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Designing sustainable refugee settlements in Türkiye: A prioritized indicator framework and network-based scenario for Kilis

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Abstract

In response to the growing demand for sustainable and resilient refugee settlements, this study proposes a comprehensive framework that integrates prioritized design indicators with network-based spatial planning. Through a comparative evaluation of six international refugee camps and the application of the Analytic Hierarchy Process (AHP) to thirteen key design categories, the research identifies the most critical factors for developing inclusive, adaptive, and environmentally sustainable settlements. A customized network analysis is employed to visualize the systemic relationships between physical features and design priorities across global case studies. The proposed framework is applied to a design scenario for Kilis, a province in Turkey significantly affected by the 2023 Kahramanmaraş earthquake and home to a dense population of Syrian refugees. Informed by local architectural traditions and socio-cultural dynamics, the scenario incorporates modular housing, decentralized sanitation systems, solar energy infrastructure, and participatory planning processes. The resulting network diagram for Kilis demonstrates how priority indicators (such as safety, sustainability, and health) can be spatially embedded within the camp design. This integrative approach offers a replicable model for future refugee settlement planning, aligning humanitarian needs with long-term urban sustainability goals.

Keywords: sustainable refugee settlements, AHP, network analysis, modular housing, post-disaster planning, Kilis, Türkiye

1. Introduction

The global refugee crisis remains one of the most pressing humanitarian challenges of our time. Millions of people have been forced to abandon their homes due to conflicts, persecution, and environmental disasters. This has highlighted the urgent need for sustainable and inclusive living spaces more than ever. In addressing the refugee crisis, both the provision of immediate aid and the prioritization of long-term sustainability goals are essential. In this context, Shultz et. al. (2020) argues for the necessity of strong international cooperation, fair asylum policies, and the development of local solutions to facilitate the integration of refugees. They also emphasize the importance of more effective resource management in refugee assistance. Although various forms of post-disaster housing have been extensively studied in the context of natural catastrophes such as earthquakes and floods, this study adopts a more focused lens namely, the shelter responses to conflict-induced displacement (Kürüm Varolgüneş, 2021c). Unlike natural disasters, which often trigger immediate but time-bound interventions, refugee situations are prolonged, politically complex, and spatially embedded within contested geographies. Thus, they require a distinct analytical framework that goes beyond emergency relief to address long-term human settlement and spatial justice concerns. Strengthening international norms is critical to preventing crises and ensuring refugees can live under safer conditions. The implementation of sustainable innovations in refugee camps is identified as a vital means of balancing environmental impacts with humanitarian aid (Seifert et al., 2023). However, although temporary shelters are initially planned to last only a few years, they often evolve into slums, resulting in long-term adverse effects on urban fabric. This creates a mismatch with sustainable urban planning goals and can hinder long-

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term recovery. When refugee camps transition into permanent settlements, urban planners and architects must play a crucial role, as these spaces require sustainable designs that integrate environmental, social, and economic dimensions beyond mere housing. Zetter and Deikun (2010) highlight the importance of urban interventions aimed at supporting the livelihoods of displaced individuals and creating humane spaces for them. While local integration of refugees is a sustainable solution, its success hinges on fostering social acceptance and establishing stable policies (Hovil & Maple, 2022). Additionally, the resilience and long-term stability of refugee communities depend not only on sustainable infrastructure but also on the provision of essential services such as water, sanitation, and hygiene (Yasmin et al., 2023). Al-Husban and Adams (2016) propose that the sustainability of refugee migrations requires viewing refugees not merely as individuals striving to survive but as people who can contribute to society. Creating sustainable living spaces for refugees must go beyond meeting immediate needs; it should include solutions that enhance resilience, promote social integration, and support refugees in achieving long-term stability (Wardeh & Marques, 2021). Holistic approaches play a key role in enabling refugees to become self-sufficient individuals who contribute value to their communities (Ismail, 2022).

1.1. Literature Review on the Refugee Crisis: Challenges, Approaches and Sustainable Solutions

The dimensions and impacts of refugee crises have increasingly been the subject of international debate in recent years. According to the mid-2024 report by the United Nations High Commissioner for Refugees (UNHCR), the number of forcibly displaced persons worldwide has reached 122.6 million. This highlights how factors such as war, persecution, violence, and human rights violations have driven millions to become refugees, asylum seekers, or internally displaced people. UNHCR's 2024 Global Trends Report underscores that this increase stems from both new conflicts and the protracted failure to resolve longstanding crises (UNHCR, 2024). The UNHCR report "Sustainable Development Goals and the Global Compact on Refugees" (UNHCR, 2020) emphasizes the alignment between the Sustainable Development Goals (SDGs) and the Global Compact on Refugees (GCR) in providing sustainable support to both refugees and host communities. It advocates that refugees should be viewed not merely as recipients of humanitarian aid but as part of the broader economic and social sustainability framework. The report further posits that refugees should be seen as actors capable of contributing to social and economic development. The topic has been addressed from various perspectives in literature (UNHCR, 2020). This study reviews specific works focusing on "architectural and spatial approaches," "sustainable and modular approaches," and "historical and sociopolitical perspectives." These studies provide diverse solutions and approaches at both local and international levels, offering a framework for the social, economic, and spatially sustainable support of refugees and displaced communities.

While post-disaster shelter literature often focuses on temporary housing solutions in the aftermath of natural disasters (e.g. earthquakes, floods, hurricanes), the context of refugee settlements arising from conflict-induced displacement presents a distinct set of challenges (Kürüm Varolgüneş, 2021a). These settlements are frequently characterized by political uncertainty, prolonged temporariness, and jurisdictional ambiguity (Kürüm Varolgüneş, 2021b). Unlike disaster recovery efforts that aim to restore pre-existing urban life, refugee camp design must address the creation of new urban forms under resource-scarce and administratively fragmented conditions. This study situates itself within this context, emphasizing the need for spatial solutions that respond to the protracted and hybrid nature of refugee urbanism. An important theme emerging from literature is the paradox of permanence within temporary refugee infrastructures. Although initially designed as short-term shelters, many camps undergo spatial, social, and infrastructural transformations that result in de facto urbanization. This shift from emergency habitat to semi-permanent urban settlement calls for a rethinking of architectural and planning approaches. Chaichian (2024) underscores that design solutions in such contexts must not only respond to basic needs, but also anticipate long-term integration, socio-economic participation, and environmental sustainability. The literature thus supports a move toward holistic and adaptable frameworks in the design of refugee settlements.

Abreek-Zubiedat (2023) examined the settlement processes of the Khan Younis refugee camp during the Cold War within the context of "militarized urbanization." The study analyses how military and political strategies shaped refugee settlements and their impact on social Dynamics. Almeniawi (2023) highlighted the importance of sustainable approaches by exploring the transformation of refugee settlements in northern Syria from temporary shelters into permanent living spaces. Siddiqi et al. (2024) examined Kenya's Dadaab Refugee Camps, situated on the Kenya-Somalia border, not as temporary settlements but as complex sites of historical, aesthetic, and architectural significance. The study challenges traditional perceptions by detailing the camps' long-term social and spatial impacts. The Irbid Refugee Camp and Al Za'atri Refugee Camp in Jordan serve as critical examples for examining the transformation of temporary shelters into permanent structures. Abu-Aridah and Ligler (2024) highlighted the importance of elements such as the use of local materials and community collaboration in the transformation processes of the Irbid Camp. Chaichian (2024) investigated the Al Za'atri Camp's evolution from a temporary shelter into an urban settlement, detailing the social, economic, and spatial implications of this transformation. Studies on refugee camps in Greece underscore the significance of participatory methods in designing shelter and living spaces. Jaradat and Beunders (2023) demonstrated that involving refugee communities in the design process fosters social cohesion and enhances the quality of living spaces. Wierzbicka et al. (2024) focused on the development of sustainable modular housing projects for individuals displaced by war. Their study highlights the potential of such structures to serve as both emergency shelters and long-term living spaces. Modular settlement projects offer flexible and scalable solutions based on principles of environmental sustainability and social cohesion. For instance, modular and energy-efficient housing solutions provide safe and cost-effective options (UNDP, 2021). In addition to contemporary refugee settlements, historical population movements also provide critical insights into the relationship between displacement, architecture, and identity. Akcan (2024) examined the 1923 population exchange between Türkiye and Greece within the context of architectural and national identity dynamics. The study discusses the role of population engineering and settlement policies in shaping national identities through architectural interventions.

Based on the reviewed literature, a set of multidimensional indicators was developed to evaluate refugee settlements in terms of spatial, environmental, and social sustainability. These indicators were derived from key themes repeatedly emphasized across prior studies—such as modularity, resilience, social inclusion, and efficient use of resources (Wierzbicka et al., 2024; Jaradat & Beunders, 2023; Almeniawi, 2023). Accordingly, the subsequent section (2.1) details the process through which these literature-based themes were operationalized into evaluation indicators used in the field analysis.

1.2. Syrian Refugees in Kilis and Türkiye: Sustainable Living Spaces and Social Integration

Türkiye plays a critical role in addressing the global humanitarian crisis by hosting a significant refugee population, with 2.933.205 individuals as of 31 December 2024 (UNHCR, 2024). The country faces multifaceted challenges, including providing shelter, integration, and well-being. The number of Syrian refugees in Türkiye and their distribution across provinces are presented in Figure 1 and Figure 2.

