Reusable Shipping Containers for Urban Resilience: Design Configuration

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Abstract- The volumetric nature of shipping containers presents significant logistical and safety limitations when mass-produced for post-disaster housing. In addition, the use of highly flammable insulation materials in conventional prefabricated shelters has raised serious fire safety concerns, especially in regions with high heating demand. In contrast, demountable warehouse racking systems provide favorable structural behavior under seismic loads, as well as ease of assembly and transport due to their modular configuration. This study proposes an alternative temporary shelter model that combines the advantages of both systems by transforming shipping containers into reusable, panelized, and modular structures. The research primarily aims to evaluate the architectural feasibility of this transformation and to develop a design framework that supports flexibility, sustainability, and rapid deployment within urban contexts. The methodology involves analyzing existing container and demountable construction systems, followed by the design of panel-based spatial configurations that evolve from a single prototype unit into modular neighborhood clusters. The design approach adopts tiny house principles, emphasizing compactness, multifunctionality, and adaptability. Accessibility and universal design considerations are conceptually integrated at the unit level, while full compliance with local building regulations is identified as a focus for future phases of the study. The findings demonstrate that the proposed panelized container system enables efficient transport, fire resistance, reusability, and compatibility with urban environments—allowing disaster-affected populations to remain within their communities rather than being displaced to peripheral areas. The proposed model introduces a human-centered and scalable approach to post-disaster temporary settlements, while also outlining a comprehensive research agenda for future studies, including structural analysis, environmental performance testing, and accessibility enhancements.

Keywords- Temporary shelter, modular panel system, shipping container, post-disaster settlement, sustainable architecture

Kentsel Dayanıklılık İçin Yeniden Kullanılabilir Yük Konteynerleri: Tasarım Konfigürasyonu

Öz- Konteynerlerin hacimsel yapısı, afet sonrası konut ihtiyacını karşılamak üzere seri üretildiklerinde önemli lojistik ve güvenlik sınırlamaları ortaya çıkarmaktadır. Ayrıca, geleneksel prefabrike barınma birimlerinde kullanılan yüksek derecede yanıcı yalıtım malzemeleri, özellikle ısıtma ihtiyacının yüksek olduğu bölgelerde ciddi yangın güvenliği sorunlarına neden olmuştur. Buna karşın, sökülüp takılabilir depo raf sistemleri, modüler yapıları sayesinde deprem yükleri altında yeterli taşıyıcı performans göstermekte; montaj kolaylığı ve taşınabilirlik açısından da avantaj sunmaktadır. Bu çalışma, her iki sistemin avantajlarını bir araya getirerek yeniden kullanılabilir, panelize ve modüler yapılara dönüştürülmüş konteynerlere dayalı alternatif bir geçici barınma modeli önermektedir. Araştırmanın temel amacı, bu dönüşümün mimari açıdan uygulanabilirliğini değerlendirmek ve esneklik, sürdürülebilirlik ve hızlı kurulum gibi özellikleri destekleyen bir tasarım çerçevesi geliştirmektir. Yöntem olarak, mevcut konteyner ve sökülebilir yapı sistemlerinin analizi yapılmış; ardından tek bir prototip birimden modüler mahalle kümelerine evrilen panel tabanlı mekânsal konfigürasyonlar tasarlanmıştır. Tasarım yaklaşımı, tiny house (küçük ev) ilkelerini benimseyerek mekânsal sıkıştırma, çok işlevlilik ve uyarlanabilirliği ön plana çıkarmaktadır. Erişilebilirlik ve evrensel tasarım ilkeleri, birim düzeyinde kavramsal olarak bütünleştirilmiş; ancak yerel yönetmeliklerle tam uyumun sağlanması, çalışmanın sonraki aşamaları için odak noktası olarak belirlenmiştir. Araştırma bulguları, önerilen panelize konteyner sisteminin taşımada verimlilik, yangın dayanımı, yeniden kullanılabilirlik ve kentsel çevreyle uyumluluk açısından önemli avantajlar sunduğunu ortaya koymaktadır. Bu sayede, afet mağdurlarının kent dışına taşınmak yerine kendi mahallelerinde yaşamlarını sürdürebilmeleri mümkün hale gelmektedir. Önerilen model, afet sonrası geçici yerleşimlere yönelik insan odaklı ve ölçeklenebilir bir yaklaşım geliştirmekte olup, gelecekteki çalışmalar için yapısal analiz, çevresel performans testleri ve erişilebilirlik iyileştirmelerine yönelik kapsamlı bir araştırma gündemi tanımlamaktadır.

Anahtar Kelimeler- Geçici barınak, modüler panel sistemler, yük konteyneri, afet sonrası yerleşim, sürdürülebilir mimari

1. Introduction

Temporary structures designed for post-disaster housing play a vital role in enabling the sustainable recovery of both individuals and communities [1]. In large urban areas, allowing disaster-affected residents to remain close to their original neighborhoods supports social cohesion and contributes to strengthening urban resilience [2, 3]. Existing research on post-disaster temporary housing has primarily concentrated on four main themes: land ownership, site selection, construction technologies, and post-use sustainability [4, 5, 6, 7, 8, 9]. While ownership and location-related issues have been widely discussed, notable gaps persist regarding the technological and environmental dimensions of shelter design [10]. Within sustainable construction practices, the concept of reuse emerges as a critical principle, emphasizing the necessity for durable, demountable, and reusable systems in temporary housing.

