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An Assessment on Temporary Post-Disaster Shelters

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Abstract

Considering the destructive effects of disasters on cities and societies, the stages of disaster prevention and mitigation are gaining prominence. Temporary shelters are a basic requirement of disaster and emergency planning. This study aims to investigate the strengths and aspects that need improvement of the shelters used in the post-disaster phase. The research consists of two stages. In the first stage, to conduct an analysis based on construction systems, 20 emergency shelter unit examples were selected from the literature review. The designs were categorised according to construction, membrane-based, compact, modular, and traditional construction systems. In the second stage, effective design criteria were established in consideration of the literature review. Shiftpod, one of the membrane systems, was the most successful design in meeting the criteria, while Icosa Village Pods, one of the modular systems, came second in the evaluation. As a result of the review, the potential of modular systems was emphasized. The shelters in the project and prototype stages were found to be inadequate in terms of comfort and cost.

Keywords: *Disaster, temporary shelter, disaster resilience, construction technology.*

Afet Sonrası Geçici Barınma Birimleri Üzerine Bir Değerlendirme

Öz

Afetlerin şehirler ve toplumlar üzerindeki yıkıcı etkileri göz önüne alındığında; hazırlık ve afet zararlarını azaltma aşamaları önem kazanmaktadır. Geçici barınma, afet ve acil durum planlamasının en temel gerekliliklerinden biridir. Bu çalışmada; günümüzde afet sonrası acil yardım aşamasında kullanılan barınakların, güçlü ve geliştirilmesi gereken yönlerinin araştırılması amaçlanmıştır. Araştırma iki aşamadan oluşmaktadır. İlk aşamada, yapı sistemlerine dayalı bir analiz yapmak amacıyla literatür taramasından 20 adet acil barınma ünitesi örneği seçilmiştir. Ele alınan tasarımlar yapım sistemlerine göre; membran mantığına dayalı sistemler, kompakt sistemler, modüler sistemler ve geleneksel yapım sistemleri olmak üzere dört ana başlıkta toplanmıştır. İkinci aşamada, literatür taraması ışığında etkin tasarım kriterleri oluşturulmuştur. İncelenen barınaklar, tasarım kriterleri bağlamında değerlendirilmiştir. Analizlerde; acil barınma birimlerinin, tasarım kriterlerini birbirine yakın oranlarda sağladığı görülmüştür. Membran sistemlerden Shiftpod kriterleri sağlamada en başarılı tasarım olmuş, modüler sistemlerden Icosa Village Pods değerlendirmede ikinci sırada gelmiştir. Değerlendirme sonucunda, modüler sistemlerin sahip olduğu potansiyeller vurgulanmıştır. Proje ve prototip aşamasında kalmış barınaklar konfor ve maliyet açısından zayıf bulunmuştur.

Anahtar kelimeler: *Afet, geçici barınma, afet dayanıklılığı, yapım teknolojisi.*

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1. Introduction

Disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources (IFRC, 2025). Disasters occur as a result of various destructive events and the fragility of life-related systems coming together.

According to the Emergency Event Database (Delforge et al., 2023), there is an increasing trend in disaster events from 1900 to 2022. While an average of 56 disasters occurred per year in the 1960s, it is known that an average of 363 disasters (2012-2022) occurred in the last decade (Asian Disaster Reduction Center, 2022). The concept of resilience comes to the fore against increasing disasters. Resilience against disasters is the ability of a community or system faced with danger to resist, adapt, and recover in a timely and effective manner against the effects of danger (UNISDR, 2009).

Disaster management consists of the work to be done in the stages of risk determination and damage reduction, preparation, intervention, and recovery (Ahder, 2022). In order to meet the health, food, and shelter needs that arise after disasters, all stages must be planned in the best way.

The need for shelter is met by a closed area for protection from natural conditions, nutrition, sleep, security, and access to health services (Akyıldız et al., 2018). As a result of the increasing population and uncontrolled urban development, the need for shelter, one of the most basic needs of individuals, has become one of the most frequently encountered post-disaster problems. For individuals to reach the closest standards to their former lives, the first need that must be met is shelter. Today, short- and long-term settlements should be designed to provide a simple shelter, a certain technical infrastructure, and humane living conditions (Fitera et al., 2019).

Post-disaster temporary shelter is an architectural design field that contains contradictions, as it is expected to respond to the psychological, sociological, and physical needs in the area where it is applied. There are many studies on the essential topics of post-disaster shelter needs. Some studies in the literature develop design proposals to solve the shelter problem. Venturini et al. (2019) developed the TERRA-ink temporary shelter unit design method, constructed by layering soil with 3D printing technologies. Ayanoğlu & Erbaş, (2023) developed a post-disaster temporary shelter unit proposal using kinetic architectural elements on a selected land in the Manavgat district of Antalya province.

Tosun & Maden (2023) proposed a new adaptive disaster relief shelter consisting of truss connections and plate elements, which are easy to transport and store. Avlar, Limoncu & Tızman (2023), investigated the usage possibilities of Cross-Layered Timber (CLT) products, determined the design parameters and designed the temporary shelter unit CLT E-BOX.