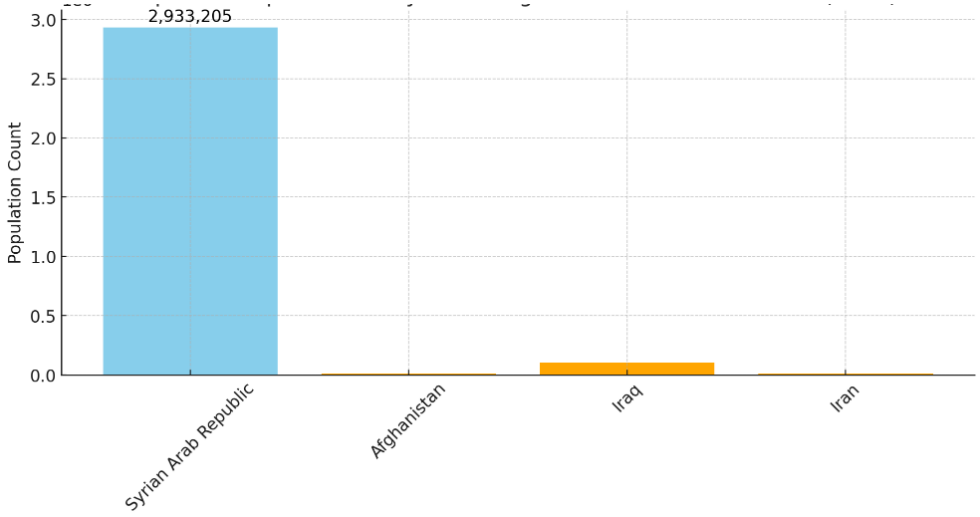

Figure 1 The number of Syrian refugees in Türkiye by the end of 2024 (UNHCR,2024)

Figure 2 Distribution of Syrian refugees by city in Türkiye (DGMM, 2024)

However, the fact that a large proportion of refugees live outside urban areas or in overcrowded settlements exacerbates these challenges (Tunç, 2015). In this context, sustainable solutions that support place attachment and social cohesion among refugees have become a critical necessity. Place attachment is defined as the sense of belonging and emotional connection individuals feel toward a specific place (Scannell & Gifford, 2010). For refugees, this concept is directly linked to feelings of safety, the formation of social networks, and processes of social integration (Altman & Low, 2012). In Türkiye, this dynamic is particularly evident in regions close to the Syrian border, such as Gaziantep, Hatay, Şanlıurfa, and Kilis. These areas, with their dense refugee populations, embody critical dynamics in terms of social cohesion, economic sharing, and cultural interaction (Haliloğlu Kahraman, 2022; Imrie-Kuzu & Özerdem, 2023; Şahin Mencütek et al., 2023). This study proposes a "sustainable living space" scenario for refugees residing in Kilis, particularly those affected by the 2023 Maraş earthquake. Figure 3 presents a timeline summarizing Türkiye's policies and practices concerning Syrian refugees between 2011 and 2022. Each period is associated with key regulations and practices addressing the refugee crisis. This timeline is not merely descriptive but analytical it highlights how shifts in Türkiye's refugee policy frameworks have progressively shaped the spatial, architectural, and social strategies that underpin the sustainable living space scenario proposed in this study.

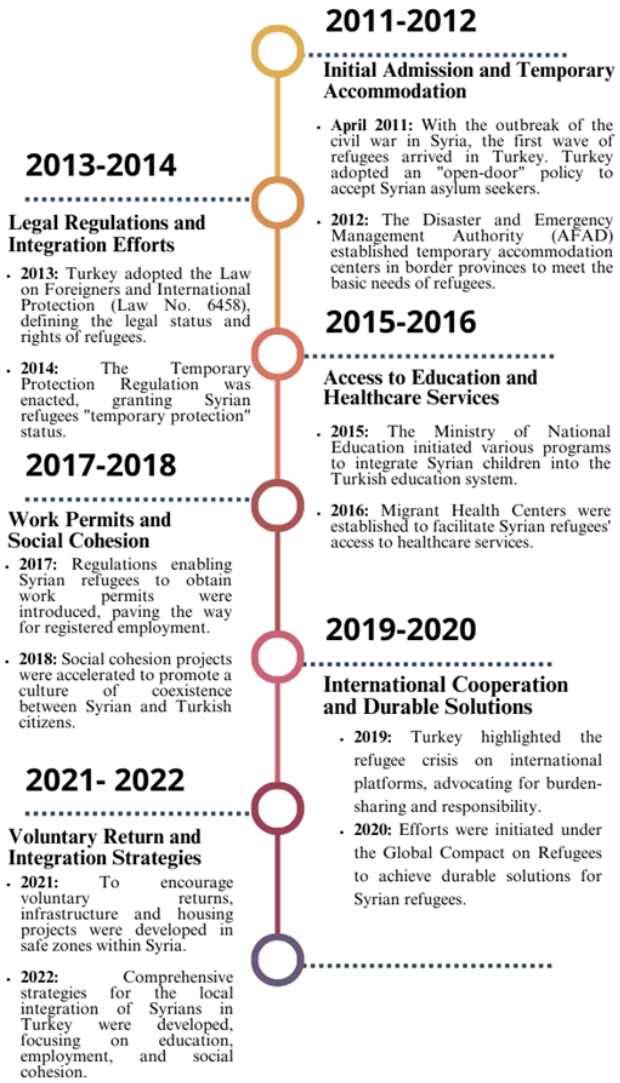

Figure 3 Timeline of efforts to address the issues faced by Syrian refugees (Aktaş, 2018; Eren, 2022)

In this context, the development of strategies to strengthen social cohesion and support environmental sustainability has become increasingly crucial, particularly in border regions like Kilis, where the refugee population has significantly impacted local demographics. Kilis, a key province along Türkiye's border with Syria, has experienced substantial demographic changes due to the influx of refugees. The refugee population in this region is noted to be very high relative to the local population, creating challenges in areas such as healthcare, the environment, and social integration (Achiri & Ibrahim, 2022). Additionally, the influx of refugees has led to environmental issues. The high concentration of refugees in Kilis has been reported to have adverse effects on waste management and environmental pollution (Aksoy & Tumen, 2021; Liszkowska, 2023). In this regard, it is evident that comprehensive strategic planning is required to improve healthcare services and enhance environmental sustainability in Kilis. Developing sustainable solutions to address the needs of both the local population and refugees is of critical importance for integration and environmental management. The 2023 Kahramanmaraş Earthquake adversely affected the living conditions of many people in the region, including Syrian refugees, and exposed the vulnerabilities in housing infrastructure (AFAD, 2023). This situation has once again underscored the importance of sustainable living spaces that adhere to modern urban planning principles, encourage community participation, and enhance local resilience (Asgary, 2018). The design of sustainable living spaces plays a vital role in strengthening refugees' place attachment and promoting social cohesion. Such spaces should not only meet the basic need for shelter but also provide environments where

refugees can engage in meaningful interactions with host communities (Mulvey, 2018). Projects involving community participation can support social solidarity and integration (Strang & Ager, 2010). In this context, a study aimed at enhancing the place attachment and well-being of Syrian refugees in Kilis could offer valuable theoretical and practical contributions. Furthermore, such an approach could directly support the United Nations' Sustainable Development Goal (SDG) 11, which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable (UN, 2015).

2. Methodology

In this study, the qualitative dimension was derived from expert consultations and desk-based synthesis of best practices in refugee settlement design, while the quantitative dimension was based on Analytic Hierarchy Process (AHP) scoring. This integration ensured interpretive insight and analytical rigor without relying on direct personal data collection. The methodology consists of four integrated stages: indicator development, weighting and prioritization, case selection, and data collection and analysis. The framework combines qualitative insight with quantitative rigor, ensuring both theoretical depth and practical applicability.

2.1. Development and Prioritization of Evaluation Indicators

Building upon the theoretical and thematic foundations discussed in the literature review (Section 1.1), the development of evaluation indicators in this study was guided by recurring concepts identified across previous research on refugee settlements, post-disaster housing, and sustainable urbanism. Drawing on a systematic literature review and expert consultation, thirteen key design indicators were identified to assess the physical, environmental, and social dimensions of refugee settlements and post-disaster living environments. Specifically, physical indicators such as Accessibility, Shelter Flexibility, and Modularity reflect the spatial and architectural adaptability of settlements; environmental indicators including Resource Efficiency and Sustainability address ecological performance and resilience to environmental stress; while social indicators (Community Involvement, Cultural Sensitivity, Mental Wellbeing, Livelihood and Resilience, Social Spaces, Safety and Security, Health and Sanitation, and Monitoring and Feedback) capture the human-centered and participatory dimensions of settlement life. Although this study primarily focuses on conflict-induced displacement, these indicators were also informed by post-disaster recovery frameworks (Citaristi, 2022), which emphasize placemaking, community participation, and long-term resilience in reconstruction contexts. Hence, the proposed model aligns both with humanitarian shelter design principles and with the broader discourse on sustainable settlement development after disasters (Table 1).

