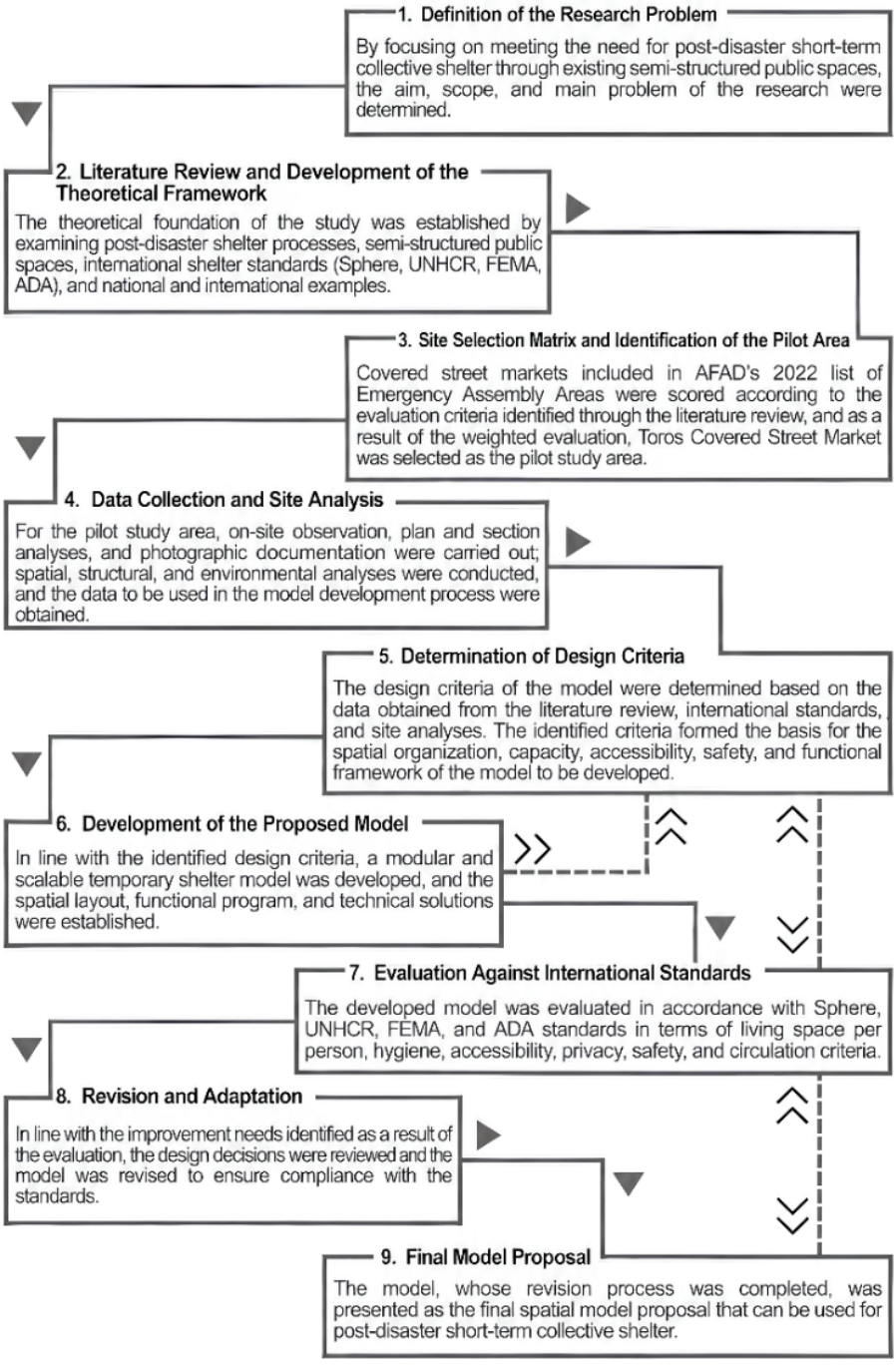


Figure 5: Research and Design Process Diagram for Post-Disaster Temporary Shelter Areas (The diagram was created by the authors.)

Although developed for the Toros Covered Neighborhood Market, the model is intended to inform planning in other covered markets and comparable semi-structured public spaces with similar roof, infrastructure, accessibility, and scale conditions.

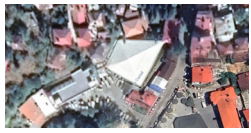
5. Study Area and Site Selection

5.1. Identification of the Pilot Study Area

Covered neighborhood markets included in AFAD's 2022 Adana Emergency Assembly Areas (Public) list were considered as potential pilot sites for post-disaster temporary collective sheltering. Candidate sites were evaluated according to predefined criteria, including roof configuration, spatial capacity, plan geometry, existing infrastructure, accessibility, surrounding population density, and adaptability to temporary shelter use (Table 3). These criteria were incorporated into an evaluation matrix, and the pilot study area was selected based on the comparative assessment results.

Table 3: List of Semi-Structured Neighborhood Markets Included in the "2022 Adana Emergency Assembly Areas (Public)" list according to AFAD's 2022 data (AFAD, 2022).

Name	District Name	Neighborhood Name	Total Area	Aerial Photographs
Neighborhood Market	Ceyhan	İstiklal	4051 m²	
Cumartesi Neighborhood Market	Ceyhan	Namık Kemal	4051 m²	
Yüzüncüyıl Neighborhood Market	Çukurova	Yüzüncüyıl	3994 m²	
Huzurevleri Neighborhood Market	Çukurova	Huzurevleri	6387 m²	
Toros Neighborhood Market	Çukurova	Yurt	3851 m²	
Toros Neighborhood Market (5106M2)	Çukurova	Toros	5106 m²	
Güzelyalı Neighborhood Market	Çukurova	Güzelyalı Mh.	6044 m²	
Neighborhood Market	Sarıçam	Yavuz Sultan Selim Mh.	2000 m²	

İmamoğlu Neighborhood Market	İmamoğlu	Fatih Mh.	3892 m²	
Neighborhood Market	Kozan	Karacaoğlan	13733 m²	
Neighborhood Market	Saimbeyli	Fatih	700 m²	
Neighborhood Market	Tufanbeyli	İstiklal	11564 m²	

Sites distant from district centers, too small for the intended program, lacking continuous roof coverage, or having insufficient comparable data were excluded. Five covered neighborhood markets in Çukurova District were retained for detailed assessment: Yüzüncüyıl, Huzurevleri, Toros, Covered Neighborhood Market (5106 m², Toros), and Güzelyalı.

The detailed matrix evaluated spatial capacity, plan geometry, roof coverage/environmental protection, technical infrastructure/hygiene capacity, transportation and emergency-service accessibility, proximity to the served population, and environmental safety (Table 4).

Table 4: Evaluation Criteria and Weights Used for the Assessment of Candidate Study Areas (The table was created by the authors.)

Site Selection Criterion	Description	Weight (%)
Spatial Capacity	The total site area and its capacity to accommodate temporary collective shelter units and shared-use spaces were evaluated.	15
Site Suitability / Plan Geometry	The plan layout, structural grid system, and suitability for modular organization were evaluated.	10
Roof Coverage and Environmental Protection	Roof continuity, weather protection, and semi-open spatial quality were evaluated.	15
Technical Infrastructure and Hygiene Capacity	The suitability of the existing electricity, water, drainage, and hygiene infrastructure for temporary shelter use was evaluated.	20
Transportation and Emergency Service Accessibility	Accessibility to main transportation routes, emergency vehicles, and logistical support was evaluated.	15
Proximity to the Served Population and Urban Context	Its location within a dense residential fabric and proximity to the population it is intended to serve were evaluated.	10
Environmental Safety and Distance from Potential Hazards	The site was evaluated in terms of environmental safety and exposure to potential hazards.	15
Total		**100**

Three researchers independently scored each candidate from 1 (very unsuitable) to 5 (very suitable). For each criterion, the arithmetic mean was standardized against the maximum score of 5 and multiplied by the criterion weight; weighted contributions were then summed to obtain a maximum overall suitability score of 100.

$$\text{Weighted Contribution} = \frac{\text{Mean Score}}{5} \times \text{Criterion Weight}$$

The weight assessment produced the comparative results shown in Table 5.

Table 5: Researcher Assessments and Overall Suitability Scores of the Candidate Study Areas

Area	Weighted Suitability Score
Covered Neighborhood Market (5106 m²) (Toros)	97.00
Huzurevleri Neighborhood Market	87.67
Güzelyalı Neighborhood Market	86.67
Toros Neighborhood Market	82.33
Yüzüncüyıl Neighborhood Market	82.00

The Covered Neighborhood Market in Toros (5,106 m²) received the highest weighted suitability score (97.00) and was selected as the pilot site. Its regular plan, continuous roof, existing electricity/water/drainage, central position within dense residential fabric, and pedestrian/vehicular accessibility collectively supported its selection.

5.2. Characteristics of the Study Area: Adana Toros Neighborhood Market

Toros Covered Neighborhood Market is in Toros Neighborhood, Çukurova District, Adana, within a dense residential fabric and is included in AFAD's 2022 Emergency Assembly Areas list (Figure 6). Its central urban location, proximity to surrounding residential areas, and integration with the existing transportation network enhance its accessibility and support its potential role as a neighborhood-scale focal point for post-disaster assembly and temporary collective sheltering.



Figure 6: a) Map of Türkiye b) City of Adana c) Site Plan of Toros Covered Neighborhood Market

Figure 7 illustrates the vehicular and pedestrian accessibility of Toros Covered Neighborhood Market within its surrounding urban context. The site is connected to both primary and secondary road networks and is located within a dense residential fabric, providing multiple approach routes for users and emergency services. These connections support access by ambulances, fire and security services, logistics vehicles, and relief operations, while the surrounding pedestrian network facilitates movement from nearby residential areas. The availability of alternative access directions may also contribute to operational continuity in the event of localized road closures or congestion. Taken together, the site's transportation connections, central location, and proximity to residential areas strengthen its suitability for post-disaster access, logistics, and user circulation.