Some studies examine emergency shelter unit designs in the literature from different perspectives. Küçükoğlu & Ülker (2022), evaluated the spatial accessibility of emergency shelters they selected within the scope of the research, considering universal design criteria. Yolaçtı & Gülten (2024), examined shelter examples in the literature within the scope of eliminating climatic problems and providing thermal comfort conditions in temporary shelter units. Şenocak & Sayıl Onaran (2023) analyzed emergency shelter projects from active fields worldwide in their studies. They read the analysis data through emergency shelter unit spatial design criteria. Afonso & Lu, (2021) and Tirella et al. (2023) worked on the use of generative design methods and BIM processes in post-disaster shelter unit production processes.

In studies in the literature, the most effective factor in terms of environmental conditions for the implementation of temporary shelter unit designs, which are addressed from many different perspectives, is construction systems. The complexity of the design parameters of temporary shelter units to be used in disaster and emergency conditions has revealed the need for qualified research on this subject. Shelters must be easy to transport, easy to install, suitable for the climate of the area, durable in physical conditions, and provide users with security, comfort, and privacy (Yılmaz, 2021). Determination of the construction methods of shelter units and design decisions are the most effective elements in solving the problem of post-disaster sheltering.

In this research, application-based literature research was conducted on the criteria that shelter designs to be used in the post-disaster emergency aid phase should meet. The question of which construction systems best meet these expectations was sought.

2. Material and Method

Post-disaster studies supported by pre-disaster preparations consist of three stages: Emergency Relief Stage, Early Recovery Stage, Reconstruction Stage (Brown et al., 2010). In this context, the emergency shelter problem that needs to be met in the Emergency Aid Stage, which is the most critical stage for individuals to overcome the shock they experience in the event of a disaster, has been addressed.

This study aims to investigate current innovations in temporary shelter design to be used in the first phase after a disaster, which have been brought to the literature by public institutions or different organizations in the world. While creating the sample section, 20 temporary shelter units, which have been brought to the literature by states or aid organizations, realistic in terms of production, applicable in terms of details, designed between 1990-2024, and based on basic geometries, were considered in the context of construction systems. Shelters are essentially used to fulfill the same function. However, in determining the examined examples, the fact that each is the product of different design approaches and different cultures, such as Japan, the USA, Turkey, China, and England, has been an important factor.

Emergency shelter units were examined under four main headings according to their construction technologies. These are modular, compact, membrane and traditional systems. In the next stage, to systematize the data regarding shelter units, each shelter unit was evaluated in the context of the determined criteria (system life, sufficient space per person, security, and expandability by addition (Figure 1).

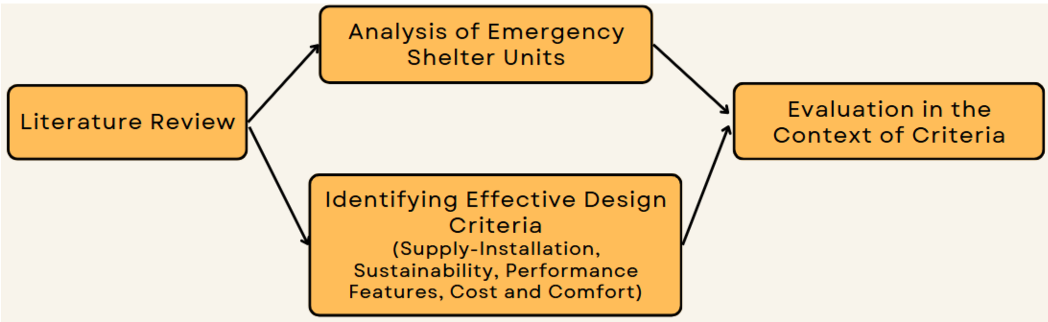

Figure 1. Research flow chart (Authors)

In addition, analyses were conducted on why some shelters were not used in any disasters and remained in the design or prototype production phase. In today's conditions where disasters and user expectations are diversified, it was aimed to draw attention to the issue of temporary shelter and to shed light on the work of designers and researchers.

2.1. Examining Post-Disaster Shelter Units

In this section, the designs of post-disaster temporary shelter units obtained in the light of the literature research are classified according to their construction systems. Shelter units are examined under four main headings: membrane systems, modular, compact and traditional construction systems.

2.1.1. Membrane systems

With the developing technology, humanity's expectations of living spaces have changed and transformed; membrane systems have gained importance with their functionality, compatibility, flexibility, extended performance, and sustainability (Bakbak et al., 2016). In the literature, systems based on membrane logic (tents, origami-based structures), which are mobile and differently positionable structures that provide ease of installation in the field, are frequently included. In this context, Rubb, Dynamic Air Shelter, Deployable Scissor Arch Shelter, and Shiftpod examples were examined (Table 1).

Table 1. Membrane system temporary shelter units

Code	A1	A2	A3	A4	A5
Name	Rubb	Dynamic Air Shelter	Deployable Scissor Arch Shelter	Shiftpod	CMAX Units
Image	 (Rubb Building Systems, 2020)	 (Taffys Group LLC, 2023)	 (Mira et al., 2014)	 (Weber, 2023).	 (Colin, 2024)
Design Year	1990	2000'ler	2014	2018	2022
Designer	Unknown	Unknown	Mira et al.	C. Weber	CMAX Inc.
Geometry	Vault	Half Ellipse	Vault	Hexagonal prism	Rectangular prism
Area (m²)	Yesiable*	40–80***	~30	~11.3	~17.5
Interior Height (m)	~3.5	~3.0	~3.2	2.1	2.8
Capacity	4–10**	6–20***	4–6	4	8
Living Space Layout	Open plan	Open plan + partitioned option	Open plan	Open plan	Open plan
Wet Area	No	Yes	No	No	Yes
Installation Time	2–6 hour(s)	4–6 hour(s)	3–4 hour(s)	5–10 min	~11 min
Service Life	5+ year(s)	3–5 year(s)	1–2 year(s)	2–5 year(s)	3–5 year(s)
Used in Disasters	Yes	Yes	No	Yes	No

* Variable: The shelter area can be customized depending on usage or configuration.
** Estimated user capacity depending on the version or setup.
*** Based on multiple standardized sizes offered by the manufacturer.