Table 1 Statistical Comparison of Recognition Intensity

Category	Best Practices	References
Safety and Security (C1)	Ensure physical protection, adequate lighting, and community safety measures.	*(Aburamadan, 2023), (AlWaer et al., 2023), (Karsu et al., 2019), (Ernst et al., 2004)*
Cultural Sensitivity (C2)	Incorporate cultural and social practices offer culturally relevant services.	*(Wardeh & Marques, 2021), (Shohel, 2022), (Gladkikh et al., 2019)*
Accessibility and Inclusivity (C3)	Provide universal access, gender-specific facilities, and equitable services.	*(Wardeh & Marques, 2021), (Almeniawi, 2023), (Siddiqi et al., 2024)*
Efficient Use of Resources (C4)	Use local materials and efficient water management strategies.	*(Matthey-Junod et al., 2022), (Akcan, 2024)*
Sustainability (C5)	Utilize renewable energy and manage waste sustainably.	*(Matthey-Junod et al., 2022), (Abreek-Zubiedat, 2023)*
Modularity and Scalability (C6)	Develop modular systems adaptable to changing needs.	*(AlWaer et al., 2023), (Jaradat & Beunders, 2023)*
Community Involvement (C7)	Engage local communities and refugees in participatory design processes.	*(Ernst et al., 2004), (Karl & Scholz Karl, 2022)*

Health and Sanitation (C8)	Implement adequate water, sanitation, and hygiene (WASH) facilities.	*(Yasmin et al., 2023), (Karl & Scholz Karl, 2022; Karsu et al., 2019)*
Social and Community Spaces (C9)	Provide spaces that foster social interaction and community building.	*(Matthey-Junod et al., 2022), (Shohel, 2022)*
Livelihood and Resilience (C10)	Empower refugees through livelihood programs and resilience-building strategies.	*(Ernst et al., 2004), (Abu-Aridah & Ligler, 2024)*
Flexibility in Shelter Design (C11)	Ensure shelters are adaptable and meet varying environmental conditions.	*(Beeman et al., 2023), (Chaichian, 2024), (Antonsson, 2010)*
Mental Health and Wellbeing (C12)	Address psychological needs with spaces and services for mental well-being.	*(Beeman et al., 2023), (Gladkikh et al., 2019)*
Monitoring and Feedback (C13)	Integrate monitoring tools to gather feedback and improve design.	*(Matthey-Junod et al., 2022)*

2.2. Analytic Hierarchy Process (AHP)

A total of 13 domain experts (comprising professionals in architecture, urban planning, disaster management, and data analysis) were consulted to construct the pairwise comparison matrices used in AHP scoring (Kürüm Varolgüneş et al., 2023). These consultations were based on structured templates distributed via email and previously published evaluation criteria, thus avoiding any need for ethical review processes. Consistency ratios were verified (CR < 0.1) to ensure reliable prioritization and mitigate subjectivity in the weighting process. The resulting values informed subsequent visual and analytical modelling stages.

The Analytic Hierarchy Process (AHP) was adopted in this study as a multi-criteria decision-making tool due to its capacity to evaluate both objective (quantifiable) and subjective (intangible) criteria through a hierarchical structure (Abdel-Basset et al., 2018; Svahnberg et al., 2003), as well as its ability to conduct consistency analysis (Razavi et al., 2011). Its advantages include ease of application in both individual and group settings, rapid data processing (Deng, 1999), adaptability to various stages of the design process, and its flexible, scalable structure. Rather than prescribing a single correct solution, AHP supports decision-makers in identifying the most suitable alternative aligned with their goals and understanding of the problem (Petkov et al., 2007; Xi & Qin, 2013). Through pairwise comparison matrices informed by experiential knowledge, AHP calculates the relative priorities of alternatives, tests consistency, and produces overall performance scores—particularly useful for assessing building lifecycle performance (Han et al., 2023).

The Analytic Hierarchy Process (AHP) was employed to determine the relative priority of the thirteen design indicators identified through the literature review and expert input. Pairwise comparisons were conducted using expert judgments, and the resulting weights were normalized to derive a composite priority vector. To maintain clarity, only the key methodological steps and summary results are presented in this section, while detailed calculation matrices, consistency ratio (CR) tests, and intermediate weight derivations are provided in Appendix A. The AHP results informed the comparative framework used in subsequent analyses, ensuring that the prioritization of design indicators reflected both theoretical consistency and expert consensus.

2.3. A Case Selection

Six refugee settlements were selected as comparative case studies, representing diverse geographic and sociopolitical contexts: Zaatari (Jordan), Kalobeyei and Dadaab (Kenya), Bidi Bidi (Uganda), Cox's Bazar (Bangladesh), and Kahramanmaraş (Türkiye). The selection of these cases followed a set of analytical criteria derived from the literature review and the study's sustainability framework. Specifically, the camps were chosen based on:

- Design innovation: Showcasing unique architectural or spatial strategies that address environmental or social challenges,

- Relevance to sustainability goals: Integration of ecological efficiency, resilience, and community participation,
- Quality and availability of documentation: Access to verified data, plans, and research materials,
- Comparative applicability to the Turkish context: Allowing cross-reference between global practices and national post-disaster settlement strategies,
- Diversity in governance and management models: Including both internationally managed and nationally coordinated refugee settlements,

These criteria ensured that the selected cases collectively represent a comprehensive range of spatial typologies, climatic conditions, and governance approaches, thereby enabling the proposed framework to be evaluated against a broad spectrum of design strategies, operational systems, and contextual realities.

2.4. Network Analysis and Visualization

To examine the multidimensional relationships between physical features of refugee camps and the established design indicators, a network analysis was conducted using NetworkX and Matplotlib in Python. For each settlement, a relationship diagram was generated in which the thickness of connections represents the aggregated importance scores derived from expert-based assessments. This visual approach enabled the identification of design elements with high strategic impacts such as the linkage between modular shelters and resilience, or between solar energy systems and environmental sustainability. In the network visualizations presented in this study, the "Fruchterman-Reingold force-directed layout algorithm" was employed using the NetworkX and Matplotlib libraries in Python. This layout configuration was chosen for its ability to spatially distribute nodes in a manner that reflects the relative strength of their connections, thereby preserving the relational topology of the design indicators and camp features. While alternative layout methods such as "PCA (Principal Component Analysis)" or "Correspondence Analysis (CA)" could offer advantages in reducing dimensionality or emphasizing latent clusters, the force-directed layout was considered more suitable for capturing and visualizing interdependencies between spatial and social indicators. "Future studies may integrate PCA/CA layouts to complement the current visual analysis and enhance pattern recognition". By applying principles of graph theory, this method not only maps the relative centrality of each component within the system but also reveals patterns of co-dependency, enabling more informed spatial and infrastructural planning. In doing so, it transforms abstract design priorities into actionable configurations and supports evidence-based decision-making in settlement design.

2.5. Local Application: Kilis Design Scenario

Based on the results of the indicator framework and comparative case analysis, a localized design scenario was formulated for Kilis, a Turkish province significantly affected by the 2023 Kahramanmaraş earthquake and noted for its high refugee-to-host population ratio. The scenario development process involved the adaptation of the framework's components to socio-cultural and environmental conditions specific to Kilis. Field-based observations and informal consultations with NGO representatives and local coordinators were incorporated throughout the design process to ensure contextual relevance and responsiveness. Rather than formal user participation, which was not conducted due to ethical and procedural constraints, the study drew upon secondary reports, field documentation, and professional insights from organizations operating within the camps. These sources provided context-specific understanding of residents' needs, enabling iterative refinements in the proposed spatial organization and programmatic distribution. As such, the design reflects on-the-ground conditions and aligns with humanitarian practice, while adhering to ethical research boundaries. The resulting scenario provides a testable prototype for the practical implementation of the developed framework in a post-disaster and refugee-dense urban context.

The overall methodological process and the sequential steps followed in developing the sustainable design scenario are illustrated in Figure 4.

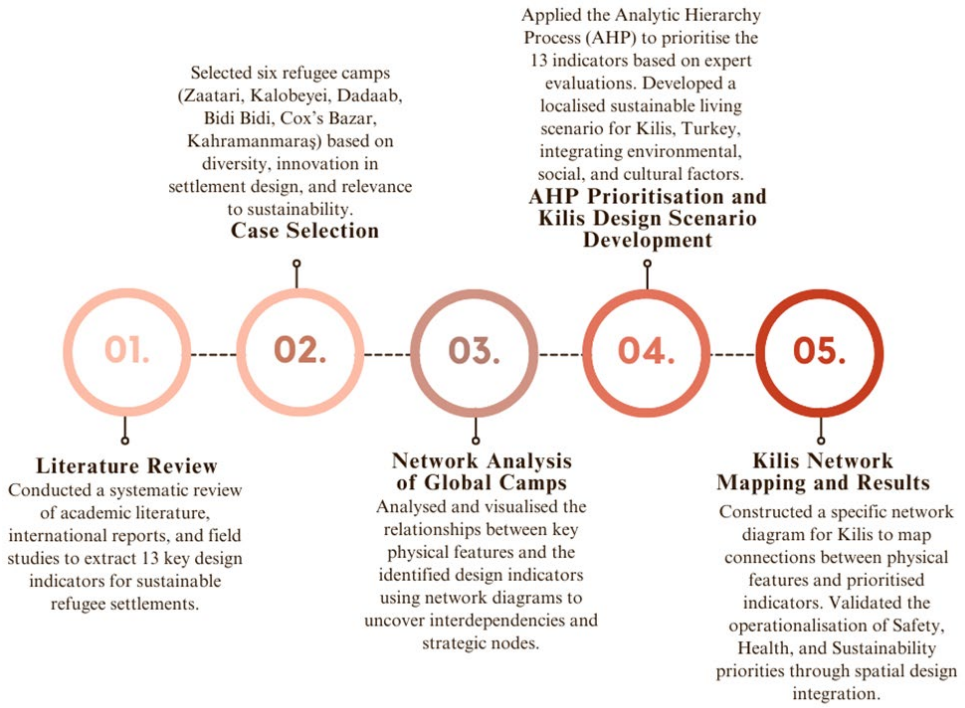

Figure 4 Process flowchart for developing a sustainable design scenario for refugee sites in Kilis, Türkiye