Resilience theory provides a complementary framework to disaster risk reduction by emphasizing the capacity of individuals, communities, and systems to withstand, adapt to, and recover from disruptive events [11, 12]. Anticipatory action, informed by resilience-based planning, enhances preparedness and enables faster recovery [13]. As Efe (2025) [13] notes, integrating impact forecasting into humanitarian risk management is essential to improve agility and responsiveness during crises. Meaningful community engagement—through preparedness, training, and participatory planning—further reinforces collective safety perceptions and strengthens social solidarity [14, 15].

The housing crisis following the February 6, 2023 Kahramanmaraş earthquakes revealed the severe inadequacy of Turkey's prefabricated construction capacity and underscored the urgent need for alternative building systems. The Ministry of Trade's temporary suspension of prefabricated building exports demonstrated that even when all production was redirected to domestic demand, the need for temporary housing remained unmet.

Building on previous research, including the author's earlier study "Shipping Containers as Temporary Shelters in Post-Disaster Scenarios: Flying Factories" [3], this work extends the discussion by focusing on the architectural reconfiguration of container-based systems. The earlier Flying Factory model addressed the logistical and participatory dimensions of temporary housing production but did not explore architectural and spatial organization in detail. The present study fills this gap by re-evaluating temporary shelter technologies, identifying key deficiencies in current systems regarding structural safety, fire resistance, and logistical efficiency. In addition to technical considerations, the study highlights the importance of ensuring that temporary housing solutions also fulfill social sustainability objectives.

1.1. Problem Definition

In post-disaster shelter practices in Turkey, significant deficiencies have been identified not only in structural safety and fire resistance but also in sustainability and environmental performance [16, 17]. Within this context, two prototype projects stand out: those developed by Şener and Altun [18] and Avlar et al. [19].

The project by Şener and Altun (2009) [18], developed at Istanbul Technical University with European Union funding, utilized wooden Structural Insulated Panels (SIPs). Although this approach offered lightweight assembly, the flammability of the EPS core material posed severe fire safety risks, especially during winter use. Similarly, the prefabricated CLT e-box model developed by Avlar et al. [19] employed OSB-clad timber panels that showed low fire resistance and high production costs, limiting large-scale applicability.

Meanwhile, standard prefabricated housing units—typically composed of steel box profiles and EPS-filled sandwich panels—continue to present similar challenges in sustainability and safety. These recurring material and design issues underline the necessity for an alternative system that balances structural durability, modularity, fire safety, and reusability.

Shipping containers have emerged as a potential resource for both permanent and temporary housing due to their modular geometry and robust steel structure [20]. In international competitions such as the Solar Decathlon, container-based systems have been showcased as adaptable, innovative construction models, often combined with SIP technologies. They have also been used in post-disaster contexts, notably in the temporary housing designed by Shigeru Ban after the 2011 Great East Japan Earthquake, which remained in use for up to eight years owing to user satisfaction [21, 22].

However, conventional shipping containers exhibit significant limitations when applied directly as housing units. Their volumetric nature leads to inefficiencies in transportation and mass production [23, 24]; interior modifications require specialized cutting and welding [20]; and their rigid geometry restricts spatial flexibility (Figure 1) [25, 26]. In colder climates, the use of flammable insulation materials has caused serious fire hazards, sometimes forcing residents to evacuate [27, 28]. Despite these drawbacks, the intrinsic properties of container materials—namely, the use of steel box profiles and corrugated corten steel—offer advantages in durability, non-combustibility, and longevity.

To overcome the limitations of volumetric container systems, this study explores a design approach that transforms them into panelized, demountable systems (Figure 2). This transformation enhances modular flexibility, enables repeated assembly and disassembly, and improves transportation efficiency. The concept is further supported by adopting mechanical fasteners for wall and floor panel connections, allowing factory-based or on-site assembly depending on logistical constraints.

Container Parts	Corner Fittings

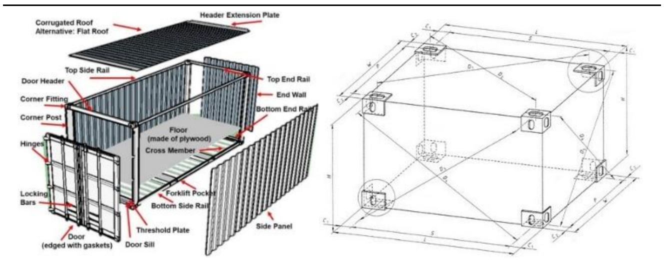


Figure 1: Components of a typical shipping container (left) [29], corner fittings in the frame (right) [30].