In the Rubb example, which is basically established with the tent logic, the system can be assembled in a few hours and reused in another area. The main structure consists of aluminum or steel elements. The outer surface is PVC-coated fabric. It can be produced in different sizes, from the basic shelter unit to the storage area (Rubb Building Systems, 2020). The Dynamic Air Shelter system is produced in 14 different standardized sizes. In addition to disaster shelters, it serves different purposes, such as temporary health and military structures. The system consists of a column-beam structure filled with low-pressure air and a PVC-coated polyester shell. It is resistant to snow and wind loads (Taffys Group LLC, 2023). Deployable Scissor Arch Shelter is formed by bringing together three aluminum trusses and is covered with a fabric membrane. The ground connection is supported by sandbags. The structural behavior of the truss arch has been studied. It has been sized to meet Eurocode requirements under dead, snow, and wind loads (Mira et al., 2014). With its carbon fiber frame system, Shiftpod provides quick installation. In this system, the skeleton is covered with hydrophobic fabric that reflects heat, insulates, and protects against mold and weather conditions. The fabric has a hexagonal pattern with blackout technology to provide good visual comfort quality at all times of the day in the interior (Weber, 2023). Developed by CMAX Systems, the Cmax foldable mobile shelter units comfortably accommodate up to eight people. The design has a high ceiling, and the system enables natural air circulation. The foldable units are installed with a modern tent logic. The assembly process includes the steps of opening the sides, adjusting the main crossbar, and stretching the cover that forms the outer walls. Assembly takes 11 minutes and does not require any tools (Colin, 2024).

Examples produced with membrane logic have been used for many years. However, new design searches can be observed in membrane systems.

2.1.2. Modular systems

Prefabrication techniques in building materials have emerged with the industrialization of building construction. In modular systems, prefabricated building components are assembled and constructed in a short time on-site with low labor and reasonable cost (Erturan & Eren, 2012). It is cost effective, and its component modules constitute building elements such as roof, floor, and walls. This section examines and tabulates examples of housing units consisting of modular components (Table 2).

Table 2. Modular temporary housing unit designs

Code	B1	B2	B3	B4	B5
Name	Hexayurt	Icosa Village Pods	DH1 Disaster House	Better Shelter	Equals Sanctuary
Image	 (Baş, 2020)	 (Meta, 2011)	 (Russel, 2015)	 (Brownell, 2020)	 (Küçükoğlu & Ülker, 2022)
Design Year	2002	2002	2006	2013	2020
Designer	V. Gupta & L. Darby	Unknown	G. Fleishmann	IKEA	Equals Architecture
Geometry	Hexagonal prism	Hexagonal prism	Rectangular prism	Rectangular prism	Rectangular prism
Area (m²)	~15	~17	15–20	17	12.9
Interior Height (m)	~2.5	~2.4	~2.5	2.0	~2.2
Capacity	6	4	4	5	2–4
Living Space Layout	Open plan	Partitioned modules	Modular interior	Partitioned	Expandable unit
Wet Area	No	No	Optional	Yes	Optional
Installation Time	~1 hour	~2–3 hours	~3 hours	~4 hours	~2 hours
Service Life	1–3 years	2–5 years	3–5 years	3 years	3–5 years
Used in Disasters	Yes	No	No	Yes	No

The walls and roof of the Hexayurt shelter with a hexagonal base are made of plywood. It is low-cost (a 15 m^2 unit costs $100) and is produced with zero waste. It can be manufactured from OSB, cardboard, or composite materials, depending on the targeted lifespan. It is compatible with the climate thanks to the reflective panels preferred for the surface coating. It can be installed on-site by people trained in the pre-construction system (Baş, 2020). In the case of Icosa Village Pods, the system is built by bringing together triangular modules made of extruded plastic material. The 17 cm thick modules provide natural cooling with air circulation. There are special modules for ventilation elements and door connections. The stagnant air layer acts as insulation by filling the openings with fiberglass felt. Its service life is 2-5 years (Meta, 2011). The DH1 Disaster House, which resembles a 3-dimensional puzzle, is built with compatible components without any fasteners. Two people can build the system in three hours by combining prefabricated plywood pieces. The outer surface can be covered with straw, linen, and plastic membrane materials. It is installed on a standard 1.5 m2 base area and can be planned in different sizes (Russel, 2015). The IKEA Foundation and the United Nations High Commission for Refugees (UNCHR) developed the Better Shelter. The 17 m2 emergency shelter is easy to transport and assemble due to its packability. It can accommodate five people and can be installed in four hours. Its roof, equipped with solar panels, produces energy and reduces solar heat by 70%, keeping the interior cool in hot weather (Brownell, 2020). Equals Sanctuary: These are shelter units designed by the London-based Equals Architecture firm. The system consists of units that can be added or removed according to need and function. The design provides users with 12.9 square meters of primary living space. The basic structure is made of plywood, and the outer coating can be planned from rubber, reused waterproof canvas, or corrugated steel (Küçükoğlu & Ülker, 2022).