3. Results and Findings

3.1. Comparative Evaluation of Global Refugee Settlements

The comparative evaluation of global refugee settlements provides a foundation for understanding how diverse physical, environmental, and social design approaches shape living conditions in humanitarian contexts. Six refugee settlements (Zaatari (Jordan), Kalobeyei and Dadaab (Kenya), Bidi Bidi (Uganda), Cox's Bazar (Bangladesh), and Kahramanmaraş (Türkiye)) were selected based on their design innovation, relevance to sustainability, and contextual applicability. These case studies illuminate the best practices and critical challenges in establishing resilient and inclusive living environments. Zaatari Refugee Camp in Jordan exemplifies the evolution of humanitarian settlements from emergency responses to semi-permanent urban forms. Noted for its modular layout and market-oriented spaces, including the community-driven "Champs-Élysées" market, Zaatari promotes economic participation while integrating renewable energy and waste management systems (Carleen & Ying, 2015; Saidan et al., 2017). Despite these advancements, the camp faces structural overcrowding, limited long-term planning, and underdeveloped mental health services, which hinder sustainable integration (Pasha, 2021; Tomaszewski et al., 2016). Kalobeyei Settlement in Kenya represents an innovative model for socio-economic integration. Designed with a sustainability lens, the settlement incorporates renewable energy systems, water conservation, and shared infrastructure between refugee and host populations. Agricultural activities and small-scale trade support refugee self-reliance and community cohesion (Betts et al., 2020; Yarza Pérez, 2017). Kalobeyei's participatory and ecologically responsive planning exemplifies how refugee settlements can be positioned as long-term development projects (Fellesson & Mählck, 2024). Dadaab Refugee Camp, also in Kenya, is one of the world's largest and most long-standing refugee settlements. While it ensures access to education, health, and basic services through international humanitarian aid, it struggles with security risks and overdependence on external support (Chkam, 2016; De la Chaux & Haugh, 2020). Nevertheless, Dadaab serves as a case of resilience, highlighting the challenges of protracted displacement in unstable geopolitical

environments. In Uganda, Bidi Bidi Refugee Settlement showcases a culturally sensitive and environmentally adaptive design. Emphasis is placed on social cohesion through clustered village layouts, communal spaces, and the use of low-cost construction materials (Logie et al., 2021). Agricultural programs support food security and livelihoods, while social services such as health centers and child-friendly spaces contribute to well-being (Ssentongo et al., 2024). However, the settlement grapples with resource scarcity and gender-based vulnerabilities, reflecting the need for more inclusive and protective spatial strategies (Berke & Larsen, 2022). Cox's Bazar in Bangladesh (home to a vast Rohingya refugee population) is a densely populated and disaster-prone settlement. Its terraced shelters, bamboo-based design, and sanitation systems reflect context-sensitive approaches to environmental constraints (Islam et al., 2022). Nevertheless, the camp remains vulnerable to cyclones and flooding, with challenges in water access and social integration. The tension between refugees and host communities, driven by limited economic opportunities, underscores the complexity of implementing sustainable coexistence (Banerjee, 2024; Hoque et al., 2023; Khan, 2024). Kahramanmaraş Refugee Camp in Türkiye was established to house Syrian refugees displaced by conflict and natural disasters. Its design prioritized modular housing, social service accessibility, and GIS-informed spatial planning (Çetinkaya et al., 2016). Although the camp provides infrastructure that improves living standards, integration with the host community remains limited, and the vulnerability to seismic hazards has revealed gaps in emergency preparedness (Çavuş & Şahinöz, 2024; Kahraman, 2024).

Together, these case studies demonstrate a spectrum of strategies and outcomes in refugee settlement design. From market-based integration (Zaatari) to ecological self-reliance (Kalobeyei) and participatory planning (Bidi Bidi), each settlement reflects the tension between humanitarian urgency and long-term sustainability. The comparative analysis provides critical insights into how physical infrastructure, community involvement, and environmental responsiveness can be harnessed to improve refugee well-being and resilience.

3.2. Indicator-Based Relationship Mapping Through Network Analysis

To explore how physical and social components of refugee settlements relate to the core design indicators developed in this study, network analysis was employed for each of the six selected cases. These visualizations offered a layered understanding of how specific built elements—such as modular housing, renewable energy systems, or social space interact with broader conceptual goals like sustainability, flexibility, and community participation. Using NetworkX and Matplotlib in Python, relationship diagrams were generated in which nodes represent either a design category or a camp-specific physical feature, while the edges reflect the strength of the connections derived from expert-weighted evaluations. The diagram presented in Figure 5 analyses the Zaatari Refugee Camp (Jordan) and illustrates how modular shelters, solar energy systems, and market areas link to key design categories. The visual mapping shows strong connections between modular shelters and categories such as flexibility in shelter design (C11), health and sanitation (C8), and safety and security (C1), indicating that structural configurations can significantly influence both physical and psychosocial outcomes. Solar energy appears centrally connected to sustainability (C5), resource efficiency (C4), and community involvement (C7), highlighting its multifaceted impact. The market zones are similarly tied to economic resilience, community interaction, and cultural sensitivity, demonstrating that economic infrastructure plays a pivotal role in both integration and social cohesion (Abreek-Zubiedat, 2023; Ernst et al., 2004; Matthey-Junod et al., 2022).

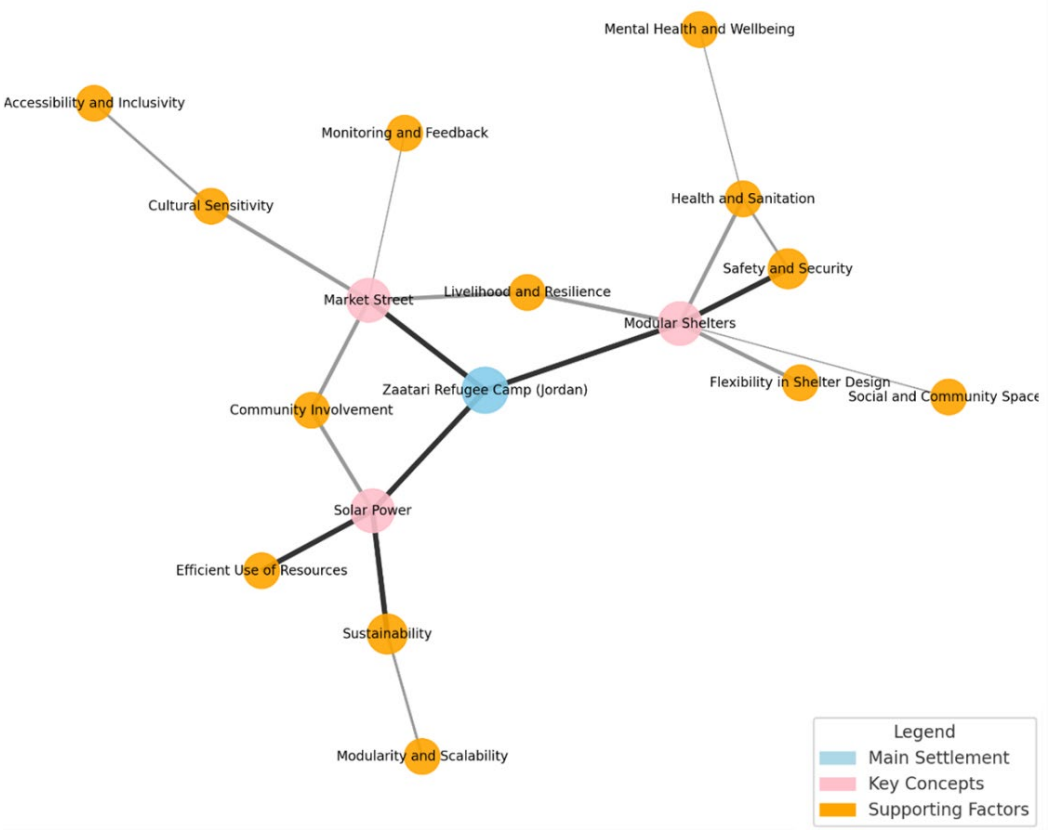

Figure 5 Relationship diagram of key design categories and features for Zaatari refugee camp

Figure 6 depicts the Kalobeyei Settlement (Kenya), where renewable energy, community integration, and permaculture practices form the core of the spatial and social strategy. The analysis shows that renewable energy systems are strongly linked to sustainability (C5), resource efficiency (C4), and community participation (C7). Community integration demonstrates ties to social spaces (C9), health (C8), and cultural sensitivity (C2), reinforcing Kalobeyei's commitment to participatory development. Permaculture links sustainability with food security, thus aligning environmental and social design goals (Yarza Pérez, 2017; Betts et al., 2020).

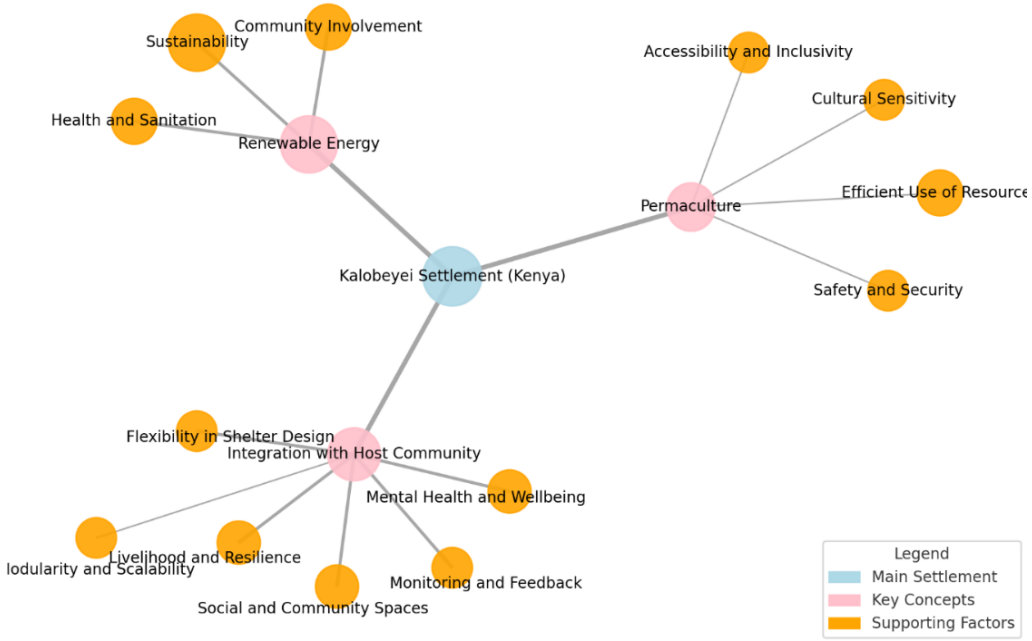

Figure 6 Relationship diagram of key design categories and features for Kalobeyei settlement area

Figure 7 focuses on Dadaab Refugee Camp (Kenya), a long-standing settlement with a strong emphasis on infrastructure provision. Key features such as water management, education, and healthcare services are central to its design. Water infrastructure connects to health and sanitation (C8), sustainability (C5), and resource efficiency (C4), while education facilities link to social spaces (C9), community participation (C7), and cultural sensitivity (C2). Healthcare access maps onto accessibility and inclusivity (C3) as well as safety (C1), showing that basic infrastructure, even when developed top-down, can have multi-dimensional social impacts (Chkam, 2016; De la Chaux & Haugh, 2020).