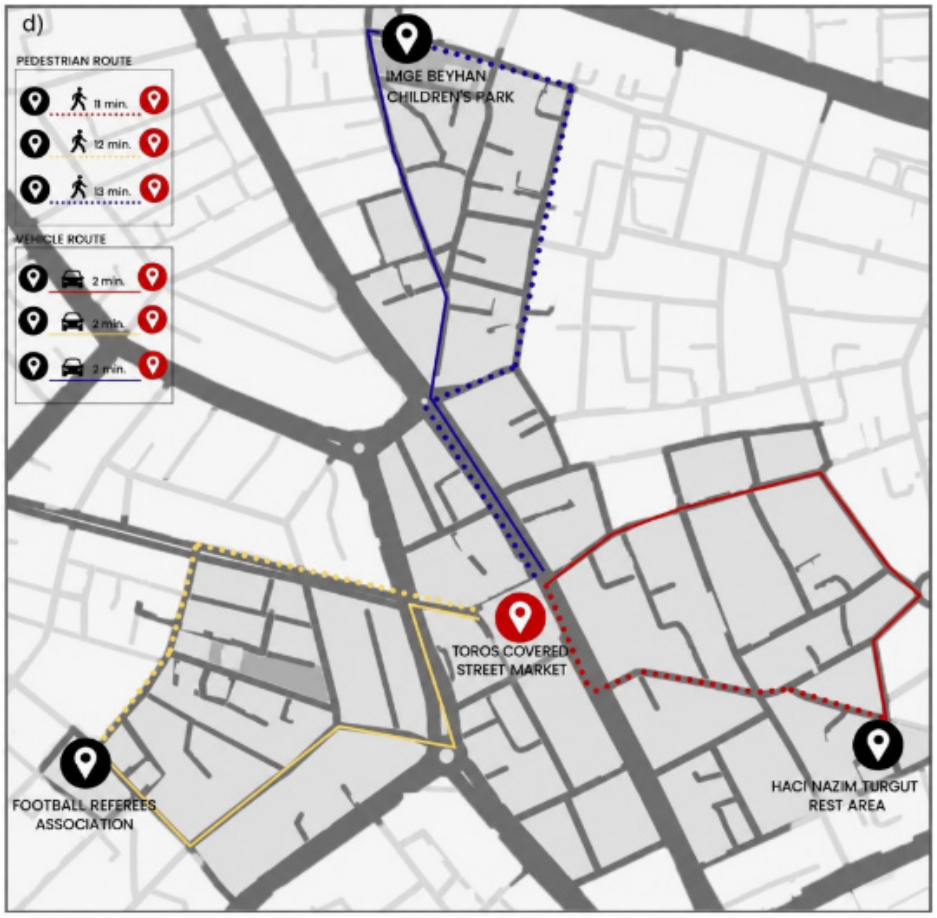


Figure 7: Toros Indoor Neighborhood Market Vehicle and Pedestrian Access

The existing plan and section show a large-span, single-volume structure organized on regular axes (Figure 8). The resulting uninterrupted floor area, defined entrances/exits, roof geometry, and interior height provide a flexible framework for temporary subdivision and modular placement.

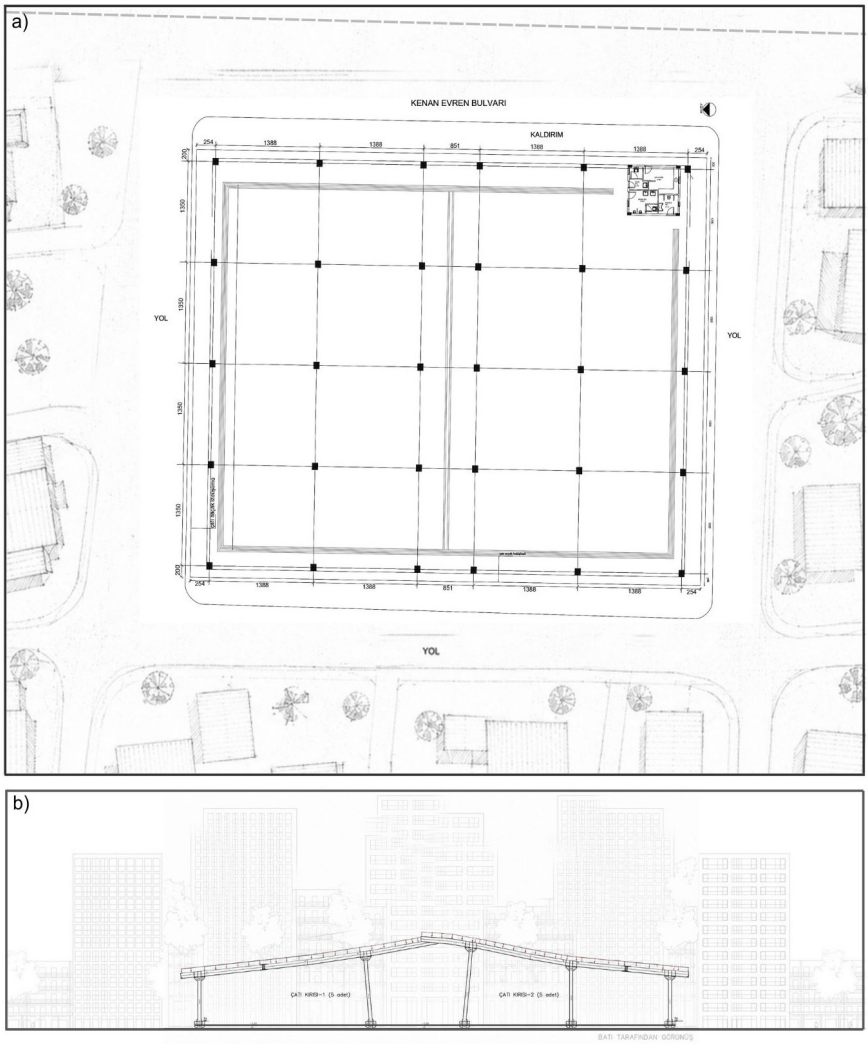


Figure 8: Existing Plan of Toros Covered Neighborhood Market

Current-conditioned photographs confirm the presence of a large-span roof, open circulation areas, electricity, lighting, and water infrastructure, together with opportunities for daylight and natural ventilation (Figure 9). These existing spatial and infrastructural characteristics may facilitate rapid temporary adaptation by reducing the need for extensive additional interventions.



Figure 9: Current-Condition Photographs of Toros Covered Neighborhood Market

6. Proposed Post-Disaster Collective Shelter Model

The post-disaster temporary collective shelter model was developed in response to the existing physical, spatial, and infrastructural characteristics of Toros Covered Neighborhood Market. The design process was informed by post-disaster shelter literature and relevant planning criteria, which were synthesized into a structured set of design parameters. These parameters, presented in Table 6, provided the analytical framework for decisions concerning site use, installation, safety, functionality, accessibility, capacity, environmental compatibility, cost, and sustainability. In this way, Table 6 served not merely as a descriptive checklist, but as the principal design framework guiding the spatial organization and development of the proposed model.

Table 6: Design Criteria and Definitions of Post-Disaster Temporary Shelter Units

No	Criteria	Definition
1	Site Selection and Infrastructure	The site should provide protection from potential post-disaster impacts, have adequate infrastructure, and be in a central, accessible, and safe area.
2	Shelter Duration	It should be designed for long-term use to adequately meet spatial and human needs.
3	Health and Safety	It should provide a protective enclosure or covering against external hazards and incorporate design measures that address users' privacy and safety needs.
4	Installation Time and Phases	It should be lightweight and easily transportable, with a simple and rapid installation process that allows deployment within a short period.
5	Functionality, Spatial Quality, and Privacy	It should be durable and easy to relocate in response to potential risks or problems. Post-disaster temporary shelter areas should provide effective, needs-based solutions that address user requirements and meet basic temporary accommodation standards.
6	Transportation, Accessibility, Proximity, and Flexibility	It should be in a controlled and coordinated area that provides protection from external threats and hazards. The site should be easily accessible and flexible enough to allow future expansion.
7	Respect for the Permanent Environment	It should be planned to minimize harm to the natural and built environment.
8	Cost	Temporary shelter units should be low-cost and financially accessible.
9	Capacity	The design should define appropriate occupancy levels based on established space standards, ensuring efficient use of area while maintaining adequate spatial quality.
10	Sustainability	Shelters should be reusable for multiple disasters and designed to adapt to various environmental conditions with minimal maintenance requirements.

Source: Prepared by the authors based on Asılkan et al. (2023, p. 107).

These criteria were used to structure the spatial relationships among accommodation, shared-use, service, and circulation components, supporting an integrated planning approach rather than the design of isolated functional units.

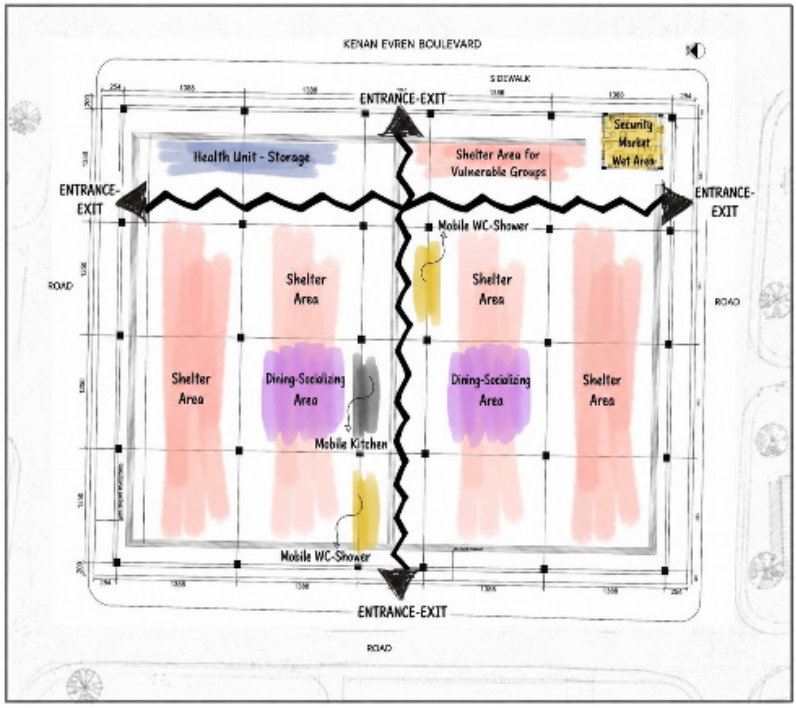


Figure 10: Functional Zoning and Spatial Relationship Diagram of Toros Covered Neighborhood Market

Model development began with the identification of functional relationships among accommodation units, communal spaces, health and support functions, technical and service areas, and circulation systems. These relationships were first explored through a conceptual bubble diagram and subsequently translated into defined functional zones within the existing spatial framework of Toros Covered Neighborhood Market. At this stage, continuity of movement, privacy, balanced access to shared facilities, and emergency access were considered as primary spatial organization criteria. Figure 10 therefore represents the intermediate design stage in which literature- and standard-derived criteria were transformed into spatial relationships, providing the organizational basis for the subsequent dimensioned layout.