In modular systems formed by the combination of prefabricated panels, the roof concept comes to the fore. Due to the modularization method, it is seen that there are no major differences in the design method.

2.1.3. Compact systems

In compact systems, all sections in the shelter units are planned and produced in advance and transported to the site ready (Ünal & Akın, 2017). Although they are costly systems, compact systems that exhibit technological possibilities stand out among others due to the extremely efficient use of space and the priority of user comfort. In this context, four compact shelter designs are examined and presented in Table 3.

Table 3. Compact temporary housing unit designs

Code	C1	C2	C3	C4	C5
Name	FEMA Trailer	AFAD Shelters	EDV-01	Shelter Pack	Folding Home
Image	 (FEMA, 2009)	 (Ünal & Akın, 2017)	 (Daiwa Lease Co. Ltd, 2011)	 (The Housing Innovation Collaborative, 2021)	 (European Product Design Awards, 2017)
Design Year	1992	Before 1999	2011	2017	2021
Designer	Unknown	Unknown	Y. Yoshimura	Designnobis	Unknown
Geometry	Rectangular prism	Rectangular prism	Rectangular prism	Rectangular prism	Rectangular prism
Area (m²)	23.3	21	20	12	10.5 / 26
Interior Height (m)	~2.2	~2.4	~2.4	~2.2	~2.5
Capacity	4–6	4–6	2	4	2 or 4
Living Space Layout	Divided (kitchen, WC, living)	2 rooms + wet areas	Compact with tech integration	Foldable with zones	Foldable modular
Wet Area	Yes	Yes	Yes	Yes	Yes
Installation Time	~2–4 hours	~2–3 hours	~1 hour	~1–2 hours	~3 min
Service Life	5+ years	5 years	1 month w/o support	1–2 years	2–5 years
Used in Disasters	Yes	Yes	No	No	No

One of the early examples of compact systems, the FEMA Trailer, is a temporary shelter unit implemented by the American Federal Emergency Management Agency (FEMA). Each trailer contains a toilet, kitchen, and living area; the shelter can only be positioned in places with clean water and electricity. A unit measuring 2.4 m x 9.7 m is equipped with a smoke detector and sprinkler system and is costly (FEMA, 2009). AFAD Shelters, container-based shelter systems, have a floor area of 3 m x 7 m. Each container contains a kitchen sink, bathroom, and two rooms. Thermal comfort can be provided with special detail solutions made according to the climate conditions of the region. Apart from housing, they are used for classroom and storage. It is known that 2000 containers can be produced in two months in the event of a disaster (Ünal & Akın, 2017). An example of a high-tech product, EDV-01 (Emergency Disaster Vehicle), is a temporary shelter equipped with advanced technology in container dimensions. It can adapt to the topography with hydraulic legs. It can accommodate two people for a month without water and energy support thanks to solar panels, accumulators, and rainwater collection systems. It consists of a kitchen, bathroom, living and sleeping units. Its facade is equipped with pixel-shaped lighting elements (Daiwa Lease Co. Ltd, 2011). Folding Home, produced by China-based AMC Box, has an aluminum alloy frame. It is lightweight but has a wind resistance of 117 km/h. After shipment, the shelters can be installed by three people in 3 minutes without using a crane. The shelter has a bathroom, folding bed, and electrical outlets and is produced in two different sizes: Two people (10.5 m2) or four people (26 m2) (The Housing Innovation Collaborative, 2021).

The compact system Shelter Pack, which won the A' Design Award 2017, is 12 m² and can be installed in 1-2 hours. It consists of a shelter unit, four single beds, a kitchen, a foldable dining table, and a bathroom. It can be positioned on sloping terrain thanks to adjustable legs. Rainwater is collected and stored. In fiber walls, two different fabric surfaces with fire and water insulation and plywood between them are used (European Product Design Awards, 2017).

In compact shelter unit designs, the repeating rectangular prism form stands out. Although compact shelter design alternatives are limited today, they are diversifying in parallel with technological developments.

2.1.4. Traditional construction systems

Traditional construction systems are uncomplicated systems used in temporary shelter units. Grouted joints are mostly used. The materials used can be customized according to the area to be applied (Farrokhsiar et al., 2020). Since these systems take time to build, they can only be used after the early stages of the disaster are completed. Four temporary shelter unit designs based on traditional construction systems are examined and are given in Table 4.

Table 4. Temporary shelter units designed with traditional construction systems

Code	D1	D2	D3	D4	D5
Name	Sandbag Shelter	Paper Log House	IFRC T-Shelter	Re:Build	Housing for Pakistan Floods
Image	 (Karimi & Adibhesami, 2022)	 (Latka, 2017)	 (Saunders, 2013)	 (Bekkering & Dimitrova, 2018)	 (Aslam, 2024).
Design Year	1991	1995	2010	2015	2024
Designer	N. Khalili	Shigeru Ban	Unknown	P. Khazaeli & C. Sinclair	Shigeru Ban
Geometry	Spiral Dome	Rectangular prism	Rectangular prism	Rectangular prism	Rectangular prism
Area (m²)	37	18	21	~256	~20
Interior Height (m)	~2.8	~2.4	~2.5	~3.0	~2.5
Capacity	4–6	4	4–6	8+	4–6
Living Space Layout	Single space	Open plan	Divided rooms	Expandable modular	Single or dual room
Wet Area	Optional	No	Yes	Yes	Yes
Installation Time	1–3 days	~5–6 hours	~1 day	2 weeks	~1 day
Service Life	5+ years	1–3 years	3–5 years	5+ years	3–5 years
Used in Disasters	Yes	Yes	Yes	Yes	No