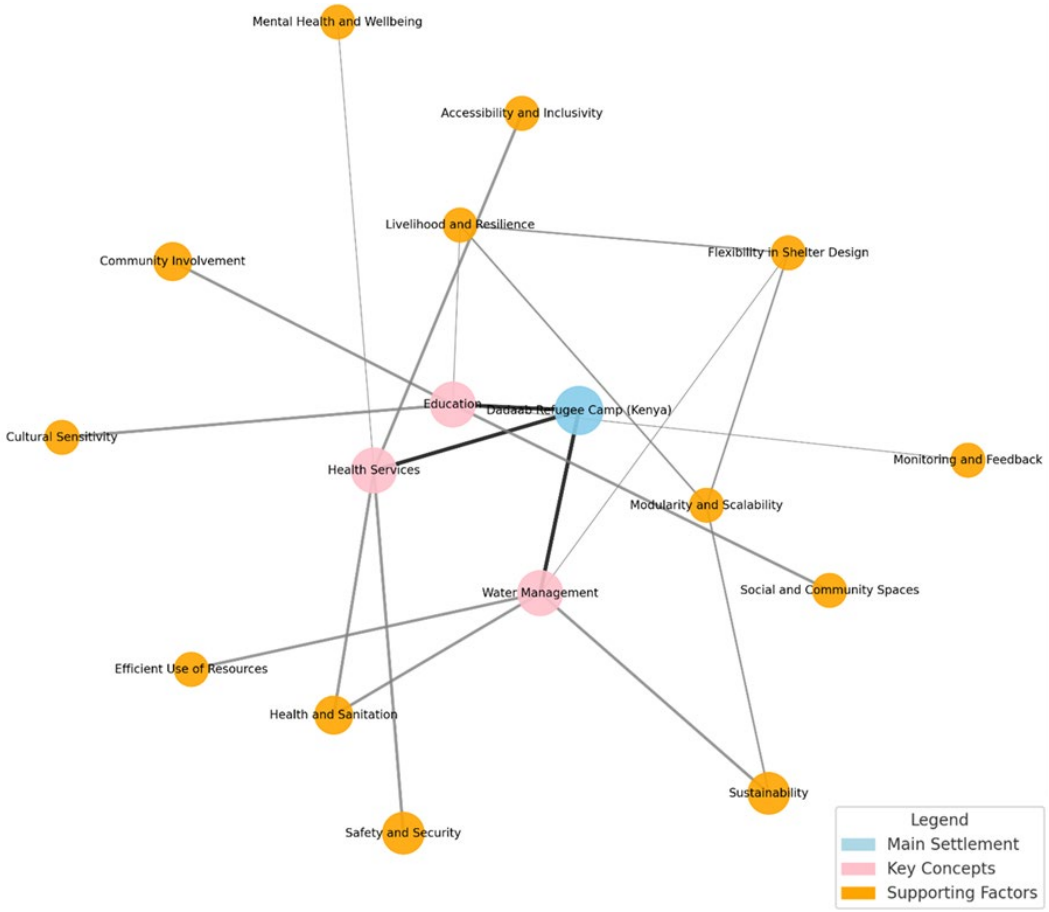

Figure 7

Relationship diagram of key design categories and features for Dadaab refugee camp

Figure 8 presents the network diagram for the Bidi Bidi Refugee Settlement (Uganda), which prioritizes clustered village structures, low-cost construction, and agricultural activities. These features are closely tied to sustainability (C5), modularity and scalability (C6), and economic resilience (C10). Agricultural areas also connect to health (C8) and food security, while community participation (C7) and cultural sensitivity (C2) are strongly present, indicating a design strategy rooted in local engagement and ecological adaptation (Logie et al., 2021; Berke & Larsen, 2022).

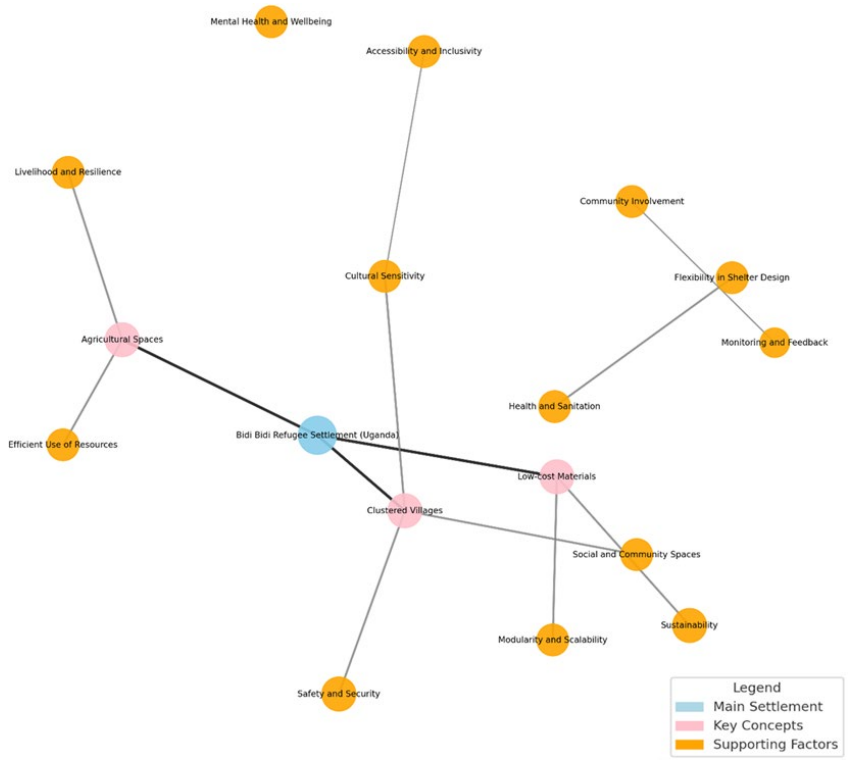

Figure 8 Relationship diagram of key design categories and features for Bidi Bidi refugee camp

Figure 9 illustrates the Cox's Bazar Camp (Bangladesh), where terraced shelters, bamboo-based construction, and sanitation systems dominate. Bamboo material is linked to sustainability (C5), resource efficiency (C4), and cultural sensitivity (C2), reflecting an environmentally attuned, culturally appropriate design strategy. Sanitation infrastructure shows strong ties to health (C8), community interaction (C9), and modularity (C6), illustrating how physical systems can support broader public health and governance goals (Islam et al., 2022; Hoque et al., 2023; Banerjee, 2024).

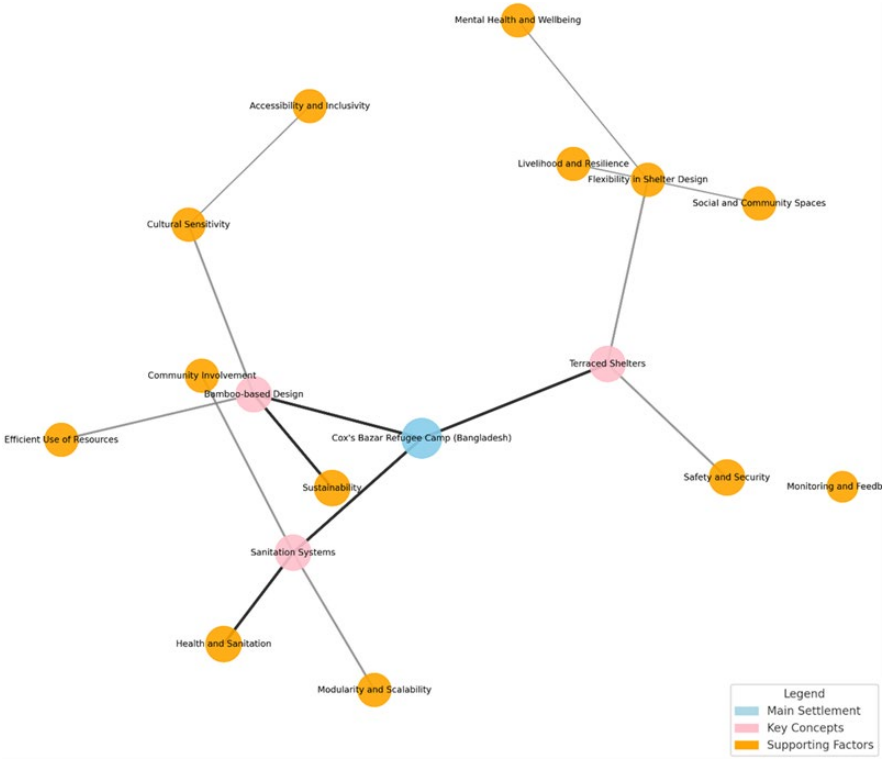

Figure 9 Relationship diagram of key design categories and features for Cox's Bazar refugee camp

Figure 10 provides an analytical view of the Kahramanmaraş Refugee Camp (Türkiye). Key elements (modular housing, social services, and urban-level infrastructure) are highly connected with flexibility (C11), safety (C1), health (C8), and accessibility (C3). Notably, social services play a bridging role by linking community participation (C7), mental well-being (C12), and social spaces (C9), suggesting that the quality and integration of service provision are central to resilience and dignity in refugee housing (Çetinkaya et al., 2016; Kahraman, 2024). These diagrams collectively reveal the complex interdependence between physical features and design goals in humanitarian contexts. The multidimensional nature of the visual models demonstrates that sustainable refugee camp design requires integrated thinking that spans infrastructure, culture, environment, and well-being. Comparative network structures across cases reinforce the need to tailor design strategies to local constraints and opportunities while maintaining fidelity to universal humanitarian standards.