Stacking of Panels	Floor Panels	Wall Panels

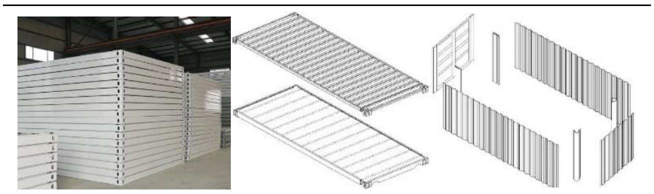


Figure 2: From a volumetric system to a panel system as a prefabrication method; manufacturing of floor panels in a factory (left), floor panels (center), wall panels [31, 32].

To ensure indoor comfort within the container, thermal insulation compatible with climatic conditions is essential. A commonly adopted approach is to retain the corten steel as the exterior façade while constructing a secondary wall with a steel stud frame on the interior side. The cavity between the two layers is filled with non-combustible insulation material such as glass wool or rock wool, and the interior finish is completed with gypsum board cladding. This design strategy creates a fully fire-resistant building envelope and enhances fire safety performance (Figure 3).

Wall Layers	Wall Cavity	Interior

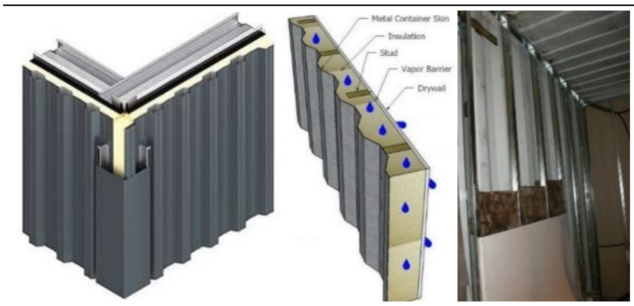


Figure 3: Thermal insulation on exterior wall in a reused shipping container [33, 34, 35].

As an alternative structural framework, demountable warehouse racking systems made from galvanized steel sheets offer significant potential for use in temporary shelter construction. Widely utilized in industrial logistics, these systems exhibit high load-bearing capacity and have proven their structural reliability under seismic loads [36]. Typically designed to be stackable up to seven or eight levels, racking systems provide a scalable structural framework that can be adapted for housing applications (Figure 4). Structurally, they employ braced frame assemblies composed of cold-formed galvanized steel members—often C-profiles with an approximate width of 14 cm—reinforced with diagonal bracing elements. This configuration offers high lateral stability while maintaining a lightweight and demountable structure.

The primary advantage of this system lies in its modularity and ease of disassembly, which are critical for rapid deployment in post-disaster contexts where mobility and flexible site adaptation are essential. The use of bolted and hooked connection mechanisms allows for fast, tool-efficient installation and repeated assembly without specialized labor. These features present clear logistical advantages over conventional prefabricated structures, which often rely on welded or permanently fixed joints. Despite these benefits, several limitations must be addressed for effective architectural adaptation. Standard racking spans typically fail to meet the spatial requirements of prefabricated housing, necessitating either double-beam configurations or the development of customized modular strategies to achieve adequate interior widths. Moreover, optimizing joint configurations to enhance load distribution and increase span capacity is essential for residential application.

While demountable warehouse racking systems offer strong potential in terms of ease of disassembly, seismic resilience, modular flexibility, and lightweight construction, their dimensional constraints and detailing requirements demand further refinement. Addressing these challenges through architectural adaptation and structural optimization could unlock their capacity to serve as the structural basis for new-generation modular temporary shelters.

Framing System	Connection Detail	Racking System Under Load

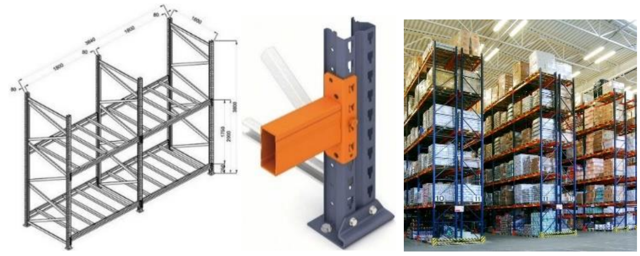


Figure 4: Demountable warehouse racking system [37, 38, 39].

1.2. Hypothesis of the Study

Based on the literature review and preceding analyses, it has been concluded that effective temporary shelter units must be reusable, demountable, fire-resistant, durable, and easily transportable. The central design challenge of this study is to develop a modular structural system that fulfills these criteria while maintaining spatial flexibility and comfort. From a material and structural perspective, steel satisfies these requirements through its strength, durability, and non-combustibility, while demountable rack systems demonstrate the potential for repeated assembly. Therefore, the hypothesis of this research is that by integrating the advantages of shipping container structures with the modular characteristics of storage rack systems, a new hybrid construction approach can be developed to produce efficient, adaptable, and sustainable temporary shelters.

In this context, the container system is redefined not as a fixed volumetric unit but as a panelized assembly composed of three primary components: floor panels, wall panels, and corner columns (Figure 5). Each component is manufactured as a separate module and assembled on-site through detachable joints, ensuring ease of transport, flexibility, and reusability. Structural joint configurations for this panelized system can be determined and optimized based on structural analysis results [40]. This paper focuses on the architectural design and conceptual development of this system, while structural performance evaluation and material testing will be addressed in subsequent research phases.