Developed by Iranian architect Nader Khalili, the Sandbag Shelter can be built with sandbags, barbed wire, and a few tools. A 37 m² Sandbag Shelter can be built by four people and costs $150-300. The dense building mass serves as thermal insulation. The building forms refer to the adobe architecture of the Middle East, while the use of barbed wire as a tensile element is reminiscent of the tent systems of nomadic cultures (Karimi & Adibhesami, 2022). After the Kobe earthquake in 1995, Shigeru Ban designed the Paper Log House, which consists of paper tubes. The system was also used in Turkey after the 1999 Marmara earthquake. The paper tubes that make up the shelter are waterproof, and the roof is covered with plastic sheeting. The 18 m2 units are supported on foundations made of beverage crates reinforced with sandbags. The inside of the tubes can be filled with different materials depending on the climatic conditions. The units are easy to disassemble, and the materials are recyclable (Latka, 2017).

With the support of the International Federation of Red Cross and Red Crescent Societies (IFRC), the IFRC T-Shelter was implemented in the region after the 2010 Haiti earthquake. In this system, a shelter has a floor area of approximately 21 m^2. The wall consists of plywood cladding and wooden studs, and the roof consists of metal roofing on wooden purlins and trusses. The floor is a cast-in-place concrete slab. The foundation consists of reinforced concrete and stone masonry. The expected service life is 3-5 years (Saunders, 2013). In the Re:Build example, the structures can be built without water and electricity. A 16m x 16m structure can be built in 2 weeks with ten people. The system utilizes scaffolding structural components and materials like stone and gravel. There are plywood panels on the ground. The roof is covered with soil strips to support a green roof system. Rainwater is collected in a special area placed under the roof cover. The structure can be expanded by adding modules (Bekkering & Dimitrova, 2018). Safe Delivery Safe Mother (SDSM) and Shigeru Ban have developed a low-cost shelter model for people whose homes were destroyed by floods in Pakistan. The frame is made of paper tubes treated to make them resistant to moisture and water, and the walls are made of bamboo. The floor of the shelter is made of plastic crates, sand and waterproof plywood, and the roof is made of natural materials such as reeds as well as plastic. The parts for assembly are prepared in advance and transported to the target area. The system does not require skilled construction labor, and it is sufficient for the people to be trained in the construction system (Aslam, 2024).In shelter designs based on traditional construction systems, material becomes the focal point. The choice of building material, shaped by the climatic conditions and resources of the region, brings about differences in designs.

3. Findings and Discussion

3.1. Post-Disaster Shelter Evaluation Criteria

In this section, the basic requirements that must be met for shelters to be buildable and habitable are determined under the title of “Emergency Shelter Unit Design Criteria”. Limoncu & Bayülgen (2005), summarized the common problems observed in shelter units used during post-disaster emergency relief and rehabilitation phases as follows: high cost, lack of sustainability and recoverability, incompatibility with local climatic conditions, inadequate interior space, absence or insufficiency of sanitary facilities, poor insulation (thermal, acoustic, humidity, and fire resistance), and security issues.

Cost: To avoid these problems in the field, cost efficiency should be considered in all stages, starting from the design of the building components.

Procurement-Installation: Units should be made ready for use by disaster victims as soon as possible (Torus & Şener, 2015). Connection methods that can be performed without specific tools should be preferred during the installation and dismantling stages of the units (Nocera et al., 2020). Shelter units move from production to storage area, storage area to earthquake area. After the usage process is completed, it is moved from the earthquake area to the storage area again. Transportation of temporary shelter units and installation on site should be provided quickly (Avlar et al., 2023).

Sustainability: It is essential to consider the concept of sustainability in pre-disaster and post-disaster processes. Sustainability is a concept that expresses continuity (Yüksel, 2012). In this context, emergency shelters should allow for changing functions and sizes as much as possible and have a high potential for reuse for future disasters (Torus & Şener, 2015).

Performance Features: Designs should help sensitive individuals after disasters feel safe in every way (Torus & Şener, 2015). Systems should be designed to provide users with visual, auditory, thermal comfort and safety.

Comfort: Shelters to be used after a disaster should be livable, beyond meeting the basic needs of individuals (Akdede & Ay, 2018). Maximizing the usability, convenience, and comfort of the houses supports post-disaster rehabilitation. In the light of literature reviews, emergency shelter unit design criteria are determined and explained (Table 5).