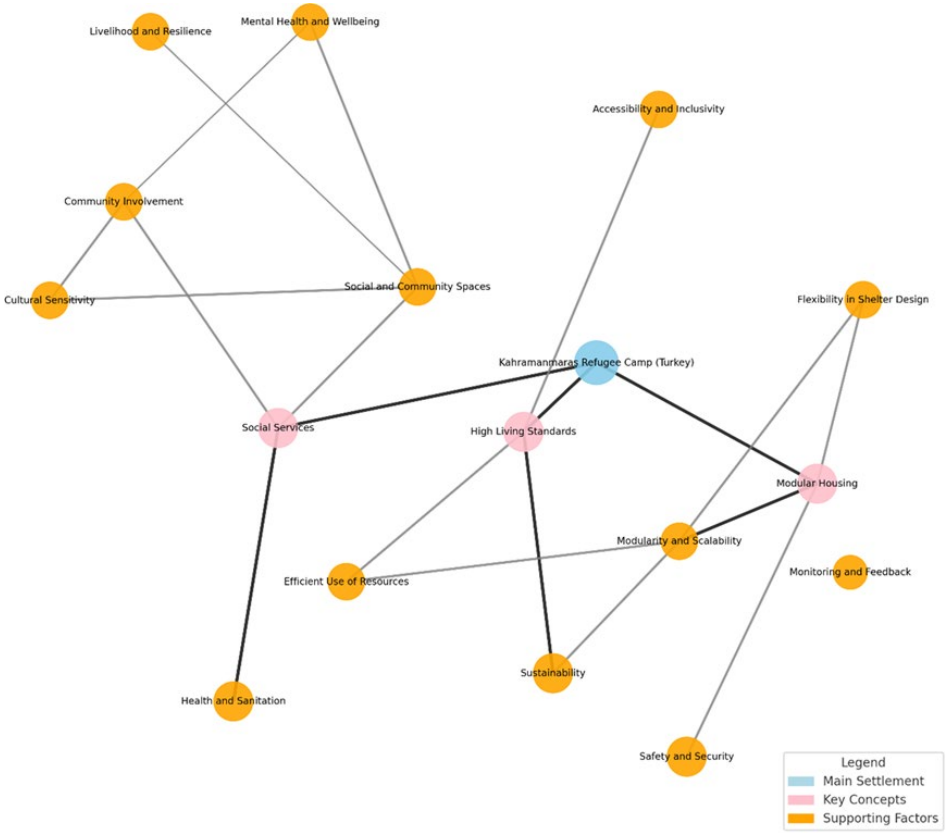

Figure 10 Relationship diagram of key design categories and features for Kahramanmaraş refugee camp

Table 2 summarizes the relative emphasis of each design indicator across the six refugee settlements analyzed in this study. The symbolic scale ((1) Very low ●○○○○, (2) Medium ●●○○○, (3) High ●●●○○, (4) Very high ●●●●○, (5) Exceptional/Dominant ●●●●●)) reflects the qualitative importance or degree of integration of each indicator within the respective settlement context. This comparative matrix allows for a holistic assessment of how sustainability, resilience, and social well-being dimensions vary between camps. It also provides an alternative to statistical correspondence analysis by visually consolidating all relationships in a single framework.

Table 2 Somparative Evaluation of Key Design Indicators Using Symbolic Rating Scale

Design Indicators	Zaatari (Jordan)	Kalobeyei (Kenya)	Dadaab (Kenya)	Bidi Bidi (Uganda)	Cox's Bazar (Bangladesh)	Kahramanmaraş (Türkiye)
Safety & Security	●●●○○	●●○○○	●●●●○	●●○○○	●●●●○	●●●○○
Cultural Sensitivity	●●○○○	●●●●○	●●○○○	●●●○○	●●○○○	●●●○○
Accessibility	●●●○○	●●○○○	●●●●○	●●○○○	●●●○○	●●●●○

Resource Efficiency	●●●●○	●●●○○	●●○○○	●●●●○	●●○○○	●●●●○
Sustainability	●●●●●	●●●●○	●●●○○	●●●●●	●●●○○	●●●●○
Modularity	●●●●○	●●●○○	●●○○○	●●●●○	●●○○○	●●●●●
Community Involvement	●●●○○	●●●●●	●●○○○	●●●●○	●●●○○	●●●○○
Health & Sanitation	●●●○○	●●●○○	●●●●●	●●●○○	●●●●●	●●●●○
Social Spaces	●●●●○	●●●○○	●●○○○	●●●○○	●●●○○	●●●●○
Livelihood & Resilience	●●●○○	●●●●●	●●●○○	●●●●○	●●●○○	●●●●○
Shelter Flexibility	●●●○○	●●○○○	●●○○○	●●○○○	●●●●○	●●●●●
Mental Wellbeing	●●●○○	●●●○○	●●●○○	●●●○○	●●●●○	●●●●○
Monitoring & Feedback	●●○○○	●●●○○	●●○○○	●●●○○	●●○○○	●●●●●

While the network analyses provided valuable insights into the relational structures among physical features and design categories in global refugee settlements, a context-specific prioritization of these indicators was necessary to guide the design framework for Kilis. Therefore, the following section employs the Analytic Hierarchy Process (AHP) to systematically determine the relative importance of each indicator.

3.3. Prioritization of Design Indicators via AHP

To quantify the relative importance of the thirteen design indicators, the Analytic Hierarchy Process (AHP) was applied, drawing on structured expert-based pairwise comparisons (Canan & Kürüm Varolgüneş, 2018; Eryürük et al., 2022). The resulting comparison matrix, shown in Figure 11, was constructed to assess the weight of each indicator in supporting sustainable refugee camp design. Each indicator was evaluated against all others using a 1–9 Saaty scale to determine comparative importance based on expert judgment. The results, as illustrated in the matrix, were processed to produce a normalized decision matrix and a vector of priority weights. The eigenvalue consistency ratio (CR) was calculated to verify the reliability of the input data. With a CR value of 0.098, which is less than the acceptable threshold of 0.1, the matrix was deemed consistent and analytically sound (Saaty, 1987; Kamaruzzaman et al., 2018).

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	1.000	7.000	7.000	5.000	3.000	5.000	3.000	4.000	5.000	3.000	3.000	5.000	3.000
C2	0.143	1.000	1.000	1.000	0.333	0.333	0.333	1.000	1.000	0.333	0.333	1.000	0.500
C3	0.143	1.000	1.000	1.000	0.250	1.000	1.000	0.250	1.000	1.000	0.333	0.200	1.000
C4	0.200	1.000	1.000	1.000	1.000	0.200	1.000	0.200	1.000	0.333	0.333	0.333	0.333
C5	0.333	3.000	4.000	1.000	1.000	1.000	3.000	1.000	3.000	3.000	3.000	0.333	3.000
C6	0.200	3.000	1.000	5.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
C7	0.333	3.000	1.000	1.000	0.333	1.000	1.000	0.333	1.000	1.000	1.000	0.333	3.000
C8	0.250	1.000	4.000	5.000	1.000	1.000	3.000	1.000	5.000	3.000	4.000	1.000	5.000
C9	0.200	1.000	1.000	1.000	0.333	1.000	1.000	0.200	1.000	1.000	1.000	0.333	1.000
C10	0.333	3.000	1.000	3.000	0.333	1.000	1.000	0.333	1.000	1.000	1.000	0.333	1.000
C11	0.333	3.000	3.000	3.000	0.333	1.000	1.000	0.250	1.000	1.000	1.000	3.000	3.000
C12	0.200	1.000	5.000	3.000	3.000	1.000	3.000	1.000	3.000	3.000	0.333	1.000	3.000
C13	0.333	2.000	1.000	3.000	0.333	1.000	0.333	0.200	1.000	1.000	0.333	0.333	1.000
Total	4.002	30.000	31.000	33.000	12.250	15.533	19.667	10.767	25.000	19.667	16.667	14.200	25.833

λmax
3.443
0.546
0.499
0.477
1.494
1.019
0.786
1.851
0.580
0.762
1.191
1.559
0.622
14.828

n	RI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

n	13	Consistency
λ_{max}	14.828	λ_{max}:n eligible
CI	0.152	
RI	1.560	
CR	0.098	0.1 consistent