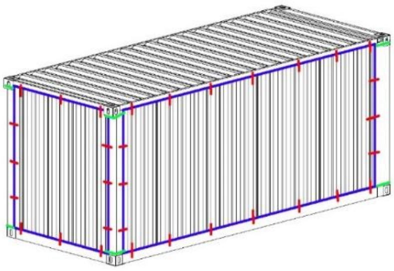
Connection Spots	Types of Structural Joints
	- *Rigid; Joints can resist moments and maintain rigidity* - *Semi-rigid; Semi-rigid joints act between flexible and rigid* - *Flexible; Pin cannot resist moment, provides flexibility between members*
	Key Features
	Metal brackets with bolted joints can be used. Furthermore, stiffening can be added to these metal brackets if necessary

Figure 5: Potential locations of panel connections for demountable shipping containers (left) and types of structural steel joints (right) (Prepared by the authors).

2. Materials & Methods

This study concentrates on the architectural design phase of a broader research framework and explores how standard shipping containers can be reconfigured into panel-based modular systems for temporary post-disaster housing. The design process focuses on spatial configuration, modular adaptability, and the integration of detachable connection mechanisms to enhance transportability and reusability.

The research is structured into two main phases. The first phase—covered in this paper—addresses the architectural feasibility and design development of the proposed system. The second phase will evaluate its structural performance, including load-bearing behavior, seismic resilience, and durability. The overall research framework is illustrated schematically in Figure 6.

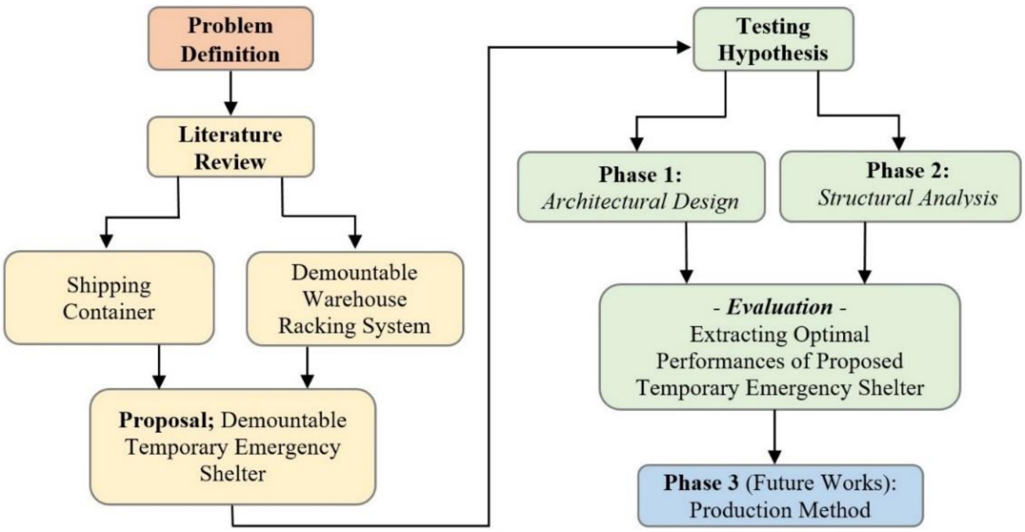


Figure 6: Phases of the integrated research framework (Created by the authors).

Building upon the problem definition and hypothesis established in the introduction, this phase specifically investigates how container-based elements and demountable construction principles can be combined within an architectural context. The analysis began with a comparative study of two existing systems—shipping containers and demountable warehouse racking structures—to identify transferable structural and material features applicable to modular housing. This evaluation informed the development of a hybrid construction system employing steel box profiles, corrugated corten panels, and detachable connection elements.

The methodological framework consists of three sequential design stages that progressively expand the architectural scope of the proposed model (Table 1). In the first stage, a primary shelter unit was developed by transforming a standard shipping container into a panel system. The spatial layout of this unit was refined to address key parameters such as thermal insulation, natural lighting, and spatial comfort. The design emphasizes functional compactness while maintaining sufficient flexibility to accommodate various user needs within limited space.

The second stage focused on the development of modular neighborhood configurations through the aggregation of multiple units. These modules were combined both horizontally and vertically to create small-scale community clusters that feature shared courtyards, circulation corridors, and communal facilities. The design process at this stage also included planning decisions related to infrastructure, pedestrian circulation, and the spatial hierarchy of collective areas, ensuring social interaction and accessibility.

The final stage involved the formulation of a scalable expansion strategy, enabling the proposed modular settlement to grow incrementally according to evolving field needs. This approach supports phased production and deployment, allowing settlements to adapt to different site conditions and programmatic requirements over time. In this way, the proposed system was conceptualized as a flexible, adaptive, and logistically efficient solution for both individual and community-scale applications.