Table 5. Emergency shelter design criteria

	Criteria	Description	Reference
Supply-Installation	Ease of Transport and Storage	Shelter units should be able to be transported and stored without having to resort to heavy transport and assembly elements such as cranes.	Abanoz & Vural (2023), The United Nations Refugee Agency (2014)
	Installation Time	They should be able to be installed in a timely manner with basic tools and a team of three to five non-specialists.	Abanoz & Vural (2023), Russel (2015), Geurts et al. (2018)
Sustainability	System Life	It should be designed with a target lifespan of three to five years, considering there may be problems in the transition from emergency shelter to permanent housing.	The United Nations Refugee Agency (2014)
	Reusability	Shelters that have not completed their lifespan should be reusable in the event of another disaster.	Ünal & Akın (2017), Geurts et al. (2018)
	Expandability by Addition	They should be able to be developed according to changing needs over time.	Geurts et al. (2018)
	Innovation	The knowledge and technology of the age should be used at every stage of disaster planning.	Waheed & Wahhab (2022), Gökgöz & İlerisoy (2022)
Performance Features	Compatibility with Climate	Shelter unit designs should be adaptable to use in different climate types.	Abanoz & Vural, (2023)
	Security	Considering the sensitivities in the post-disaster process, the systems are expected to be structurally sound and protected against factors such as theft.	Abanoz & Vural (2023), The United Nations Refugee Agency (2014), Russel (2015)
	Fire Safety	Materials that are non-flammable or do not emit toxic gases should be selected, considering fire incidents that have occurred in the past.	Dadaş & İlerisoy (2019)
Cost	Production Cost	The raw material and labor costs required during the initial production should be low.	The United Nations Refugee Agency (2014), Russel (2015)
	Transportation Cost	Transportation and carrying costs should be aimed to be low.	Russel (2015), Ünal & Akın, (2017)
Comfort	Adequate Space Per Person	A standard unit should provide shelter for four to six people. Each unit requires 4.5 to 5 m^2 of space per person.	Russel (2015), Ünal & Akın, (2017),
	Audio-Visual Comfort	Noise control and adequate lighting should be provided, considering disaster victims' privacy needs.	Ünal & Akın, (2017)

Based on these studies, expectations from post-disaster shelter units are grouped under the titles of Supply-Installation, Sustainability, Performance Features, Cost, and Comfort. As a result of literature reviews, disaster and emergency shelters examined according to their construction systems were evaluated by creating design criteria (Table 5) and comparing them in the context of the criteria (Table 6).

3.2. Evaluation of Post-Disaster Shelter Units in the Context of Criteria

In this section, emergency shelter units designed between 1990-2024 were classified according to their construction systems and evaluated in the context of effective design criteria (Table 6).

Table 6. Evaluation of emergency shelters

	Criteria	Membrane Systems					Modular Systems					Compact Systems					Traditional Construction Systems				
		Rubb	Dynamic Air Shelter	Deployable Scissor Arch*	Shiftpod*	Cmax Units*	Hexayurt	Icosa Village Pods	DH1 Disaster	Better Shelter	Equals Sanctuary*	FEMA Trailer	AFAD Shelters	EDV-01*	Shelter Pack*	Folding Home*	Sandbag Shelter	Paper Log House	IFRC T-Shelter	Re:Build	Housing for Pakistan floods
Supply-Installation	Ease of Transport and Storage	●	●	●	●	●	●	●	●	●	●	❍	❍	❍	●	●	❍	●	❍	❍	❍
	Installation Time	●	❍	●	●	●	●	●	●	●	●	●	❍	●	●	●	❍	❍	❍	❍	❍
Sustainability	System Life	●	●	❍	●	●	❍	●	❍	●	❍	●	●	●	●	●	●	❍	●	●	●
	Reusability	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	❍	❍	❍	❍	❍
	Expandability by Addition	❍	❍	❍	●	❍	❍	❍	●	❍	●	❍	❍	❍	❍	❍	●	❍	❍	●	●
	Innovation	❍	●	●	❍	❍	●	●	●	●	❍	●	❍	●	●	❍	❍	●	❍	❍	●
Performance Features	Compatibility with Climate	❍	❍	❍	●	●	●	●	❍	●	●	●	●	●	●	●	●	●	●	●	●
	Security	●	❍	❍	●	●	❍	●	❍	●	●	●	●	●	●	●	●	●	●	●	❍
	Fire Safety	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	●	●	●	●	❍	●	❍	❍	●	❍
Cost	Production Cost	●	●	●	●	●	●	●	●	●	●	❍	❍	❍	❍	❍	●	●	●	●	●
	Transportation Cost	●	●	●	●	●	●	●	●	●	●	❍	❍	❍	❍	●	●	●	●	●	●
Comfort	Adequate Space Per Person	●	●	●	●	●	❍	●	❍	❍	❍	●	●	●	❍	●	●	●	●	●	●
	Audio-Visual Comfort	❍	❍	❍	●	●	❍	❍	❍	❍	●	●	●	●	●	●	●	●	●	●	●

* Samples that have not been used in any disaster and remain in the design or prototype production phase

The comparative evaluation was based on a set of effective design criteria derived from the literature, including factors such as supply-installation process, sustainability, cost, performance, and comfort. Each shelter unit was scored based on how well it satisfied these criteria, using both qualitative and quantitative indicators. As shown in Figure 2, Shiftpod and Icosa Village Pods scored highest across the board, particularly in comfort and performance criteria, which justified their ranking in the final analysis.