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	Row Averages
0.250	0.233	0.226	0.152	0.245	0.322	0.153	0.372	0.200	0.153	0.180	0.352	0.116	0.227
0.036	0.033	0.032	0.030	0.027	0.021	0.017	0.093	0.040	0.017	0.020	0.070	0.019	0.035
0.036	0.033	0.032	0.030	0.020	0.064	0.051	0.023	0.040	0.051	0.020	0.014	0.039	0.035
0.050	0.033	0.032	0.030	0.082	0.013	0.051	0.019	0.040	0.017	0.020	0.023	0.013	0.033
0.083	0.100	0.129	0.030	0.082	0.064	0.153	0.093	0.120	0.153	0.180	0.023	0.116	0.102
0.050	0.100	0.032	0.152	0.082	0.064	0.051	0.093	0.040	0.051	0.060	0.070	0.039	0.068
0.083	0.100	0.032	0.030	0.027	0.064	0.051	0.031	0.040	0.051	0.060	0.023	0.116	0.055
0.062	0.033	0.129	0.152	0.082	0.064	0.153	0.093	0.200	0.153	0.240	0.070	0.194	0.125
0.050	0.033	0.032	0.030	0.027	0.064	0.051	0.019	0.040	0.051	0.060	0.023	0.039	0.040
0.083	0.100	0.032	0.091	0.027	0.064	0.051	0.031	0.040	0.051	0.060	0.023	0.039	0.053
0.083	0.100	0.097	0.091	0.027	0.064	0.051	0.023	0.040	0.051	0.060	0.211	0.116	0.078
0.050	0.033	0.161	0.091	0.245	0.064	0.153	0.093	0.120	0.153	0.020	0.070	0.116	0.105
0.083	0.067	0.032	0.091	0.027	0.064	0.017	0.019	0.040	0.051	0.020	0.023	0.039	0.044
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

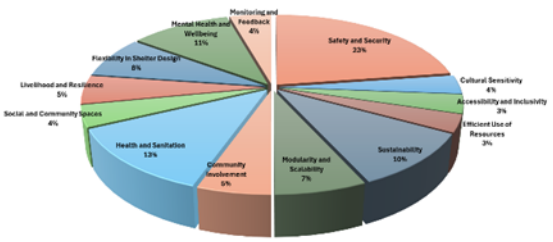

Figure 11 Relationship diagram of key AHP calculation matrices, weight values, and priority pie chart

The priority scores indicate that Safety and Security (C1) is the most influential design indicator, receiving a weight of 0.227 (23%), highlighting the foundational role of physical protection and risk reduction in camp environments. This is followed by Health and Sanitation (C8) at 0.125 (13%), underlining the centrality of hygiene, water infrastructure, and disease prevention in refugee well-being. Mental Health and Wellbeing (C12), with a priority weight of 0.116 (11%), emerges as a surprisingly strong priority, showing increasing awareness of psychological resilience in displacement settings (Beeman et al., 2023; Gladkikh et al., 2019). Sustainability (C5) ranks fourth (0.102 or 10%), showing the embeddedness of long-term environmental planning in modern camp design frameworks. Indicators such as Modularity and Scalability (C6) and Flexibility in Shelter Design (C11), which allow camps to adapt to population flux and environmental conditions, score 7% and 8% respectively. Meanwhile, Community Involvement (C7) and Livelihood and Resilience (C10) both hold 5%, reflecting the increasing but still secondary emphasis placed on participatory and empowerment-based strategies. Lower-weighted indicators, including Monitoring and Feedback (C13) (4%), Cultural Sensitivity (C2) (4%), and Accessibility and Inclusivity (C3) (3%), suggest either underrepresentation in existing design strategies or challenges in operationalizing these categories across diverse contexts (Wardeh & Marques, 2021; Shohel, 2022). Overall, the AHP results reinforce the idea that refugee camp design is still heavily guided by survival-driven metrics such as safety and hygiene, while social, participatory, and culturally adaptive dimensions are gradually gaining importance. The priority vector serves as a foundational input for the subsequent visualization (network analysis) and design adaptation phases, especially in the Kilis scenario. These results not only quantify expert preferences but also offer a structured basis for decision-making in complex humanitarian design environments.

3.4. Application of the Framework: Sustainable Living Scenario in Kilis

Kilis is a province located along Türkiye's border with Syria (see Figure 12) that has experienced significant demographic changes due to the influx of Syrian refugees. With one of the highest refugee-to-host population ratios in Türkiye, Kilis has witnessed intense pressures on housing, infrastructure, and community dynamics. These conditions necessitate an innovative, inclusive, and sustainable resettlement model. The sustainable living space project designed for Syrian refugees in Kilis offers a holistic and locally grounded approach. The project draws upon the city's spatial typologies, particularly its traditional courtyard houses—and the thirteen design indicators derived from global camp evaluations and prioritized through AHP. Each spatial decision has been developed by mapping these indicators onto the local architectural language, cultural expectations, and climatic conditions.

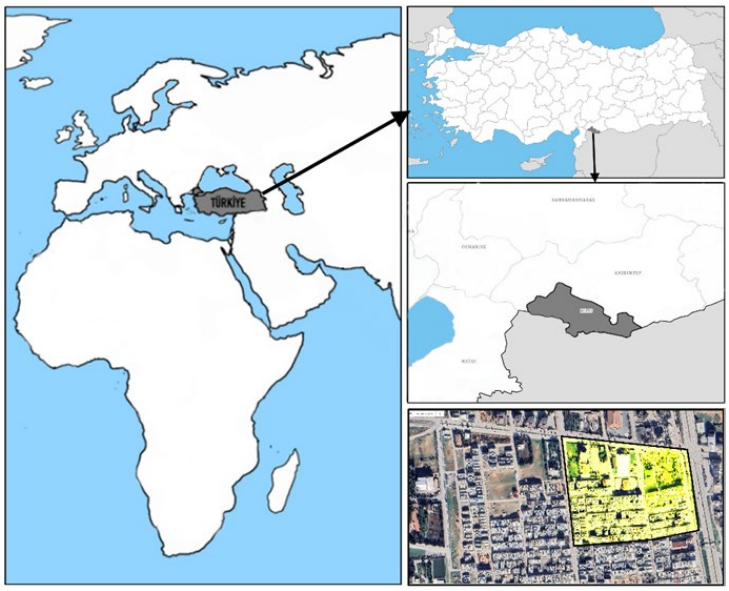

Figure 12 Location: From Türkiye to Kilis, Ekrem Çetin neighborhood

The design scenario prioritizes Safety and Security, implemented through low-rise modular units, open visual corridors, improved lighting, and designated safe spaces for women and children. Accessibility and Inclusivity are addressed via wide pathways, ramps, public transport access, and navigable zones for individuals with limited mobility. Cultural Sensitivity was a guiding principle, with Syrian family structures and Kilis's historic courtyard tradition merged in hybrid housing modules. Environmental and economic sustainability were embedded through solar panel integration, rainwater harvesting systems, greywater reuse, and urban agriculture zones. Vocational training centers and women-only workshop spaces support Livelihood and Resilience, while educational and recreational zones enhance Mental Wellbeing and Social Cohesion. To inform the design strategy, a word cloud was generated from expert consultations and participatory design sessions, highlighting recurring needs and priorities such as safety, sustainability, flexibility, and mental health (see Figure 13).

Figure 13 Word cloud from field studies and expert interviews informing the design process

The Kilis scenario offers a scalable model for post-disaster and high-density refugee settings. Its hybrid spatial layout, anchored by modular clusters and shared infrastructure, is visualized in the consolidated design representation shown in Figure 14, which maps all thirteen categories onto the master plan.

Figure 14 Kilis refugee sustainability center: An integrated and human-centered design scenario

3.5. Visualization of Local Design Integration: Network Diagram for Kilis

To validate and refine the Kilis design proposal, a customized network analysis was developed based on the same methodology applied to global camps. In this analysis, the Kilis Refugee

Sustainability Centre was placed at the core (Layer 1), with key physical features such as modular housing, social services, and living standards connected as intermediary nodes (Layer 2), and finally linked to the 13 design indicators (Layer 3) derived from AHP rankings and literature (see Figure 15).

The resulting diagram demonstrates strong, high-weight linkages between Modular Housing and indicators such as Safety and Security, Sustainability, and Shelter Flexibility. These align with the high priority weights assigned through AHP (C1: 23%, C5: 10%, C11: 8%). Likewise, Social Services connect directly to Health and Sanitation, Mental Wellbeing, and Community Involvement, confirming the centrality of service hubs in enhancing psychosocial and physical resilience. Interestingly, High Living Standards emerged as a bridging node—although not defined as a standalone indicator, it aggregates features like Resource Efficiency, Livelihood, Cultural Sensitivity, and Monitoring, suggesting a convergence of soft and hard design elements. The inclusion of this intermediary layer provides new insights into how design priorities coalesce at the neighborhood scale. This diagram reveals how the AHP-derived priorities were effectively operationalized within a spatial strategy. For instance, the centrality of Safety, Health, and Sustainability in both the network and the AHP analysis underscores their double validation as both expert-endorsed and structurally embedded elements.