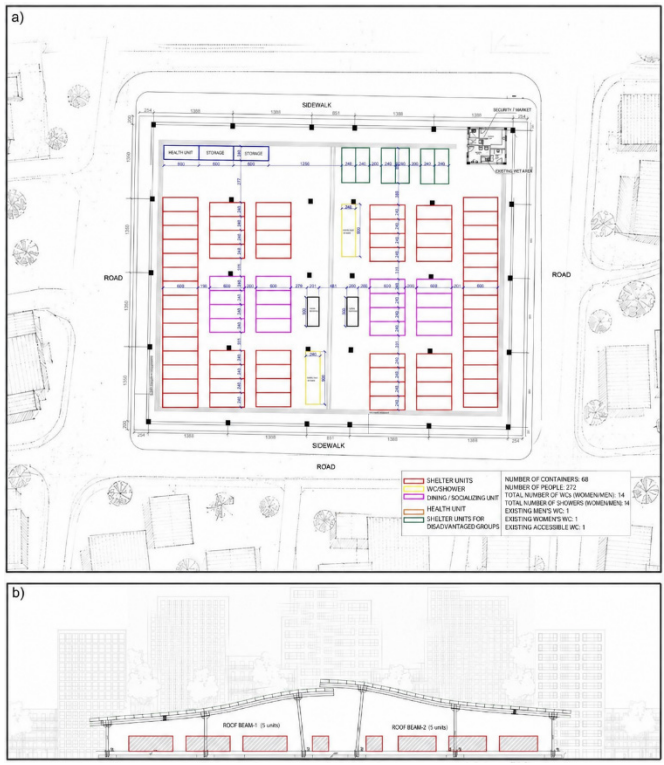


Figure 11: Proposed Layout Plan Model for Toros Covered Neighborhood Market

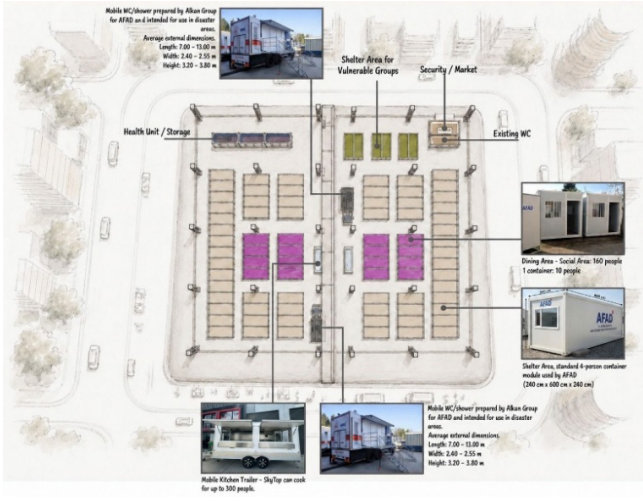


Figure 12: Final Layout Plan of the Proposed Post-Disaster Temporary Collective Shelter Model and the Units

The dimensioned layout was developed within the constraints of the existing plan geometry and structural grid of Toros Covered Neighborhood Market (Figures 11-12). Accommodation units, circulation routes, shared-use spaces, and support functions were organized as an integrated spatial system in order to maintain accessibility, spatial capacity, and the continuity of emergency operations. Mobile kitchen, toilet, shower, and other service units were positioned to remain accessible to users while preserving uninterrupted pedestrian circulation and emergency-vehicle access. Their portable configuration also allows the layout to be installed rapidly and subsequently adjusted in response to changes in occupancy levels and operational requirements.

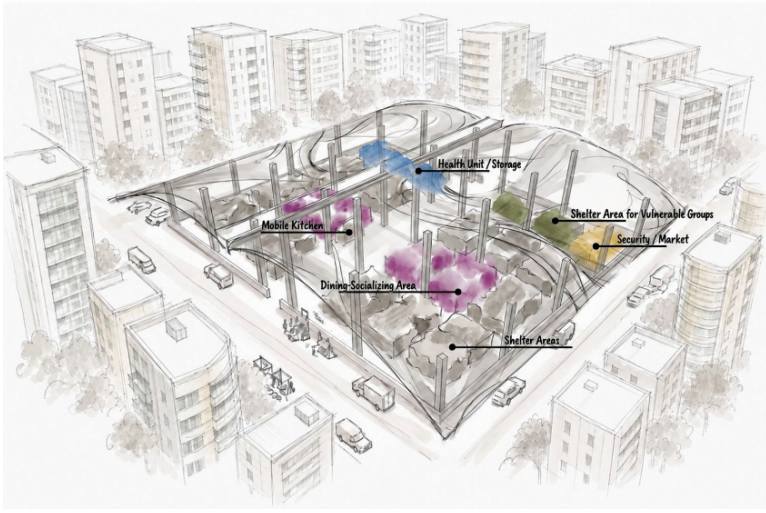


Figure 13: 3D Visualization of the Container Layout in Toros Covered Neighborhood Market

The three-dimensional visualization (Figure 13) illustrates the integrated organization of accommodation units, dining and social areas, health and safety functions, sanitary facilities, and mobile support components within a shared circulation framework. By incorporating the existing roof structure, open-plan configuration, and available infrastructure of Toros Covered Neighborhood Market, the proposal seeks to limit the need for extensive additional interventions. The modular components can be relocated or reconfigured in response to changes in occupancy and functional requirements, while maintaining access to essential services, supporting privacy, and preserving opportunities for social interaction.

Containers measuring 600 × 240 cm, with a gross floor area of 14.4 m², were adopted as the basic accommodation unit. Based on AFAD's temporary

accommodation guidance, which indicates an enclosed area of approximately 3.5–4.5 m² per person for container-based accommodation and the allocation of one container per family, each unit was planned for four occupants. This corresponds to approximately 3.6 m² gross area per person, if sanitation and dining functions are accommodated in shared facilities. Within the proposed layout, 68 shelter containers provide accommodation for 272 users, including six units reserved for users requiring additional support (AFAD, 2015).

As AFAD's publicly accessible guidance does not specify mattress dimensions, the UNHCR technical specification for polyurethane mattresses used in emergency settings was adopted as a reference. Based on the specified mattress dimensions, four 80 × 190 × 10 cm mattresses were arranged within each four-person shelter unit (UNHCR, 2023). The resulting interior arrangement is illustrated in Figure 14.

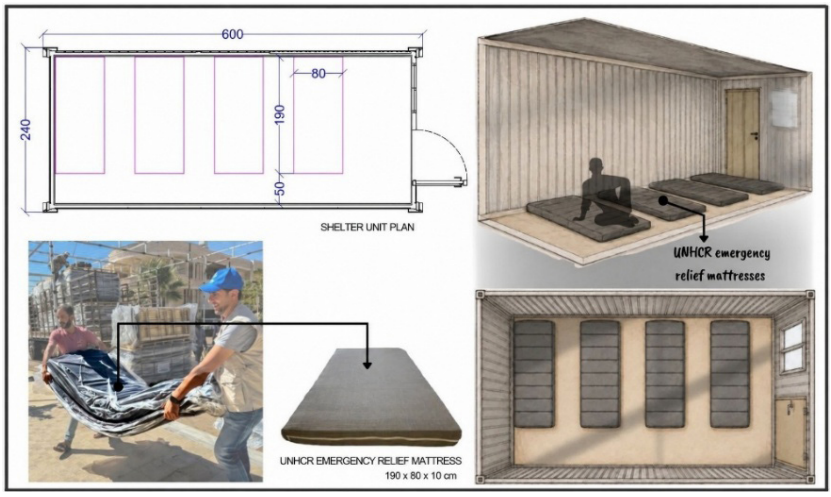


Figure 14: Plan and Elevation of the Proposed Four-Person Shelter Unit Based on UNHCR Mattress Dimensions.

The 600 × 240 cm dining container has a gross floor area of 14.4 m². According to the *Guide to the Regulation on the Protection of Buildings from Fire*, a user load factor of 1.5 m² per person is specified for dining spaces, with occupancy calculations based on the net usable floor area (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change [MoEUCC], 2024). On this basis, and assuming that kitchen and service functions are accommodated in separate units, the dining container was configured for approximately 8–10 users, subject to the net area remaining after furniture placement and circulation

requirements are considered. The seating layout was also arranged to preserve an accessible route and the clear floor space required for accessible use, with reference to the accessibility provisions of the *2010 ADA Standards for Accessible Design* (Figure 15) (U.S. Department of Justice, 2010).

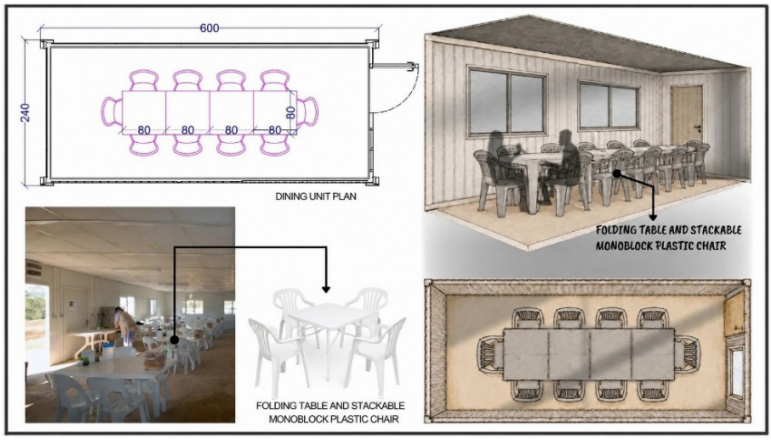


Figure 15: Plan, Elevation, and Perspective Views of the Proposed Dining Unit

7. Conclusion

This study investigated the potential of covered neighborhood markets as pre-identifiable spatial resources for short-term post-disaster collective sheltering. In contrast to shelter solutions that require the establishment of entirely new settlements, existing semi-structured urban spaces with roof coverage, hard-surfaced floors, transportation connections, and basic infrastructure may facilitate more rapid adaptation for emergency use. The spontaneous use of covered market areas following the 6 February 2023 earthquakes in Adana further demonstrates their practical relevance and highlights the importance of integrating such spaces into pre-disaster spatial planning.

The proposed framework combines international humanitarian and accessibility criteria with site-specific spatial analysis. Candidate covered neighborhood markets were evaluated through a weighted assessment process, and the 5,106 m² Toros Covered Neighborhood Market received the highest suitability score (97.00) among the five comparable sites examined in Çukurova District. The subsequent design process treated accommodation units, sanitary facilities, health and support functions, dining and social areas, service components, and circulation systems as interrelated elements within an integrated spatial organization.

The resulting layout accommodates 272 users in 68 four-person shelter units and organizes complementary functions in relation to the existing plan geometry, structural grid, access points, and infrastructure of the pilot site. The principal contribution of the study lies not in proposing a fixed layout to be reproduced unchanged, but in developing a modular and scalable planning logic that can be adapted according to site area, geometry, structural organization, entrance and exit conditions, infrastructure capacity, accessibility, and operational requirements. In this respect, the model provides a case-based framework that may inform the planning of other covered neighborhood markets and comparable semi-structured public spaces with similar physical and infrastructural characteristics.

The study also has several limitations. First, the model was developed and spatially evaluated within a single pilot site and has not yet been tested through full-scale implementation. Second, the weighted site-selection process was based on expert judgments by the researchers, without a formal inter-rater reliability analysis. Third, operational variables such as installation time, life-cycle cost, management capacity, user experience, and performance under different climatic conditions were beyond the scope of the present study. These limitations should therefore be considered when interpreting the transferability and generalizability of the proposed model.

Future research should test the framework in covered neighborhood markets of different sizes, geometries, and infrastructural conditions, as well as under varying user capacities and operational scenarios. Pilot applications and simulation-based assessments could further evaluate installation processes, management requirements, user experience, and functional performance. At the practice level, local authorities and disaster-management institutions could prepare pre-disaster inventories of suitable covered neighborhood markets, assess them using explicit spatial and infrastructural criteria, and develop site-specific layout scenarios in advance. Such an approach may contribute to faster activation of existing urban resources while supporting the humanitarian requirements of safety, privacy, accessibility, hygiene, and continuity of essential services.

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CHAPTER VIII

EARTHQUAKE-PRIORITIZED PLANNING AND A BIM-INTEGRATED LIFE CYCLE ASSESSMENT FOR STRUCTURAL SYSTEM SELECTION

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1. Introduction

An earthquake is a natural phenomenon resulting from rupture within the Earth's crust and is one of the most destructive natural disasters worldwide. Designing and constructing structures in accordance with appropriate architectural and engineering practices is an important measure for mitigating earthquake hazards. Earthquake-prioritized architectural planning is a holistic approach in which building geometry, structural system integration, and urban risk factors are considered during the early design stage to minimise structural damage and loss of life (Shareef, 2023). Earthquake-prioritized architectural planning is not confined to preventing building collapse; it constitutes a broader resilience framework that brings together early design decisions, urban site selection, and post-earthquake functionality. The literature indicates that architectural decisions directly influence seismic behaviour and that the planning stage should therefore not rely exclusively on engineering calculations.