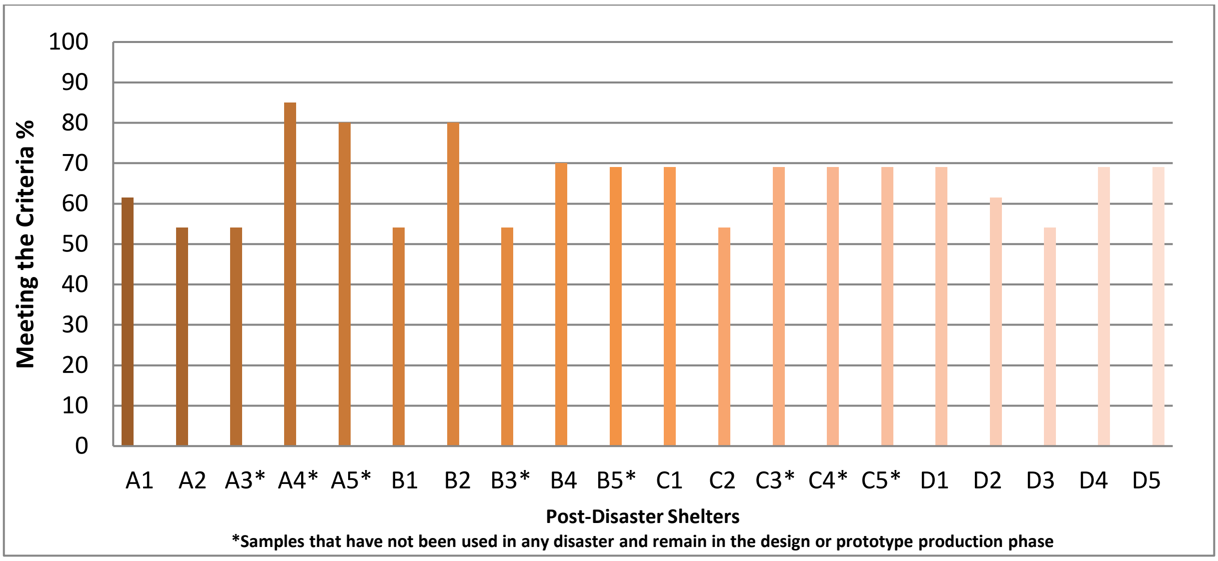

Figure 2. Graph of the status of the accommodation units examined in terms of meeting the criteria (Authors)

One of the most basic social needs of disaster victims who lost their relatives, homes, and jobs after a disaster is a sense of security. When post-disaster planning is made, it is aimed that disaster victims with fragile psychology do not encounter a new disaster, such as flood or fire, in the areas they settle in during the recovery phase. When a general evaluation is made in light of the data in Table 6, it is seen that the **Fire Safety** criterion should be taken into consideration during the designs.

When the relevant literature is examined, it is seen that living spaces that can meet the changing needs of disaster victims should be provided. In addition, shelter units should have the opportunity to be developed to serve different needs, such as health and education, in addition to housing needs. Considering the importance of the criteria of **Expandability by Addition** presented under the heading of Sustainability, it was determined that the shelter units examined were inadequate in meeting this criterion.

Wagemann (2015) stated that the solutions offered in the first stage after a disaster focus on providing immediate assistance rather than a long-term physical and emotional recover process. It is noted that short-term shelter solutions are often based on universal prototypes; it is not directly related to climate, local culture, or local conditions (Ayanoğlu & Erbaş, 2023).

For this reason, it is thought that emergency shelter units should be standardized as much as possible to respond to possible disaster conditions. In the analyses conducted within the scope of the research, it was seen that emergency shelter units meet the design criteria in general terms at close rates according to their construction systems (Figure 3).

When the analysis is detailed for the development and standardization of each construction system;

- Membrane systems, in terms of performance features and comfort conditions,
- Modular systems, in terms of providing comfort conditions,
- Compact systems, in terms of cost features and installation-supply processes,
- Traditional systems, in terms of installation-supply conditions, have been seen to be developed.

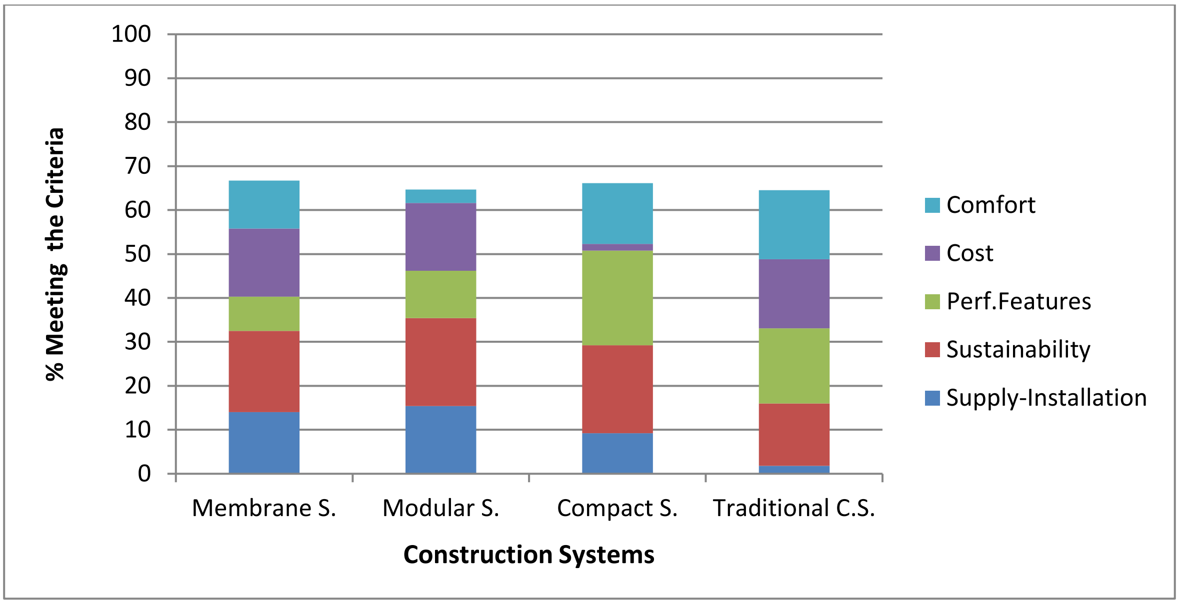

Figure 3. Graph of meeting the design criteria of shelters according to construction systems (Authors)

When the examples that have not been used in any disaster and have remained in the design or prototype production phase are evaluated in a general framework, it is seen that the comfort and cost features are behind the systems that have been used in disasters (Figure 4).