The system's structural components—steel box profiles, corrugated corten steel panels, and custom connection joints—were selected for their fire resistance, reusability, and structural durability. Insulation layers were specified using non-combustible materials such as glass wool or rock wool to ensure thermal comfort and safety. By fabricating containers as a panelized rather than volumetric system, the design achieves substantial logistical advantages in terms of transportation, handling, and storage.

All design development and modeling were conducted using CAD-based digital tools, enabling iterative refinement and visualization of alternative spatial configurations. The resulting architectural models were analyzed across multiple scales—from individual unit design to urban-level integration scenarios—to evaluate their feasibility within high-density urban environments. By proposing a system that allows disaster-affected populations to remain within existing urban areas rather than being relocated to peripheral sites, the study emphasizes not only physical reconstruction but also social sustainability as a key component of post-disaster resilience.

Table 1: Stages and content of the research methodology (Prepared by the authors).

Stage	Content Description
1. Design of Primary Unit	*- Transformation of the container into a panelized system* *- Development of floor plans and sections for a single unit* *- Design of interior layout, insulation, and daylighting strategies* *- Definition of user capacity and spatial comfort standards*
2. Modular Neighborhood Clusters	*- Horizontal and vertical combinations of multiple units* *- Design of modular neighborhood clusters with shared courtyards* *- Planning of infrastructure, circulation, and communal spaces* *- Development of urban in-fill settlement scenarios*
3. Modular Expansion Strategies	*- Development of a phased expansion model for the container settlement* *- Planning for integration into the production and delivery process*

3. Shipping Container Conversion into Shelter

This section elaborates on the architectural design process through which shipping containers were reinterpreted as modular and panelized temporary shelter units. The design development follows the methodological sequence outlined in Table 1, progressing from single-unit design to neighborhood configuration and finally to modular expansion strategies.

3.1. Primary Unit Configuration

The prototype structure developed in this study consists of a three-story temporary housing block generated by transforming standard shipping containers into a panel system. Each floor accommodates two independent residential units of approximately 2.40 × 6.00 m, yielding six dwellings in total. The design emphasizes modularity, user comfort, structural efficiency, and rapid assembly.

Three containers are aligned side by side to form the building's basic footprint. The centrally positioned module functions as a service core, housing the staircase, vertical circulation shaft, and wet areas such as bathrooms and entrance halls (Figure 7). The outer containers accommodate the primary living spaces. The hinged container doors have been reinterpreted as balconies: by reinforcing the open doors with lightweight floor structures, semi-open spaces were created that extend the interior toward the exterior. This feature improves natural ventilation, daylight access, and the psychological quality of limited interior spaces.

From a structural standpoint, the long side walls remain the main load-bearing elements; therefore, large openings were avoided on those façades. Window openings are positioned on the shorter sides—primarily in kitchens and bathrooms—to provide daylight without compromising stability. Prefabricated "kitchen pods" and "bath pods" are inserted during assembly, reducing construction time and enabling easy replacement when needed. The upper floors include additional bedrooms, enhancing privacy and accommodating family use.

In the ground floor plan, both residential units feature an open-plan layout that includes kitchen and living areas. The wet spaces are designed as independent “kitchen pod” and “bath pod” modules that are later inserted into the containers. This modular system accelerates the production process and facilitates easier maintenance. The typical floor plan, which represents the first and second floors, includes an additional bedroom in each unit, thus offering greater privacy and better suitability for family living. The balconies serve as semi-open living spaces that connect residents to the outdoors and support social interaction. The unit design has been developed to ensure both functionality in addressing individual shelter needs and flexibility for integration into larger-scale temporary settlement schemes through its modular scalability.

In terms of spatial planning, the proposed unit is elevated three steps above ground level to prevent moisture ingress and improve ventilation beneath the structure. An accessibility ramp is integrated into the entrance level, enabling individuals with physical disabilities to access the ground-floor units. However, to ensure full usability, bathroom facilities within these units must be redesigned according to the principles of universal design and relevant accessibility standards [41, 42, 43, 44]. Beyond accessibility, the overall layout has been influenced by the compact and efficient spatial organization strategies characteristic of the tiny house concept. In line with this approach, the main living space incorporates a convertible sofa that can be transformed into a bed, thereby maximizing functionality within a limited footprint. While this configuration offers high spatial efficiency, its applicability within the Turkish context should be reviewed in relation to official guidelines. Therefore, alignment with temporary housing design manuals issued by local authorities should be evaluated in subsequent phases of the study. Nevertheless, it is important to note that although accessibility features are incorporated at this design stage, a dedicated study of accessibility—including detailed design solutions, user-based testing, and compliance with accessibility regulations—falls beyond the scope of the present work and is proposed as a future research direction.