Design decisions directly determine a building's dynamic behaviour during an earthquake; consequently, the preliminary design stage is the most critical determinant of structural performance. Architectural decisions are generally examined under three categories: building geometry, the arrangement of building elements, and the design of non-structural elements. Moreover, the safe operation of evacuation routes, emergency exits, and assembly areas following an earthquake depends on the continuity of the architectural plan layout.

Türkiye is frequently affected by earthquakes. Türkiye ranks fourth worldwide in the number of major earthquakes since 1900, with a total of 77 earthquakes. Given its location in one of the world's most seismically active regions and its history of numerous destructive earthquakes, Türkiye will inevitably experience further destructive earthquakes in the future (Özşahin, 2022). The Kahramanmaraş earthquakes, which occurred on 6 February 2023 with magnitudes of 7.8 and 7.7 (Mw), represent one of the most significant examples of Türkiye's susceptibility to severe earthquakes, having caused immense destruction and tens of thousands of deaths and become one of the deadliest natural disasters to affect Türkiye and Syria in the last millennium. Figure 1 shows Hatay following the 2023 Kahramanmaraş earthquakes.



Figure 1. Hatay after the February 6, 2023 Maraş Earthquakes (Anadolu Agency, 2024)

Steel and, in particular, reinforced concrete are widely used for structural frames worldwide (Oladazimi et al., 2020). Concrete is an important component of the construction sector because of its many advantages, including its mechanical properties and adequate durability, heat storage capacity, chemical inertness, and ease of casting into different sizes and shapes (Vieira et al., 2016).

Türkiye is one of the leading countries in concrete production. However, the 2023 earthquake in the Türkiye–Syria region highlighted the urgent need to reposition the local construction sector.

Assessing the environmental impacts of the construction sector, which is responsible for a substantial proportion of global carbon emissions and energy consumption, is another major priority. Life cycle assessment (LCA) is a robust, systematic, and integrated environmental management tool for analysing and evaluating a product, system, or process throughout its entire life cycle, from raw material extraction to final disposal. Structural elements constitute the largest proportion of all building materials and components and have a greater environmental impact than most other building elements, such as cladding, flooring, and roofing (Stek et al., 2011). Structural frames are therefore of considerable importance in terms of environmental impact as well as earthquake resistance. Life cycle principles and system limits for buildings are defined in the international standard EN 15978:2011. The life cycle framework is defined in the international standard EN 15978 (2011) and is shown in Table 1.

Table 1. Life Cycle Assessment Principles and System Boundaries (EN 15978:2011)

Production Stage	Construction Stage	Use Stage	End-of-Life Stage	Benefits and Loads Beyond the System
A1: Raw Materials Supply	A4: Construction-installation	B1: Use	C1: Deconstruction, demolition	Reuse
A2: Transport	A5: Transport	B2: Manufacturing	C2: Transport	Recovery
A3: Manufacturing		B3: Repair	C3: Waste process for reuse	Recycling Potential
		B4: Replacement	C4: Disposal	
		B5: Refurbishment		
		B6: Operational energy use		
		B7: Operational water use		

The building LCA framework comprises four main life cycle stages and an additional module covering benefits and loads beyond the system boundary. The product stage accounts for raw material supply, transport and manufacturing, while the construction process stage covers transport and construction or installation. Environmental burdens arise from the activities undertaken within these stages. The use stage encompasses use, maintenance, repair, replacement and refurbishment, together with operational energy and

water consumption. In addition to embodied impacts, this stage includes the operational burdens associated with running the building. Operational energy refers to the energy required for heating, cooling, ventilation, air conditioning, lighting and equipment operation. Activities such as maintenance and repair contribute to embodied environmental burdens. The end-of-life stage covers deconstruction or demolition, transport, waste processing and disposal. The additional module addresses potential benefits and loads beyond the system boundary arising from reuse, recovery and recycling. Across the framework, indicators such as energy demand and carbon emissions are used to quantify the environmental burdens associated with the activities within each stage and module. These burdens are classified as embodied or operational according to the activity assessed.

Energy consumption, carbon emissions, and other environmental releases are associated with the life cycle stages and their constituent submodules outlined in Table 1. Both operational and embodied environmental loads occur in each module. The energy consumed by a building for heating, cooling, air conditioning, ventilation and equipment is operational energy, and the carbon released is operational carbon (Lechner, 2015). Embodied loads occur for operations occurring in other modules and submodules.

Concrete is the most widely used construction material in infrastructure. Approximately one tonne of concrete per person is produced worldwide each year, and its extensive global use makes it necessary to assess its environmental impacts accurately, taking into account its effects on greenhouse gas emissions and climate change (Vieira et al., 2016). In contrast, steel offers a strong alternative owing to its earthquake resistance, recyclability, and widespread use. Accordingly, this study focuses on reinforced concrete and steel structural systems. Despite the extensive literature on building material stocks and flow dynamics, the role of building-specific decisions, such as building size or material selection, is less well understood (Heeren & Hellweg, 2019). Large material stocks are found in the residential built environment (Reyna & Chester, 2015; Marinova et al., 2020). To achieve a building stock with high environmental performance, it is important first to analyse the existing condition of buildings and to enable designers to analyse and define their architectural forms, basic planning, and structural systems.

The comprehensive nature of life cycle assessment and its substantial data requirements are encouraging greater emphasis on process optimisation studies. The Building Information Modelling (BIM) data management approach stands

out for its contribution to optimising LCA processes. Building Information Modelling (BIM) is an information management methodology that supports the construction of sustainable built environments (Maglad, 2023). It is characterised by information management, parametric thinking and modelling, data integration, interoperability, BIM–BEM (Building Energy Modelling) workflows, and interdisciplinary collaboration (Vaz et al., 2024; Ciccozzi et al., 2025).

Building Information Modelling (BIM) is characterised by its capacity to parameterise models, transfer information, integrate data, facilitate collaboration, apply parametric thinking, conduct life cycle-oriented analyses, and connect projects from different disciplines (Vaz et al., 2024; Ciccozzi et al., 2025). BIM is a modern data management tool and information platform that supports the development of sustainable buildings (Maglad et al., 2023). It is an important tool for sustainable construction and design, primarily because specific information can be incorporated into a digital model during the design stage and subsequently used for different types of model analysis (cost estimation and planning, sustainability performance, and energy performance).

A substantial proportion of research on BIM and LCA integration concentrates on software integration, with analyses performed using automated, integrated software (Strelets et al., 2025; McNeil-Ayuk & Jrade, 2025). Digital (software) integration is of considerable importance for integrating BIM and LCA. However, the integration of principles is also highly important. BIM–LCA integration has seen significant advances, yet it remains an area requiring further development (Potrč Obrecht et al., 2020). Studies addressing earthquakes and life cycle environmental impacts generally focus on the life cycle of earthquake-induced damage (Guerrero et al., 2023; Simonen et al., 2015). Research integrating earthquake-prioritized planning with a BIM-based LCA approach remains very limited in the literature. In this context, this study aims to address structural system selection in the context of earthquake-prioritized planning and BIM-integrated environmental impact and to develop an integrated approach.

2. Material and Method

In this study, a plan typology for residential buildings is first determined in line with earthquake-prioritized planning. Residential buildings account for 86% of all buildings in Türkiye. These buildings, which account for 30–50% of the residential construction sector and material consumption, represent a significant material stock that has increased in recent years and is expected to continue growing (Somer, 2025).

Considering residential buildings in terms of planning and environmental impacts is particularly important at a time when urban transformation is on the agenda in Türkiye. Accordingly, this study focuses on residential buildings. The scientific research project conducted within the scope of the TOKI mass housing project (BAP2012-27, 2015) indicated that a classification system based on the schematic location of the building core could provide insights into the floor plans of mass housing buildings and their exposure to physical environmental impacts. The basic classification was established as follows:

- Central-core plan types have the core and floor halls concentrated at the center of the building.
- In external core plan types, the core and the floor hall are partially adjacent to one facade of the building.
- In buildings carob system plan types, common areas, including floor halls, elevators, and stairs, are arranged on an axis that will cut vertically through two opposite facades of the building.
- Double-axis corridor plan type is a building form consisting of a central core and corridors located on two axes intersecting in this core.

Central cores are more widely used than other core types because they provide resistance to lateral loads, open the building perimeter to daylight and views, and support efficient working environments. Another important reason for their preference over asymmetric central cores and edge cores is that, in symmetrical configurations, they do not induce torsional moments under lateral loading.

Central cores are more frequently adopted than other core types because they open peripheral spaces to daylight and views, facilitate access to fire escape stairs, resist lateral loads, allow the building perimeter to benefit from daylight and views, and provide efficient working environments. Furthermore, the absence of torsional moments under lateral loading in symmetrical central core configurations is another key reason why they are preferred to asymmetric central cores and edge cores (Özşahin, 2022). Accordingly, the central core plan typology was selected for this study, and Figure 2 schematically illustrates the central, peripheral, and atrium core plan typologies.

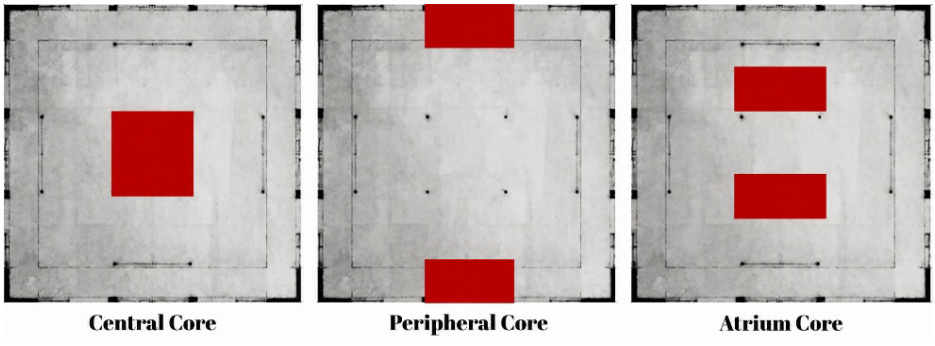


Figure 2. Classification of plan types according to core layout (adapted from Özşahin (2022))

A BIM-based LCA approach requires BIM principles to be clearly defined at the outset. This study proposes an integration approach grounded in fundamental BIM principles that extends beyond software integration alone. These principles can be classified as follows (Eastman et al., 2018; Vaz et al., 2024; Cicozzi et al., 2025):

- Information management
- Parametric modelling
- Application of parametric thinking
- Data integration
- Data consistency
- Life cycle-oriented process integration
- Collaboration
- Interoperability

The study adopts the BIM principles of information management and parametric modelling, together with a digital inventory development approach, to optimise life cycle assessment (LCA) processes. Revit was used for parametric modelling and the development of the building information model. Life cycle assessments were conducted using GaBi thinkstep, a software tool used in scientific research that enables comprehensive analysis throughout the life cycle. Conducting life cycle assessment (LCA) requires dedicated tools, and numerous software packages have been developed for this purpose. These tools differ in their ease of use, modelling principles and database coverage. Some software packages may support a broader range of applications than others

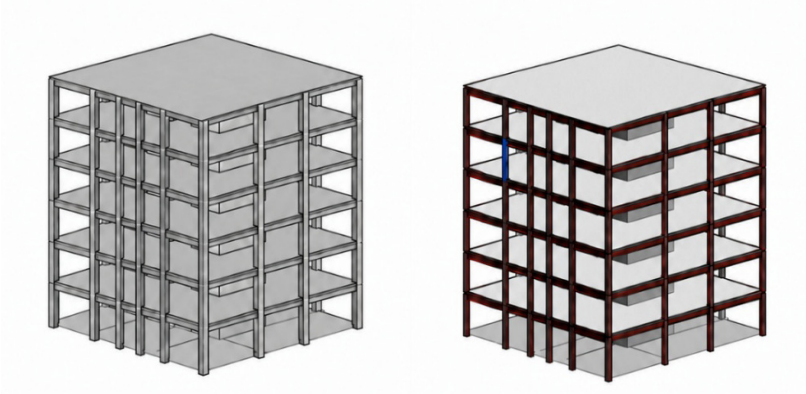
because of differences in functionality, data management and the modelling principles used to construct product systems or unit processes (Unger et al., 2004; Silva et al., 2017). Selecting software suited to the context of the study is therefore important.