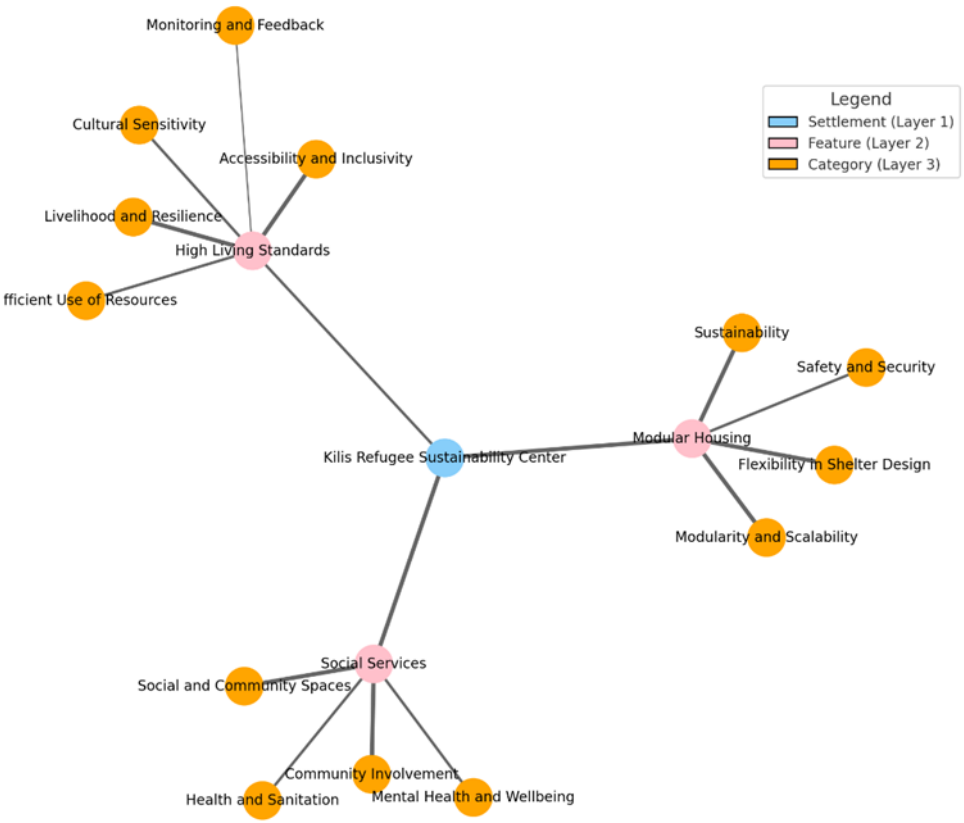

Figure 15 Relationship diagram of key design categories and features for Kilis refugee sustainability center

3.6. Design Implications and Policy Reflections

The findings of this study highlight the importance of integrating both global best practices and local contextual needs in refugee settlement design. The use of a prioritized indicator framework, grounded in expert assessments and visualized through network analysis, demonstrates how strategic design decisions can simultaneously address safety, sustainability, and community resilience. For policymakers and humanitarian planners, the Kilis scenario offers a replicable model that aligns architectural solutions with social policy goals. Emphasizing modularity, community participation, and environmental performance, the framework supports evidence-based planning for future refugee settlements in Türkiye and beyond. Moreover, the inclusion of feedback

mechanisms and participatory design processes ensures adaptability and long-term relevance critical factors for durable and inclusive urban integration.

4. Conclusions

This study proposed a comprehensive, context-sensitive framework for designing sustainable refugee settlements, integrating global design principles with local needs through a structured, indicator-based approach. By combining systematic literature analysis, expert-based prioritization via Analytic Hierarchy Process (AHP), and relationship mapping through network analysis, the research identified critical design priorities and revealed their interconnected roles in shaping effective settlement strategies. The comparative evaluation of global camps demonstrated the diversity of design responses to displacement, while the Kilis scenario showcased how such insights can be locally adapted. Key indicators—such as safety and security, health and sanitation, mental well-being, and sustainability—emerged as central nodes, both in expert ranking and network structures. Their translation into tangible spatial and infrastructural elements within the Kilis Refugee Sustainability Centre model validated the applicability of the framework in real-world settings. From a policy and planning perspective, the study highlights the necessity of integrating design thinking with humanitarian programming. The indicator-based approach enables prioritization of limited resources, supports community engagement, and strengthens resilience. As forced displacement becomes increasingly protracted and urbanized, the insights and tools developed here can guide future interventions toward more adaptive, inclusive, and sustainable refugee environments. Future research may expand on this framework by incorporating post-+occupancy evaluations, exploring dynamic spatial simulation tools, or extending the model to other at-risk regions. Ultimately, this research contributes not only to the academic discourse on refugee architecture but also to the actionable knowledge base required for equitable and future-oriented humanitarian design (Figure 16).

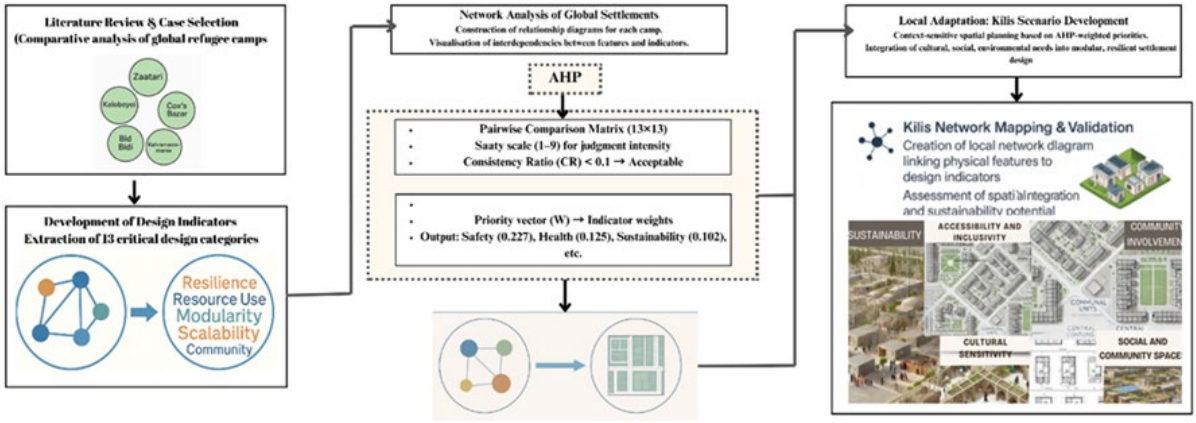

Figure 16 Graphical abstract

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Appendix A

Analytical Hierarchy Process (AHP)

In design contexts, it is widely used to compare alternatives and determine the most reliable option during problem-solving processes. The purpose of using AHP is to organize tangible or intangible factors in a systematic way and provide a simple solution to the decision-making process of problems. The pair-wise comparison matrix shows the importance levels of the criteria relative to each other within a certain logic (Gass & Rapcsák, 2004). With pair-wise comparisons, the criteria are transformed into a matrix. If aij gives the pair-wise comparison value of feature i and feature j, the pair-wise comparison matrix (Saaty, 1987; Saaty, 1990) is generally written as follows (Thanki et al., 2016):

Development of pair-wise comparison matrix (A) Building normalized matrix (A1)

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ a_{21} & \cdots & \cdots \\ \cdots & \cdots & \cdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \qquad A_1 = \begin{bmatrix} a'_{11} & \cdots & a'_{1n} \\ a'_{21} & \cdots & a'_{2n} \\ \cdots & \cdots & \cdots \\ a'_{n1} & \cdots & a'_{nn} \end{bmatrix} \quad (1)$$

and is calculated with the following formula:

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \; for \; i, j = 1; 2; 3; \ldots; n \quad (2)$$

The pair-wise comparison matrix has a number of properties. These are listed below:

- All elements of the matrix are positive numbers, and it is a square matrix.
- If the matrix is fully consistent, the equality aij . ajk = aik is satisfied.
- If the matrix is fully consistent, all other factors of the matrix are obtained from any row.
- Expansions are made as many as 2 combinations of the number n.

- The eigenvector corresponding to the largest eigenvalue of the matrix is defined as the weight or relative importance vector in the AHP matrix.
- The diagonals of matrix A are equal to 1 (Saaty, 1987; Saaty, 1990).

In order to determine the importance of the criteria and alternatives relative to each other in the Analytic Hierarchy process, each alternative is scored by looking at its weight in the AHP pair-wise comparisons scale table with other alternatives. These weights are equally important (1), moderately important (3), strongly important (5), very strongly important (7), extremely important (9), intermediate weights. The relative importance vector to be obtained from the solution of the pair-wise comparison matrix is denoted by W = (w1, w2, ..., wn). The wj values here are defined as priorities or eigenvectors. The W* matrix is obtained from these values.

$$A_1 = \begin{bmatrix} \frac{w_1}{w_1} & \cdot\ \cdot & \frac{w_1}{w_n} \\ \cdot & \cdot\ \cdot & \cdot \\ \cdot & \cdot\ \cdot & \cdot \\ \frac{w_n}{w_1} & \cdot\ \cdot & a'_{nn} \end{bmatrix} \quad \text{and} \quad w_i = \frac{\sum_{j=1}^{n} a'_{ij}}{n} \tag{3}$$

The largest eigenvalue of matrix A is known as λmax, and its corresponding eigenvector w consists solely of positive entries. The consistency of the matrix is defined as the ratio of CI to RI, or consistency index to random index. The random index table (Table 3) is employed for the RI calculation. To obtain the consistency ratio, use CI= λmax -n / n-1. A CR value less than 0.10 is considered consistent; however, if the consistency ratio surpasses 0.10, pair-wise comparisons should be reassessed (Kamaruzzaman et al., 2018; Razavi et al., 2011; Saaty, 1987).

Consistency Ratio is calculated as follows;

$$\text{Consistency Index } (CI) = \frac{\lambda_{max} - n}{n-1}, \tag{4}$$

$$\text{Consistency Ratio}(CR) = \frac{\text{Consistency Index(CI)}}{\text{Random consistency Index(RI)}} \tag{5}$$

Table 3 Random Consistency Index Values (Saaty, 1987)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

CRediT Authorship Contribution Statement

Fatma Kürüm Varolgüneş: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization.

Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

Ethics Committee Approval

Ethics committee permission is not required.

Resume

Dr. Fatma Kürüm Varolgüneş is a Assoc. Professor of Architecture at Bingöl University, with a distinguished academic career focusing on architectural design and sustainability. She earned both her Bachelor of Architecture (B.Arch.) and PhD from Selçuk University, where her research centered on innovative approaches to architectural quality and energy-efficient design. Her scholarly interests encompass a broad range of topics, including architectural design education, ecological architecture, the integration of contemporary and traditional housing design, and the application of multi-criteria decision-making methods in architectural design. Dr. Kürüm Varolgüneş has contributed extensively to the field through numerous peer-reviewed articles, as well as presentations at both national and international conferences. Her publications address critical aspects of the built environment, with a particular emphasis on how sustainable building practices from the past can be adapted to future architectural design challenges. Through her research, she continues to explore how design strategies can balance sustainability, efficiency, and aesthetic quality in contemporary architectural practice.