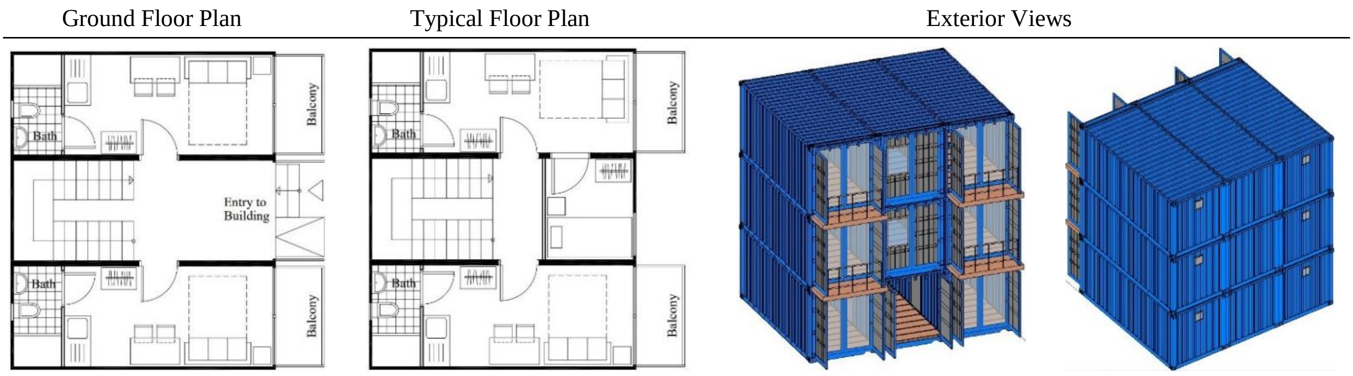


Figure 7: Plan solutions for the container conversion designed for the primary unit configuration with 6 units (Illustrations drawn by Zahraa Taha).

3.2 Modular Settlement Organization Based on the Replication of the Prototype Unit

This stage focuses on the organization of modular settlements through the repetition of the prototype unit defined in Section 3.1. In the proposed neighborhood model, four three-story housing blocks are arranged around a shared courtyard that serves as the communal core of the layout (Figure 8).

Each block’s entrance faces the courtyard, facilitating social visibility and interaction while maintaining equal access to natural light and ventilation. The courtyard also functions as a flexible open space for temporary gatherings, children’s play, and community activities.

A minimum separation of three meters is maintained between buildings to ensure fire safety, emergency access, and the passage of service vehicles. This modular configuration supports the creation of compact but socially active settlements, where shared open spaces strengthen community ties and collective resilience during the recovery phase.

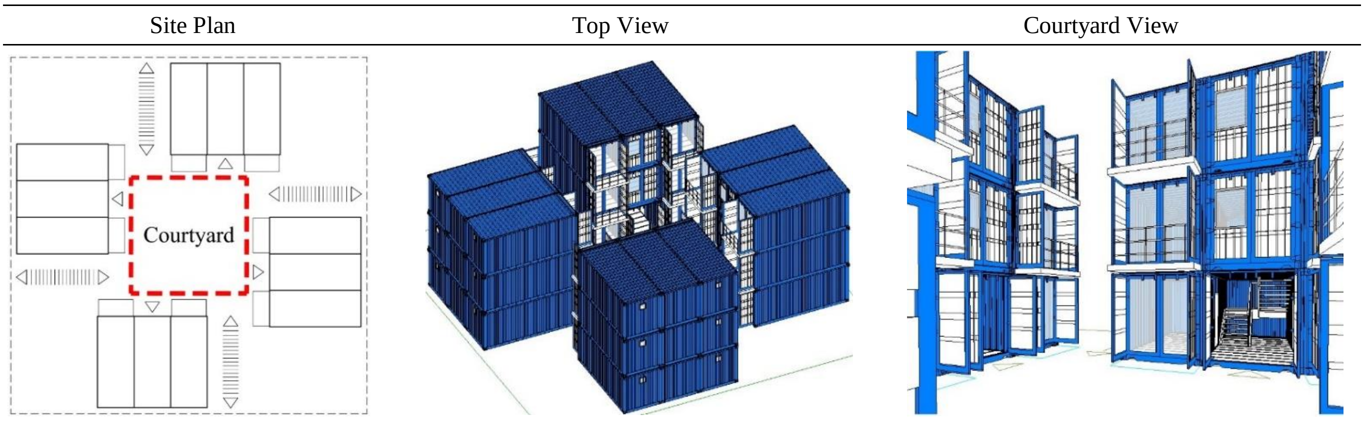


Figure 8: Combined unit and neighborhood model with 24 units (Illustrations drawn by Zahraa Taha).

3.3 Modular Expansion Strategy Based on the Primary Unit and Neighborhood Model

Building upon the prototype unit and neighborhood organization, this section proposes a modular expansion strategy that allows the settlement to scale up into a coherent urban district. Clusters of three-story modules are systematically replicated to form a networked settlement pattern comprising 96 units (Figure 9).

The plan includes a hierarchy of open and circulation spaces—primary and secondary roads—that regulate pedestrian and service access. Voids between clusters ensure ventilation, daylight, and safety while creating a rhythmic spatial order.

The modular growth approach provides both physical and operational flexibility. Neighborhoods can expand incrementally according to site conditions or population needs, allowing phased production and deployment. The stackable system, accommodating up to three stories, ensures efficient land use and makes the model suitable for dense urban contexts (Figure 10).