Based on the research undertaken for the project, GaBi thinkStep was selected as the LCA tool for its prominence in academic research and its flexible, powerful capabilities for analysing building components. GaBi is an LCA software tool designed to help reduce carbon and other environmental emissions and support sustainability. It analyses a product's entire life cycle, from raw material extraction to disposal, to support environmentally informed decision-making (Sphera, n.d.). There is no integration between Revit and GaBi. The main objective of the study is to integrate LCA at the methodological level based on BIM principles.

In this study, the usage phase (B1–B7) was not included in the LCA assessment. This exclusion is based on the distinction between the 100-year service life specified for load-bearing systems by international standards and the 50-year period commonly adopted in life cycle assessments. Furthermore, interventions involving the repair, deconstruction, or reuse of structural systems require static or seismic performance analyses. The International Energy Agency (IEA) also emphasises the need to develop scenarios addressing the maintenance, repair, and reuse of structural systems in Annex 57 (IEA ANNEX 57, 2016).

3. Findings and Discussion

Alternative structural systems are analysed within the proposed framework, and the findings are presented in this section. The dimensioning of the structural systems was based on general assumptions consistent with the Turkish Building Earthquake Code (Disaster and Emergency Management Authority, 2018), TS500 (Turkish Standards Institution, 2000), and the Steel Structures Code (Ministry of Environment, Urbanization, and Climate Change, 2018). The Revit BIM model served as the source of the main material quantities for the steel and reinforced concrete systems. Reinforcement and steel connection elements were quantified separately following the applicable regulations, and the resulting quantities were incorporated into the LCA inventory. Figure 3 illustrates the structural systems modeled in Revit.



(a) (b)

Figure 3. 6-story reinforced concrete (a) and steel (b) structures in Revit (created by the authors)

The reinforced concrete and steel structural system properties are presented in Table 2. The buildings are located in Earthquake Ground Motion Level-1.

Table 2. Structural systems' properties

Properties	**6-Story RC Building**	**6-Story Steel Building**
Building Lifespan	50 Years	50 Years
Total Gross Residence Area	400 m^2	400 m^2
Building Height	18 m	18 m
Column Dimension (cm)	45x55	HEB 400
Beam Dimension (cm)	55x45	IPE 550
Flooring Type	RC	Composite
Flooring Height (cm)	16 cm	13 cm
Core Type	RC	Steel
Core Dimension (cm)	330x560 cm	330x560 cm
Total Concrete (t)	1855 t	748.5 t
Total Rebar (t)	67.50 t	7.5 t
Total Structural Steel (t)	-	245 t
Total Steel Connection Elements (t)	-	1.5 t
Total Trapezoidal Sheet Amount (t)	-	22.50 t

The BIM models developed in this study provide a basis for creating a digital inventory of building systems and managing material information. Revit's parametric modelling capabilities allow modifications to structural components to be incorporated rapidly into the model, with the corresponding quantity data updated automatically. The present study assessed steel and reinforced concrete structural systems under a single scenario. In assessments involving multiple scenarios, this capability would offer a substantial advantage, while also helping to maintain data consistency and supporting the preparation of LCA inventories.

The study demonstrated that parametric modelling and information management contribute substantially to optimising LCA processes. It also highlighted the potential of BIM principles to support process optimisation in LCA applications. With environmental performance as its central focus, the study selected a powerful software tool capable of comprehensive environmental performance analysis and proposed a framework for methodological integration. This approach represents an important and original aspect of the study.

This study handles embodied energy and embodied carbon factors, which are at the heart of global climate change and environmental problems. The modeling of steel and reinforced concrete structural systems, for which life cycle assessment analyses were performed using GaBi software, is shown in Figure 4 and Figure 5.

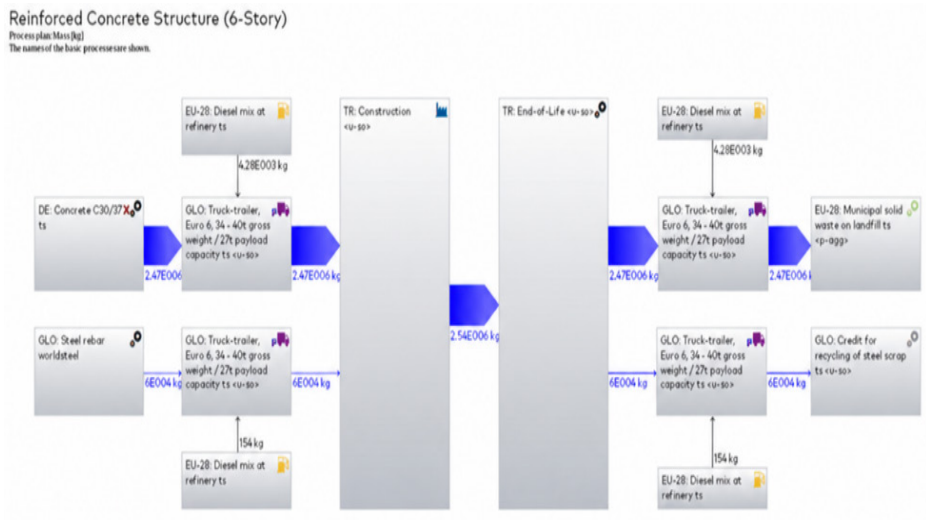


Figure 4. GaBi models developed for reinforced concrete structural system (created by the authors)

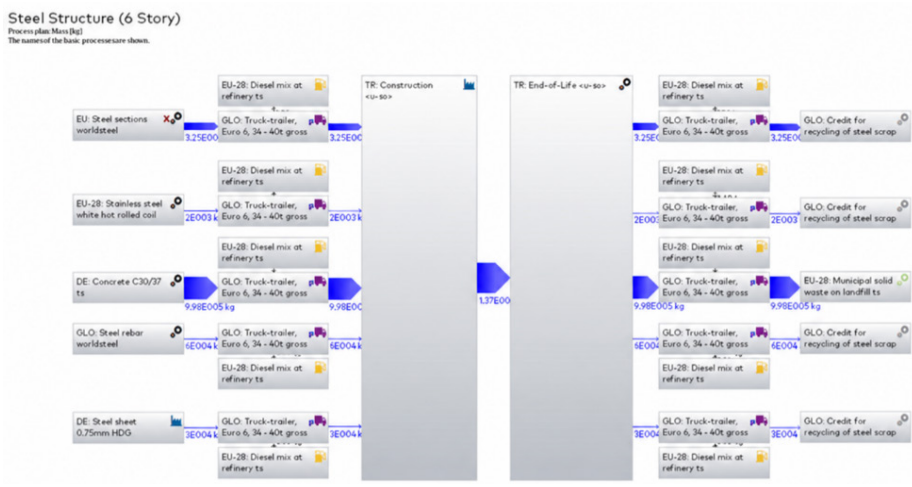


Figure 5. GaBi models developed for steel structural system (created by the authors)

Life cycle environmental performance analysis results of reinforced concrete and steel structure systems are presented in Figure 6.

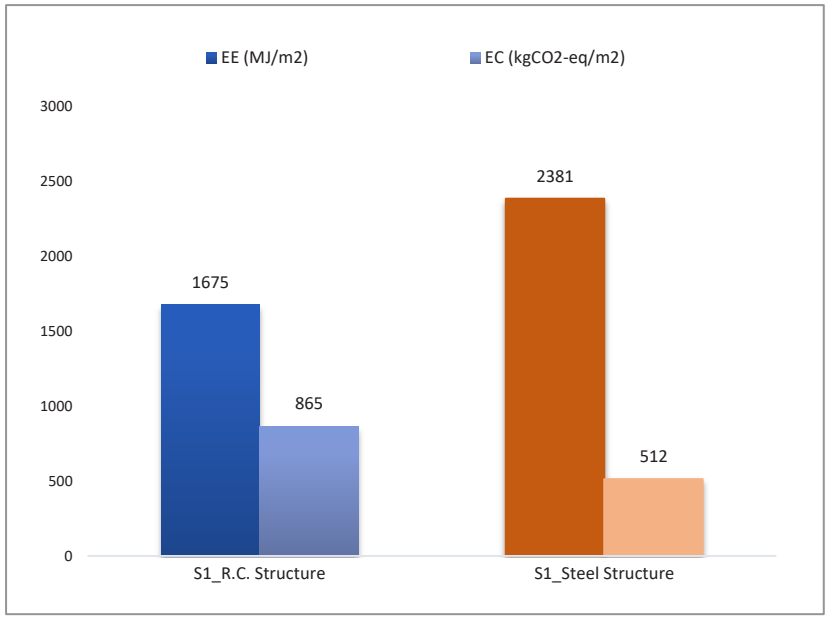


Figure 6. Life Cycle Analysis (LCA) results for steel and reinforced concrete structural systems (created by the authors)

The reinforced concrete structural system has an embodied energy of 1,685 MJ/m² and a normalised embodied carbon value of 865 kg CO_2-eq/m². The steel structural system has an embodied energy of 2,381 MJ/m² and an embodied carbon value of 512 kg CO_2-eq/m². These life cycle results indicate that the reinforced concrete structural system is more favourable in terms of embodied energy, whereas the steel structural system is more favourable in terms of embodied carbon.

Steel and reinforced concrete building systems each have advantages and disadvantages in terms of life cycle environmental performance. Published studies report both favourable and unfavourable performance for these systems across different environmental indicators (Guggemos & Horvath, 2005; Oladazimi et al., 2020). In this context, the literature does not provide a definitive answer to the question of "Steel or Reinforced Concrete?". Therefore, a life cycle-oriented decision-making mechanism is necessary in the selection of a structural system. Selecting a building system based on life cycle environmental performance therefore requires a multifaceted decision-making process that must be optimised. This is one of the key findings of the study.