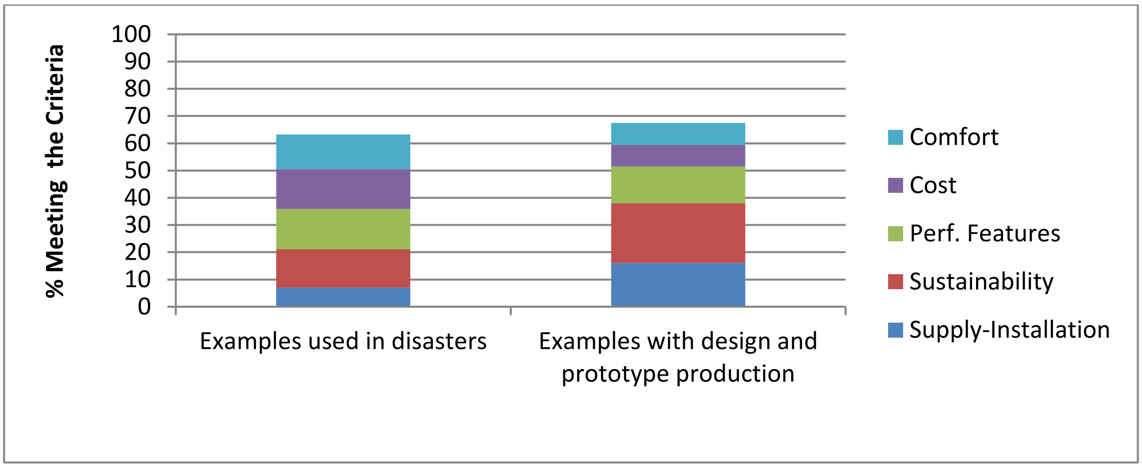

Figure 4. Graph of used/unused shelters meeting design criteria during disasters (Authors)

When explicitly evaluated in terms of construction systems, studies should be conducted to improve the performance characteristics of modular systems and reduce the costs of compact system designs.

4. Evaluation and Suggestions

After disasters that can have devastating effects on society, the first stage is faced with health, food and shelter problems for the victims. If sufficient preparations are made against disasters and emergencies, the effects of the disaster are felt less.

In this research conducted to contribute to the pre-disaster preparation stage, 20 emergency shelter units based on basic geometries, brought to the literature by non-governmental organizations, public institutions, and design firms for shelter needs in the emergency aid stage, were examined. The examined designs were evaluated by dividing them into four main headings according to their construction systems: membrane systems, modular systems, compact systems, and systems created with traditional construction techniques.

In light of the literature review, emergency shelter unit design criteria were created, and the designs in question were evaluated. As a result of the analyses, the aspects that need to be developed for each construction system were presented in the evaluation section.

- Especially for the efficient use of resources, modular systems have been found to be advantageous due to their short and easy installation, accessible transportation, and the potential of many modular system designs to create flexible structures that can respond to changing spatial needs. In this respect, it is thought that developing modular system design alternatives in future research and workshops will be useful, considering performance characteristics and comfort conditions.
- If emergency shelters are planned to be used until permanent buildings are built, traditional systems may be a rational choice.
- The type of shelters to be used as temporary shelters and the construction system with which they will be built should be determined during the preparation phase based on site-specific inputs.
- It is thought that future studies on re-functioning temporary shelter units that have not yet reached their end of life after the disaster and emergency conditions are over will make significant contributions to the literature.

In the analyses conducted within the scope of the research, it was determined that the examined shelter units were inadequate in providing the fire safety and expandability criteria. The examined shelters provided effective design criteria at different rates, between 54% and 85%. However, when the shelters were classified and analyzed according to their construction systems, it was seen that each construction system performed similarly to each other. Reaching a greater number of people with moderately performing but scalable solutions may be more impactful in certain disaster scenarios.

Rather than offering a single best solution, it is crucial to evaluate shelter systems within the specific parameters of each disaster scenario. In addition to architectural and structural criteria, the number of people expected to be affected by the disaster, the season in which the disaster occurs, and the characteristics of the climate zone are all significant factors influencing shelter selection.

Based on the findings of this study, shelter unit preferences should be made according to specific contextual needs:

- For short-term emergency use: Membrane-based systems such as Shiftpod or CMAX Units are suitable due to their rapid installation and ease of transport.
- For medium-term use: Modular shelters such as Icosa Village Pods or Better Shelter provide better comfort and spatial organization.
- For hot-dry climate regions: Structures with passive ventilation and reflective materials (e.g., Hexayurt, Icosa Pods) are preferable.
- Considering cost-effectiveness and mass production: Compact systems with prefabricated assembly (e.g., Shelter Pack) offer a balanced solution.

The frequency of disasters and their destructive effects are increasing day by day. This research aims to shed light on those who design shelters to be used after disasters in disaster planning. It should not be forgotten that, as Özden (2006) stated, it is only possible to develop holistic disaster management with long-term strategy and planning.

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