Overall, this scalable design framework offers a sustainable and adaptive strategy for post-disaster settlements. It combines human-centered spatial organization with logistical efficiency, supporting both rapid deployment and long-term livability within the existing urban fabric.

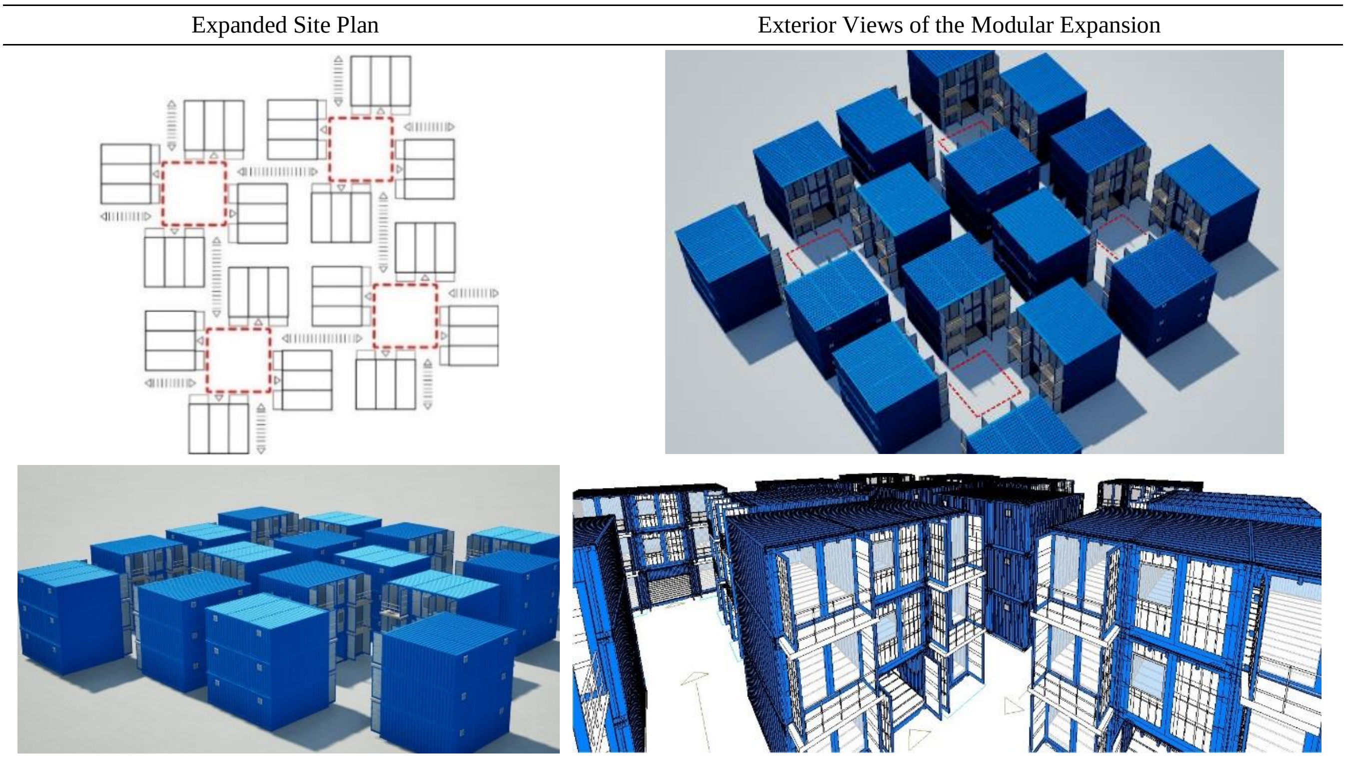


Figure 9: Schematic site layout illustrating the repetitive arrangement of modular neighborhood clusters (top-left); Perspective view showing the courtyard-oriented configuration of units and the internal street network (top-right); High-density temporary neighborhood pattern composed of 96 units, formed through three-storey modular combinations (bottom-left and right) (Illustrations drawn by Zahraa Taha).

Figure 10: Silhouette of modular growth strategy for post-disaster settlements (Illustration drawn by Zahraa Taha).

4. Findings

This section presents the findings derived from the design process detailed in Section 3. Both the transformation of the container into a panel-based system and the configurations developed through the clustering of these units into neighborhood and settlement models have generated innovative and applicable insights for the design of temporary housing environments (Table 2). The findings have been analyzed on three levels: the primary housing unit, the neighborhood model, and the modular expansion strategy.

The conversion of the container into a panel system has offered significant advantages in terms of transportation, storage, and on-site assembly. Unlike conventional volumetric systems, the proposed structure is composed of dismountable components such as floor panels, wall panels, and corner columns, making it adaptable to diverse scenarios. The integration of both welded and bolted connection details has ensured structural integrity while enabling fast assembly and disassembly in the field. In terms of interior design, spatial decisions that enhance thermal comfort—achieved through the use of non-combustible insulation materials such as glass wool or rock wool—as well as improved natural lighting and ventilation, have contributed to an enhanced user experience. Accordingly, the proposed unit is evaluated not only as a temporary solution but also as a habitable and high-quality shelter structure.