Seismic loading is one of the design loads prescribed by structural codes for building design and structural system planning. It is related to a building's location and becomes a governing design factor in regions where seismic effects are dominant. Buildings in these regions must have adequate stiffness and load-bearing capacity to withstand earthquakes (Gervasio & Dimova, 2018). Structural systems comprise the building elements that determine a building's response to seismic loading. Seismic loading therefore shapes structural system planning and, consequently, the quantities of materials required. The quantity and type of material, in turn, determine its environmental impact.

At the early design stage, seismic considerations are addressed in isolation, with a focus on structural performance. By prioritising the life cycle, this study will enable the evaluation of many factors that are not incorporated into early design decision-making. A key original contribution of the study is the integration of a building information management approach to bring architectural planning and environmental impact considerations together in structural system selection, while also optimising LCA processes.

4. Conclusion and Suggestions

Climate change, resource depletion, and destruction caused by earthquakes highlight the need for an environmentally sensitive approach to building design. Research into new construction technologies and sustainable materials

aims to create a more sustainable built environment of higher quality. In this context, building design and structural system selection should be evaluated in terms of both structural strength and environmental performance. A life cycle approach provides a strong, systematic basis for selecting structural systems and components with high environmental performance. Energy consumption and environmental emissions are key parameters that must be optimized in this process because of their national and global significance.

Modern architectural planning is evolving into a hybrid discipline that combines empirical socio-spatial research, computational automation, and systematic project management to address the complex requirements of the built environment. Earthquake-prioritized architectural planning requires building geometry, structural system integration, and urban risk factors to be considered together during the early design phase. This holistic approach aims to reduce structural damage and loss of life, preserve functionality, and optimize recovery at the urban scale. In residential buildings, plan typology can be assessed through the horizontal and vertical organization of spaces, access relationships, the number and floor area of apartments per floor, building height, and core geometry. In addition to its role in vertical circulation, the core layout is an important architectural and structural parameter for space efficiency, operational effectiveness, and lateral load resistance. Core dimensions vary according to the level of seismic activity, building height, and floor plans. Classifying cores by location, form, number, and arrangement highlights the role of the core in plan typology.

In this study, the importance of plan typology was first explained, and a typology was selected. An integrated approach is being developed to select the structural system with optimal environmental performance among structural frames with the same plan layout and equivalent seismic resistance. The central hypothesis of the study is that the environmental benefits of structural frames with equivalent seismic performance can be evaluated from a life cycle perspective. A BIM-integrated assessment framework is proposed to optimize LCA processes and support information management. Studies adopting such an integrated approach remain limited. In this respect, the study can inform future research and the development of decision systems that adopt an integrated perspective on earthquake-prioritized planning and BIM-based LCA.

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CHAPTER IX

BEYOND REBUILDING: INTERNATIONAL LESSONS FOR POST-EARTHQUAKE SPATIAL RECOVERY

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1. Introduction

Earthquakes are among the disasters that most directly transform the built environment. Their effects are immediately visible through the collapse or damage of buildings, infrastructure and public spaces; however, the consequences of an earthquake extend well beyond physical destruction. Housing displacement, loss of community networks, interruption of education and economic activity, changes in land use and the disruption of cultural practices may continue for years after the initial event. Consequently, post-earthquake reconstruction should not be considered solely as a technical process through which damaged buildings are repaired or replaced. It is a long-term process in which physical, social, cultural, economic and institutional dimensions intersect.

The contemporary literature on disaster recovery increasingly distinguishes between structural safety and broader functional recovery. A building may survive an earthquake structurally but remain unusable because of damage to non-structural components, building services, infrastructure or surrounding urban systems. Similarly, the reconstruction of individual buildings does not necessarily restore neighbourhood life or social continuity. Systematic research on post-disaster recovery has therefore emphasised governance, resources, stakeholders, innovation and reconstruction strategies alongside physical construction (Charles et al., 2022; Li et al., 2023).

This distinction is particularly important for architecture and interior architecture. A building can be technically strengthened while its spatial organisation, accessibility, cultural meaning or relationship with its users remains unresolved. In historic buildings, the problem becomes even more complex because structural intervention must be balanced with the preservation of architectural character and cultural significance. In residential environments, meanwhile, reconstruction decisions affect not only the physical dwelling but also household structures, daily routines and community relationships.

Post-earthquake reconstruction consequently involves a spectrum of interventions rather than a single approach. In some situations, complete demolition and rebuilding may be necessary. In others, repair and seismic strengthening can allow an existing building to remain in use. Historic buildings may require restoration combined with structural reinforcement, while buildings with new functional requirements may be adapted or reused. Temporary facilities can provide immediate continuity of housing, education and public services while permanent reconstruction proceeds.

The relationship between reconstruction and education is another important dimension. Reconstruction requires architects, engineers, planners, craftspeople, contractors, public authorities and communities to acquire and exchange knowledge. The Nepal experience demonstrates particularly clearly how technical guidance and construction training can influence the adoption of earthquake-resistant practices. Similarly, recent research on architectural education indicates that seismic design remains insufficiently integrated into architectural curricula and design studios.

Policy and governance provide a further layer. Decisions concerning funding, land allocation, building regulations, heritage protection, participation and reconstruction priorities determine which forms of reconstruction become possible. The same physical disaster may therefore produce very different spatial outcomes under different institutional conditions.

This chapter examines these relationships through a comparative review of five international experiences: Kobe, L'Aquila, Christchurch, Nepal and Mexico City. The objective is not to construct a new theoretical or operational model but to examine how different reconstruction approaches have been implemented and what they reveal about the relationship between design, education and policy. The cases also provide a basis for considering the implications of international experience for Türkiye, particularly following the 2023 Kahramanmaraş earthquakes.

2. Post-Earthquake Reconstruction: From Rebuilding to Spatial Recovery

Post-earthquake reconstruction is often associated with rebuilding damaged structures. However, the literature demonstrates that reconstruction is considerably broader than physical replacement. It may involve repair, strengthening, restoration, reconstruction, adaptive reuse, infrastructure renewal, public-space recovery and the reorganisation of urban systems. The appropriate intervention depends on the level and type of damage, the significance of the building, economic resources, regulatory requirements and the social expectations of affected communities.

An important distinction is therefore the difference between **rebuilding** and **recovery**. Rebuilding focuses primarily on replacing physical assets, whereas recovery concerns the restoration of the functions and relationships supported by those assets. Li et al. (2023), in their systematic review of post-disaster functional recovery, emphasise that the ability of the built environment to return to operation depends on interconnected systems rather than on individual buildings alone.

This distinction becomes particularly visible in housing reconstruction. The experience of Kobe demonstrated that the rapid physical reconstruction of housing does not automatically ensure equitable social recovery. Hirayama (2000) showed that existing socio-economic and spatial inequalities affected the distribution of recovery benefits, while Maly and Shiozaki (2012) emphasised the importance of resident participation and differentiated housing options.

A second distinction concerns the treatment of existing buildings. Demolition and replacement may be appropriate when a building has lost its structural capacity or when repair is technically or economically unfeasible. Nevertheless, repair and seismic retrofit can provide an alternative in many cases. The Mexico City experience is particularly important in this respect. Research following the 1985 earthquake documented numerous repair and strengthening interventions, while later studies demonstrated that several buildings rehabilitated after 1985 performed comparatively well during the 2017 earthquake (Aguilar Carboney et al., 1989; Jara et al., 1989; Murcia-Delso et al., 2020).

The issue becomes more complex in historic environments. Heritage buildings cannot simply be evaluated through the criteria used for conventional contemporary buildings because their value is also associated with material authenticity, spatial configuration, urban relationships and cultural memory. The reconstruction of L'Aquila and Christchurch illustrates how seismic rehabilitation and heritage conservation can become intertwined.

From an interior architectural perspective, this issue is particularly significant. Seismic strengthening can alter circulation systems, wall configurations, ceiling systems, material assemblies, building services and accessibility. Restoration may preserve architectural character while requiring carefully integrated structural interventions. Adaptive reuse may introduce new functions into buildings whose original spatial organisation no longer corresponds to contemporary requirements. Consequently, the interior is not merely the final layer of reconstruction; it is one of the scales at which safety, identity, functionality and user experience are negotiated.

Reconstruction is also a temporal process. Emergency shelters, transitional schools and temporary public facilities respond to immediate needs, whereas permanent housing, heritage restoration and urban redevelopment require much longer timeframes. Recovery therefore extends from immediate stabilisation and temporary accommodation to long-term transformation of the built environment.

3. International Experiences of Post-Earthquake Reconstruction

The five cases examined in this section represent different geographical, cultural and institutional contexts. They were selected because each illustrates a different relationship between design, education and policy. Kobe demonstrates the relationship between housing reconstruction and community continuity; L'Aquila illustrates the complexity of historic urban environments and heritage; Christchurch highlights seismic retrofit, heritage reconstruction and long-term recovery; Nepal demonstrates owner-driven reconstruction and knowledge transfer; and Mexico City provides a long-term perspective on existing-building rehabilitation and seismic regulation.

3.1. Kobe, Japan: Housing Reconstruction and Community Continuity

The 1995 Hanshin-Awaji earthquake was a major turning point in Japanese disaster-recovery policy. Kobe experienced extensive damage to housing, infrastructure and urban systems, while large numbers of residents were displaced. The reconstruction process therefore involved both the physical rebuilding of the city and the reorganisation of housing and community life.

The scale of physical destruction is particularly evident in the photographic documentation maintained by Kobe City. The municipality has made an extensive archive of Hanshin-Awaji earthquake photographs available as open data, including documentation of damaged buildings, streets and neighbourhoods. The archive is licensed under Creative Commons Attribution,

making it particularly useful for academic publication subject to the stated attribution conditions. (see Figure 1)



Figure 1: Kobe: Aerial View Of Extensive Urban Destruction After The 1995 Hanshin-Awaji Earthquake
Source: Kobe 1.17 earthquake-record photographic archive (kobe117shinsai.jp), as supplied by the author.

The visual transformation of Kobe demonstrates that post-earthquake reconstruction was not limited to the replacement of individual buildings. In several districts, reconstruction was accompanied by changes in streets, land parcels, public spaces and housing provision. The physical reconstruction of the city was therefore accompanied by decisions concerning where residents would live and how neighbourhood structures would be reorganised.

One of the important lessons from Kobe concerns the relationship between housing policy and pre-existing social inequalities. Hirayama (2000) demonstrated that housing recovery did not occur uniformly across the population. Groups that were already socially or economically vulnerable, including low-income and elderly residents, faced particular difficulties during reconstruction. The post-earthquake production of new housing could therefore address the quantitative problem of housing shortage without necessarily reproducing the social structures and community relationships that had existed before the disaster.

This issue became particularly important in the relocation of residents into newly constructed housing. Large-scale housing projects could provide safe and permanent accommodation, yet relocation could simultaneously weaken neighbourhood relationships. Maly and Shiozaki (2012) argue that people-centred housing recovery requires residents to participate in decision-making and that differentiated housing options are necessary because affected populations do not share identical needs. (see Figure 2)

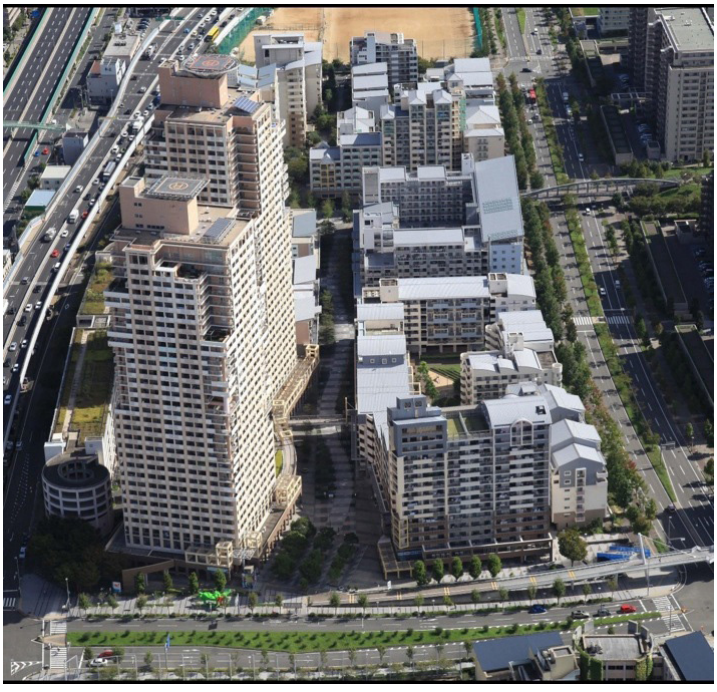


Figure 2: Kobe: reconstructed high-density residential environment illustrating the post-earthquake housing landscape
Source: user-supplied photographic reference; original webpage/source metadata should be retained in the author's image archive.

From an architectural perspective, the Kobe experience demonstrates that reconstruction quality cannot be evaluated only through construction quantity or structural safety. The location, spatial organisation and social accessibility of reconstructed housing influence whether residents can maintain their daily routines and community networks. The question therefore becomes not simply how many houses have been reconstructed, but where they have been reconstructed, for whom, and with what consequences for existing communities.

Kobe is especially relevant to interior architecture because the social dimension of housing recovery operates at the scale of everyday life. A dwelling is not simply a structural container. Its spatial organisation accommodates household relationships, domestic practices and cultural routines. When reconstruction produces standardised housing without adequately considering these factors, physical recovery may be achieved while experiential and social continuity remains incomplete.

The principal lesson from Kobe is therefore that housing reconstruction should be evaluated simultaneously as a physical, spatial and social process.

3.2. L'Aquila, Italy: Historic Urban Fabric, Seismic Rehabilitation and Reconstruction

The earthquake that struck L'Aquila and the surrounding Abruzzo region in April 2009 presents a substantially different reconstruction problem. The earthquake caused extensive damage to a historic urban environment containing masonry buildings, historic building aggregates, monuments and culturally significant public spaces.

The architectural significance of L'Aquila makes the distinction between rebuilding and reconstruction particularly important. The historic centre could not simply be replaced with contemporary buildings without fundamentally transforming the city's identity. Reconstruction therefore required the simultaneous consideration of structural safety, architectural heritage, urban morphology and social continuity.

The Italian Ministry of Culture has documented the reconstruction of L'Aquila's cultural heritage through extensive photographic and archival material. One institutional collection contains more than 2,000 photographs documenting damage, emergency stabilisation and restoration activities following the 2009 earthquake. (see Figure 3)



Figure 3: L'Aquila: earthquake debris and severe damage within the historic urban fabric after the 2009 Abruzzo earthquake
Source: Sky TG24 photographic/news documentation of L'Aquila earthquake damage (tg24.sky.it), as supplied by the author.

Studies of damaged buildings demonstrated significant differences between isolated contemporary structures and historic building aggregates. De Martino et al. (2023) showed that reconstruction funding and strengthening costs required different approaches according to building typology and urban configuration. Historic centres presented particular complexity because individual buildings were structurally and spatially interconnected.

The problem is also visible on the scale of individual historic buildings. Research on Palazzo Pica Alfieri examined seismic retrofit interventions using operational modal analysis, demonstrating the importance of assessing strengthening interventions while preserving historic structures (Aloisio et al., 2022).

A particularly clear example is the restoration of the Church of San Vito at Borgo Rivera. The Italian Ministry of Culture reports that the building suffered major damage during the 2009 earthquake, including the collapse of part of the upper façade. Subsequent structural consolidation and restoration allowed the church to regain its architectural integrity and return to full use. (see Figure 4)



Figure 4: L'Aquila: restored historic architecture and public space following post-earthquake reconstruction

Source: Contrasti Urbani photographic documentation (contrastiurbani.it), as supplied by the author.

The L'Aquila experience therefore illustrates a central problem in heritage reconstruction: how can structural safety be improved without erasing the architectural and cultural characteristics that make the building significant?

This question extends into the interior. Historic interiors contain material, spatial and symbolic information. Wall thickness, ceiling structures, staircases, decorative elements, room proportions and circulation patterns can all contribute to the identity of a building. Structural interventions may therefore have direct consequences for interior character. In this context, seismic rehabilitation becomes an architectural design problem rather than solely an engineering intervention.

At the urban scale, reconstruction also produced changes in movement patterns, urban dispersion and the relationship between the historic centre and

peripheral areas. Reconstruction was consequently both a process of repair and a process of urban transformation.

An additional dimension concerns education and higher education. L'Aquila is a university city, and research has increasingly considered the role of higher-education institutions in post-disaster recovery and knowledge production. This expands the meaning of education beyond professional training and positions universities as potential institutional actors within long-term reconstruction.

L'Aquila's principal contribution to the comparative discussion is therefore the recognition that reconstruction in historic environments is a negotiation between safety, continuity, authenticity, use and governance.

3.3. Christchurch, New Zealand: Retrofit, Heritage and Long-Term Reconstruction

The Canterbury earthquake sequence of 2010–2011 provides another important perspective because Christchurch combines extensive damage to conventional buildings with significant losses to historic structures and an unusually long reconstruction process.

A major issue following the earthquakes was the vulnerability of unreinforced masonry buildings. Research documented widespread damage and collapse within the URM building stock, highlighting the vulnerability of older buildings that had not been adequately strengthened (Moon et al., 2014).

At the same time, Christchurch demonstrated that seismic retrofit could substantially improve the performance of heritage buildings. The Arts Centre provides a particularly valuable example. The Great Hall was extensively strengthened, repaired and restored after the earthquakes. The intervention involved inserting new concrete and steel structures within the existing heritage building, while much of the strengthening was deliberately concealed. The Arts Centre documentation also records the careful removal, numbering, storage and reinstatement of thousands of historic timber and decorative elements. (see Figures 5–6)



Figure 5: Christchurch: severe earthquake damage to the Arts Centre heritage complex following the Canterbury earthquake sequence
Source: user-supplied Christchurch Arts Centre earthquake-damage photograph; source webpage visible in the author's screenshot archive.



Figure 6: Christchurch Arts Centre during seismic strengthening and restoration works
Source: Canterbury Stories, Christchurch Arts Centre earthquake-damage/restoration documentation (canterburystories.nz), as supplied by the author.

These examples challenge the assumption that heritage buildings must either remain untouched or be demolished. Retrofit provides a third possibility: retaining the existing building while modifying its structural performance.

Research on retrofitted stone masonry buildings at the Arts Centre showed the effectiveness of post-tensioned seismic strengthening, while Misnon et al. (2021) examined the performance of another retrofitted heritage masonry building during the Canterbury earthquakes.

The Christchurch case also illustrates the importance of time. Reconstruction was not completed within a short emergency period. Decisions concerning demolition, repair, strengthening, reconstruction and redevelopment continued for many years. This long-term perspective reveals that the meaning of "recovery" changes over time. Immediately after the disaster, safety and basic functionality dominate. Several years later, questions of architectural quality, heritage, urban identity, economic viability and resilience become increasingly important.

Christchurch also provides a clear example of the relationship between reconstruction and professional knowledge. The scale of reconstruction generated shortages of professionals and skilled tradespeople, particularly in seismic assessment, design, project management and site supervision (Chang-Richards et al., 2017).

For interior architecture, Christchurch provides a particularly useful example of the tension between heritage character and contemporary performance requirements. Retrofitting existing buildings may affect structural walls, service routes, circulation, accessibility and environmental performance. The Great Hall is especially significant because its restoration involved not only structural strengthening but also restoration of lighting, acoustics, heating, accessibility and heritage elements.

The Christchurch experience ultimately demonstrates that retrofit, heritage conservation and contemporary use can coexist, but doing so requires technical expertise, long-term investment, regulatory support and an understanding of heritage as a living rather than static condition.

3.4. Nepal: Owner-Driven Reconstruction, Community Participation and Knowledge Transfer

The 2015 Gorkha earthquake in Nepal provides a contrasting reconstruction experience. The earthquake destroyed hundreds of thousands of houses, particularly traditional mud-brick and mud-stone housing in rural areas. The

scale and geographical distribution of damage made centralised professional intervention alone insufficient.

One of the most significant features of the Nepal reconstruction programme was the use of owner-driven reconstruction. Rather than relying exclusively on contractors or centrally managed construction, affected households were supported in rebuilding their own homes with technical guidance and financial assistance.

The World Bank's documentation provides particularly useful photographic material showing both damaged homes and the reconstruction process. Its post-earthquake programme was based on owner decision-making combined with socio-technical assistance, training, inspections and staged financial support. (see Figure 7)



Figure 7: Nepal: widespread destruction of traditional rural housing following the 2015 Gorkha earthquake
Source: user-supplied Nepal earthquake photographic documentation; original source metadata retained in the author's screenshot archive.

The contrast between damaged traditional houses and reconstructed housing is important because reconstruction in Nepal was not simply a matter of replacing buildings. The programme explicitly linked financial assistance to compliance with safer construction practices. The owner-driven approach gave

households control over key reconstruction decisions while technical personnel provided guidance on earthquake-resistant construction. (see Figure 8)



Figure 8: Nepal: reconstructed housing within a rural post-earthquake recovery setting
Source: user-supplied post-earthquake Nepal reconstruction photograph; original source metadata retained in the author's screenshot archive.

Hendriks and Opdyke (2021), examining reconstructed housing across numerous communities, found substantial adoption of seismic-resistant techniques. The importance of the case therefore lies not only in the number of houses reconstructed but also in the transfer of technical knowledge.

The Nepal programme also employed mobile masons, social mobilisers, engineers and other technical personnel to provide socio-technical assistance. World Bank documentation records the mobilisation of hundreds of mobile masons and social mobilisers to provide household-level guidance.

This makes Nepal particularly important for understanding the relationship between reconstruction and education. Education was not restricted to universities or professional schools; it was integrated into the reconstruction process itself. Households, masons, engineers and local officials became participants in a distributed learning system.

The distinction between house and home is also critical. A technically safe house may still fail to meet household needs if its spatial organisation does not

correspond to family structures, livelihood practices or cultural expectations. Shneiderman et al. (2023) demonstrate that post-earthquake reconstruction in Nepal can therefore be understood through the relationship between house, household and home.

The owner-driven model nevertheless had limitations. Lam (2024) found that although the programme generated substantial housing output, some reconstructed houses did not fully correspond to household needs or spatial adequacy. Participation alone therefore does not guarantee successful spatial outcomes; residents require both agency and access to appropriate technical knowledge and resources.

The main lesson from Nepal is that reconstruction capacity is also knowledge capacity. Safe and culturally appropriate reconstruction depends not only on regulations and technical standards but also on the ability to communicate, teach, adapt and exchange knowledge at the community level.