Table 2: Summary of key findings from the design process (Prepared by the authors).

Design Level	Key Features	Main Findings
a) Primary Unit Design	*- Panel-based system (floor, wall, corner column)* *- Hybrid joints (welded + pinned)* *- Fire-resistant materials*	*- Enhanced transport and storage efficiency* *- Fast and flexible on-site assembly* *- Improved thermal comfort and daylighting* *- Structurally adaptable system*
b) Neighborhood Model	*- Three-story modular clusters* *- Shared central courtyard* *- Horizontal and vertical combinations*	*- Stronger social interaction compared to standard camps* *- Spatial efficiency with human-centered design* *- Adaptability to various urban plots*
c) Modular Expansion Model	*- Scalable up to 96 units* *- Defined access hierarchy (primary & secondary roads)* *- Min. 3 m spacing between units*	*- Supports phased deployment and scaling over time* *- Enables emergency access and service delivery* *- Spatial organization enhances community resilience*

The neighborhood model, formed by combining multiple container units in both horizontal and vertical configurations, has yielded positive outcomes in terms of spatial efficiency and social sustainability. Each neighborhood cluster consists of three-story modular groupings centered around a shared courtyard. Unlike conventional container camps, this layout promotes stronger social bonds among users by offering a more integrated and interactive spatial organization. Moreover, the proposed system allows for flexible settlement scenarios that can adapt to various site conditions, enabling not only rapid deployment but also context-sensitive planning strategies for temporary housing.

The modular expansion scenario, based on the replication of neighborhood clusters, demonstrates that post-disaster needs can be met through a phased production and delivery strategy. In the proposed model, a high-density settlement consisting of 96 units has been developed and visualized through three distinct layout diagrams shown in Figure 9. The modular site plan incorporates primary and secondary access routes designed to accommodate both pedestrian and service circulation, with a minimum distance of three meters between buildings. This configuration ensures a balanced solution for emergency response and daily circulation requirements. The spatial organization model, which supports social solidarity, offers not only a physical but also a psychosocial contribution to post-disaster recovery processes.

This study presents several limitations that should be acknowledged. First, accessibility considerations have been addressed conceptually within the proposed design framework; however, detailed accessibility solutions, user testing, and compliance verification with universal design standards remain beyond the scope of this phase. Second, the structural behavior of the proposed panelized system—including load-bearing capacity, seismic performance, and durability—has not yet been experimentally evaluated. Third, environmental factors such as thermal comfort, insulation performance, and climatic adaptability were considered only at a theoretical level. Additionally, the applicability of the modular settlement model within dense urban contexts, such as Istanbul, has been assessed conceptually but requires further investigation through real-site implementations and regulatory assessment. Lastly, user participation and community-based design processes, which are critical to post-disaster resilience, have not been empirically studied within this research stage. These limitations highlight the need for multidisciplinary collaboration in the subsequent phases of the study.

5. Conclusion

This study demonstrates that a sustainable, reusable, and modular building system can be developed at the architectural scale to address the urgent need for temporary shelter in post-disaster scenarios. The proposed model introduces an innovative design approach by combining the structural durability of shipping containers with the modular flexibility of demountable warehouse racking systems. As the first phase of a broader research framework, the present study focuses on the architectural design dimension, while the structural and environmental performance assessments will be addressed in subsequent phases.

The panel-based configuration offers considerable advantages in terms of transport efficiency, rapid assembly, fire safety, and reusability. Moreover, its compatibility with the existing urban fabric enables the integration of temporary shelters within city centers, thereby supporting both physical and social sustainability. Allowing disaster-affected individuals to remain in or near their communities helps preserve social networks and contributes to urban resilience.

From a design standpoint, the study adopts the tiny house concept as a guiding principle, emphasizing compactness, multifunctionality, and efficient spatial organization. This approach positions the proposed units not merely as standard emergency shelters but as livable, human-centered environments that balance immediacy with comfort and dignity. Features such as convertible furniture, efficient use of natural lighting, and modular aggregation strategies further enhance adaptability and long-term usability.

While this study primarily focused on the architectural configuration of the proposed system, several aspects remain to be explored in subsequent research phases. Detailed evaluations of environmental comfort—including wall section optimization, roof detailing, and thermal insulation performance—will be essential to ensure climate adaptability. Accessibility should also be further developed in accordance with universal design principles and verified through local regulatory frameworks. In addition, future studies should address the structural performance of the panelized system through engineering simulations and testing, while design validation and procedural coordination with local authorities remain key priorities.

Future research should therefore adopt a multidisciplinary approach that integrates architectural design, structural engineering, and user-centered evaluation. Pilot implementations in dense urban environments, such as selected districts in Istanbul, may serve as testbeds to assess spatial, regulatory, and social feasibility. Collectively, these efforts aim to advance the proposed panel-based temporary housing system into a comprehensive, adaptable, and human-centered framework that bridges architectural innovation with urban resilience.

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