3.5. Mexico City: Existing Building Stock, Seismic Retrofit and Regulatory Learning

Mexico City provides a long-term perspective on reconstruction because it allows the consequences of post-earthquake interventions to be observed across more than one major earthquake event.

The September 1985 earthquake caused extensive damage to Mexico City's building stock and generated an important body of research on repair and strengthening. Aguilar Carboney et al. (1989) documented retrofit techniques applied to reinforced-concrete buildings, while Jara et al. (1989) examined typical cases of repair and strengthening. (see Figure 9)



Figure 9: Mexico City: large-scale building collapse and debris following the 1985 earthquake
Source: user-supplied historical photographic documentation of the 1985 Mexico City earthquake; original source metadata retained in the author's screenshot archive.

These studies shifted considerable attention toward the vulnerability of existing reinforced-concrete buildings and the need for systematic repair and strengthening. A large city cannot realistically become resilient by replacing every vulnerable building. Assessment, prioritisation and rehabilitation are therefore essential components of seismic risk reduction.

The longer-term importance of the 1985 interventions became visible following the 2017 Puebla-Morelos earthquake. Murcia-Delso et al. (2020) examined several concrete buildings rehabilitated after the 1985 earthquake and found evidence that previous rehabilitation interventions contributed to comparatively improved performance during the later event. (see Figure 10)



Figure 10: Mexico City: existing multi-storey residential building environment relevant to seismic rehabilitation and continued use of the existing building stock
Source: user-supplied photographic documentation; original source metadata retained in the author's screenshot archive.

The 2017 earthquake nevertheless revealed continuing vulnerabilities within the existing building stock. Research identified extensive damage, including problems associated with soft-storey configurations. These findings contributed to renewed discussions concerning assessment, strengthening and the treatment of existing structures.

The Mexico City case therefore demonstrates a cycle of damage, assessment, intervention, monitoring and regulatory learning. Each earthquake becomes an opportunity to evaluate the performance of existing policies and technologies.

For interior architecture, the lesson is significant. Retrofit can affect spatial configuration, circulation, façade openings, building services, partitions, accessibility and interior environmental quality. The treatment of existing buildings therefore requires collaboration between structural engineering and architectural and interior architectural design.

Mexico City demonstrates that resilience cannot depend exclusively on post-earthquake rebuilding. The resilience of a city depends substantially on the capacity to assess and improve its existing building stock before the next earthquake occurs.

4. Design, Education and Policy: A Comparative Discussion

The five cases demonstrate that post-earthquake reconstruction cannot be reduced to one dominant strategy. Instead, different forms of intervention emerge according to the characteristics of buildings, communities and institutions.

From a design perspective, the cases range from new housing construction in Kobe to retrofit and rehabilitation in Mexico City and Christchurch, heritage restoration in L'Aquila, and owner-driven construction in Nepal. These differences show that reconstruction decisions should respond to context rather than follow a universal formula.

Rebuilding may be necessary where buildings have suffered irreversible damage. However, demolition and replacement can also result in the loss of social relationships, architectural identity or cultural memory. Repair and retrofit provide alternatives when the existing building can be safely retained. Heritage buildings introduce further requirements because material and spatial continuity may be significant. Adaptive reuse provides another possibility when buildings remain physically viable, but their original functions have changed.

These distinctions are especially important for interior architecture. The interior is the scale at which users encounter reconstructed space on a daily basis. Structural safety, spatial organisation, accessibility, lighting, acoustics, thermal comfort, materiality and psychological experience converge at this level. Consequently, the post-earthquake interior should not be considered an afterthought following structural reconstruction.

The cases also demonstrate that education is not external to reconstruction. In Kobe, reconstruction generated institutional learning about housing and community recovery. In Christchurch, the scale of reconstruction exposed shortages in professional and construction skills. In Nepal, training became an explicit component of owner-driven reconstruction. In L'Aquila, higher education institutions contributed to long-term recovery and knowledge production. In Mexico City, successive earthquakes created opportunities for professional and regulatory learning.

Architectural and interior architectural education can therefore address earthquake resilience through design studios, building rehabilitation projects, heritage conservation exercises, temporary shelter design, existing-building analysis and post-disaster spatial studies. Such approaches can help students understand that resilience is not simply a structural engineering problem but a design problem involving multiple scales.

The policy dimension is equally influential. Kobe demonstrates how housing policy can affect social continuity. L'Aquila shows the consequences

of governance structures in historic reconstruction. Christchurch illustrates the importance of long-term heritage and reconstruction policy. Nepal demonstrates how financial assistance and technical guidance can be combined with household-level decision-making. Mexico City demonstrates how successive earthquakes can contribute to regulatory development.

These cases collectively indicate that reconstruction policy must negotiate between speed and quality. Immediate recovery requires rapid decisions, yet premature decisions can create long-term spatial consequences. Similarly, highly centralised approaches may increase administrative efficiency while reducing community participation. Conversely, completely decentralised reconstruction may create variability in technical quality.

A further common theme is continuity. Continuity may refer to the continuation of social networks, architectural identity, urban morphology, cultural practices, educational activities or economic functions. The five cases demonstrate different forms of continuity:

Table 1: Comparative Dimensions of Post-Earthquake Reconstruction Cases

Case	Primary reconstruction emphasis	Design response	Education / knowledge	Policy emphasis
Kobe	Housing and community recovery	Reconstruction and housing redevelopment	Institutional and community learning	Housing and participation
L'Aquila	Historic urban and cultural heritage	Restoration and seismic strengthening	Heritage and technical expertise	Heritage governance
Christchurch	Heritage and urban recovery	Retrofit, repair and reconstruction	Professional and construction skills	Long-term recovery and heritage
Nepal	Household and community recovery	Owner-driven reconstruction	Community and mason training	Decentralised/ owner-driven assistance
Mexico City	Existing building stock	Repair and seismic retrofit	Professional and regulatory learning	Building regulation

The comparison demonstrates that resilience does not necessarily mean returning to the exact pre-earthquake condition. In some cases, recovery requires transformation. The challenge is determining which characteristics of

the previous environment should be retained, which should be modified and which should be replaced.

For heritage environments, this distinction is particularly important. Authenticity cannot always mean physical immobility. Historic buildings may need structural strengthening, new services, accessibility improvements and contemporary uses. Christchurch demonstrates how new structural systems can be integrated within existing heritage fabric, while L'Aquila demonstrates how restoration can combine structural intervention with the recovery of architectural character.

The cases also demonstrate that post-earthquake reconstruction produces new knowledge. Each earthquake creates an opportunity to evaluate existing buildings, construction techniques, regulations, educational systems and institutional practices. This knowledge should not disappear after reconstruction ends. It should be incorporated into future building standards, professional education, design studios and community preparedness.

5. Implications for Türkiye and Conclusion

The international cases examined in this chapter have direct relevance to Türkiye. The 1999 Marmara earthquake, the 2020 İzmir earthquake and, most significantly, the 2023 Kahramanmaraş earthquake have demonstrated the scale of vulnerability within Türkiye's existing built environment. Research on the Gölcük experience has already shown that housing recovery involves complex relationships between reconstruction processes, household conditions and institutional arrangements (Ganapati, 2013).

The 2023 earthquakes have further demonstrated that reconstruction cannot be considered exclusively through the production of new housing. The affected region contains historic urban environments, traditional buildings, contemporary housing, schools, public buildings, commercial spaces and interiors with different levels of vulnerability and cultural significance.

The international cases suggest several implications.

First, existing buildings should be treated as an important resource rather than automatically as replaceable assets. The experiences of Christchurch and Mexico City demonstrate that seismic assessment and retrofit can extend the life of existing buildings. For Türkiye, this is particularly important given the scale of the existing building stock.

Second, historic environments require context-sensitive reconstruction. L'Aquila demonstrates that the reconstruction of historic centres involves

relationships among structural safety, heritage, urban morphology, community identity and governance. This is directly relevant to historic settlements affected by the 2023 earthquakes, particularly where reconstruction decisions can permanently alter urban character.

Third, interior architecture should have a more explicit role in post-earthquake reconstruction. The interior is where structural interventions, accessibility, environmental performance, psychological recovery and everyday life converge. Temporary accommodation, permanent housing, schools, healthcare facilities and public buildings all require interior architectural consideration. Recent Turkish research on post-disaster temporary shelter and interior architectural theses demonstrates increasing academic attention to these issues (Karaoğlan & Alaçam, 2019; Tarakçı, 2025; Tarakçı & Kavut, 2025).

Fourth, education should become part of disaster resilience rather than a response that begins after disaster. Architectural education in Türkiye has been criticised for insufficiently integrating seismic design into design studios and curricula. Recent research following the 2023 Kahramanmaraş earthquakes similarly argues for curricular transformation that more systematically integrates disaster awareness and seismic resilience into architectural education (Tarakçı et al., 2026). Architectural and interior architectural programmes therefore have an important role in developing students' capacity to work with existing buildings, temporary environments, heritage, structural constraints and post-disaster community needs.

Fifth, reconstruction should be understood as a knowledge-transfer process. The Nepal experience demonstrates the value of training communities and local construction actors. Christchurch demonstrates the importance of professional capacity, while Mexico City illustrates the value of learning from successive earthquake events. For Türkiye, this suggests that reconstruction should generate knowledge that can be transferred to universities, professional organisations, municipalities and local communities.

Finally, policy should establish the conditions under which design and education can operate effectively. Regulations, funding mechanisms, heritage policies, participation procedures and institutional responsibilities influence the spatial quality of reconstruction. Physical reconstruction without coordinated governance can lead to fragmented or inequitable outcomes.

The comparative review demonstrates that post-earthquake reconstruction cannot be understood as a simple sequence of demolition and rebuilding. The five cases reveal a broader spectrum of strategies: rebuilding where necessary,

repairing where possible, retrofitting existing structures, restoring heritage, adapting buildings to new functions, providing temporary environments and transferring knowledge to communities and professionals.

The cases also demonstrate that the meaning of resilience changes according to context. In Kobe, resilience was strongly connected to housing and community continuity; in L'Aquila, to heritage and urban identity; in Christchurch, to the capacity to combine seismic strengthening with long-term heritage and urban recovery; in Nepal, to community participation and knowledge transfer; and in Mexico City, to the continuous assessment and rehabilitation of the existing building stock.

Taken together, these experiences suggest that post-earthquake reconstruction is best understood not as a single act of rebuilding but as a long-term transformation of the built environment. Design determines how physical spaces are repaired, retained or transformed; education determines how knowledge is produced, transferred and renewed; and policy determines the institutional conditions under which these processes occur.

For architecture and interior architecture, the most important implication is that resilience begins before and extends beyond the earthquake itself. It is embedded in the capacity to understand existing buildings, recognise cultural and social values, design adaptable spaces, educate professionals and communities, and develop policies that allow safe reconstruction without unnecessarily erasing the identities of places.

In this sense, the experience of international reconstruction processes does not provide a universal model but rather a body of accumulated knowledge. Their value for Türkiye lies precisely in their differences. Each case demonstrates a different way of negotiating between safety and continuity, technology and local knowledge, reconstruction and transformation, and professional expertise and community participation. The challenge for future earthquake-resilient environments is therefore not simply to rebuild what has been lost, but to learn from what has been experienced and to translate that knowledge into better buildings, better education and more responsive policies.

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