



YAŞAR UNIVERSITY

GRADUATE SCHOOL

MASTER THESIS

**DESIGN OF POST-DISASTER TEMPORARY SHELTER  
USING SCISSOR LINKAGES AND FOLDABLE PLATES**

SEDA TOSUN

THESIS ADVISOR: ASSOC.PROF.(PHD) FERAY MADEN

MSC IN ARCHITECTURE

BORNOVA / İZMİR  
JUNE 2024



## **JURY APPROVAL PAGE**

We certify that, as the jury, we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master in Science /Master of Arts/ the Doctor of Philosophy/Proficiency in Art.

### **Jury Members:**

### **Signature:**

Assoc.Prof.(PhD) Feray MADEN  
Yaşar University

.....

Prof.(PhD) Koray KORKMAZ  
İzmir Institute of Technology

.....

Assist.Prof.(PhD) Eray BOZKURT  
Yaşar University

.....

-----  
Prof. (PhD) Yucel Ozturkoglu  
Director of the Graduate School



## ABSTRACT

### DESIGN OF POST-DISASTER TEMPORARY SHELTER USING SCISSOR LINKAGES AND FOLDABLE PLATES

Tosun, Seda

MSc, Architecture

Advisor: Assoc. Prof. (PhD) Feray MADEN

June 2024

Millions of people are displaced yearly due to natural disasters such as earthquakes, wildfires, landslides, and floods. Generally, conventional shelters such as tents, container-type shelters, and prefabricated structures are provided after disasters for the use of people affected by disasters. However, they do not provide spatial flexibility and adaptability to changing circumstances. Although using kinetic structures in temporary shelter design allows the creation of adaptive systems, the majority of temporary shelters are limited to certain types. This study aims to develop an adaptive disaster relief shelter that can deploy from a compact state to an expanded one to provide formal flexibility and ease of transport and storage. First, it investigates spatial and structural solutions developed for temporary shelters and analyzes to what extent kinetic structural systems provide solutions regarding adaptation to changing circumstances. Based on the findings obtained from the analysis, a novel adaptive shelter composed of scissor linkages and foldable plates is proposed. The proposed *Shelter Module X* is adaptive enough, functioning as an accommodation module during distinct sheltering periods and serving different functions by module combinations.

**Keywords:** temporary shelters, disaster relief shelters, adaptability, natural disasters, kinetic structures.



## ÖZ

### MAKAS BAĞLANTILAR VE KATLANABİLİR PLAKLAR KULLANARAK AFET SONRASI GEÇİCİ BARINAK TASARIMI

Tosun, Seda

Yüksek Lisans, Mimarlık

Danışman: Doç. Dr. Feray MADEN

Haziran 2024

Deprem, yangın, heyelan, sel gibi doğal afetler nedeniyle her yıl milyonlarca insan yerinden olmaktadır. Genellikle çadır, konteyner tipi barınak ve prefabrik yapılar gibi geleneksel barınaklar afet sonrasında afetten etkilenen insanların kullanımına sunulmaktadır. Ancak, bunlar mekânsal esneklik ve değişen koşullara uyum sağlamazlar. Geçici barınak tasarımında kinetik yapıların kullanılması uyarlanabilir sistemlerin oluşturulmasına olanak sağlasa da geçici barınakların çoğunluğu belirli türlerle sınırlıdır. Bu çalışma, biçimsel esneklik, taşıma ve depolama kolaylığı sağlamak için kompakt bir formdan genişletilmiş bir forma geçebilecek uyarlanabilir bir afet yardım barınağı geliştirmeyi amaçlamaktadır. Öncelikle, geçici barınaklar için geliştirilen mekânsal ve yapısal çözümler incelenmekte ve kinetik yapı sistemlerinin değişen koşullara uyum konusunda ne ölçüde çözüm sağladığı analiz edilmektedir. Analizden elde edilen bulgulara dayanarak, makas bağlantılar ve katlanabilir plakalardan oluşan yeni bir uyarlanabilir barınak önerilmektedir. Önerilen *Barınma Modülü X* yeterince uyarlanabilir olup, farklı barınma dönemlerinde bir barınma modülü olarak işlev görmekte ve modül kombinasyonları ile farklı işlevlere hizmet etmektedir.

**Anahtar Kelimeler:** geçici barınaklar, afet yardım barınakları, adaptasyon, doğal afetler, kinetik strüktürler.



## ACKNOWLEDGEMENTS

First and foremost, I would like to extend my deepest gratitude to my thesis advisor, Associate Professor Feray MADEN, for her endless support and patience from the beginning of this journey. This thesis has been supported by the scientific research project titled “BAP 134: Development of Transformable Disaster Relief Shelters Using Scissor Linkages and Foldable Plates” funded by Yaşar University. I also wish to convey my sincere appreciation to the members of the ISMA Research Group, the professors involved in BAP134, my teammates İrem YETKİN and Semih SÜMEROĞLU, and also my friend Mert MISIRLIOĞLU whose invaluable support has continually motivated me to persevere. Lastly, I express my deepest gratitude to my family for their unwavering support and love, which fuels my passion for life.

Seda TOSUN  
İzmir, 2024



## **TEXT OF OATH**

I declare and honestly confirm that my study, titled “DESIGN OF POST-DISASTER TEMPORARY SHELTER USING SCISSOR LINKAGES AND FOLDABLE PLATES” and presented as a Master’s Thesis, has been written without applying any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Seda TOSUN

12.06.2024





## TABLE OF CONTENTS

JURY APPROVAL PAGE .....	iii
ABSTRACT.....	v
ÖZ .....	vii
ACKNOWLEDGEMENTS .....	ix
TEXT OF OATH .....	xi
TABLE OF CONTENTS.....	xiii
LIST OF FIGURES .....	xv
LIST OF TABLES .....	xix
CHAPTER 1 .....	1
1.1. Motivation of the Study .....	1
1.2. Problem Definition.....	2
1.3. Objectives and Scope of the Study .....	2
1.4. Methodology of Research .....	3
1.5. Significance of the Study .....	5
1.6. Outline of the Thesis .....	5
2. CHAPTER 2 .....	7
2.1. Sheltering As a Disaster Response.....	7
2.2. The Duration and Phases of Shelter .....	8
2.3. Shelter Types and Transitional Approaches .....	12
2.4. Characteristics of Temporary Shelters .....	16
3. CHAPTER 3 .....	19
3.1. Habitability in Temporary Shelters.....	19
3.2. Habitability Standards and Criteria for Disaster Relief Shelters .....	20

3.3.	Living Space Standards, Technical Requirements and Design Criteria for Disaster Relief Shelters .....	22
3.3.1.	Living Space Standards .....	23
3.3.2.	Technical Requirements .....	27
3.3.3.	Design Criteria .....	28
4.	CHAPTER 4.....	33
4.1.	Classification of Kinetic Structural Systems.....	33
4.2.	Evaluation of Kinetic Structural Systems Having Variable Mobility .....	37
4.2.1.	Evaluation of Selected Demountable Temporary Shelters .....	38
4.2.2.	Evaluation of Selected Relocatable Temporary Shelters .....	43
4.2.3.	Evaluation of Selected Portable Temporary Shelters.....	46
4.3.	Evaluation of Kinetic Structural Systems Having Variable Geometry .....	48
4.4.	Discussion .....	51
5.	CHAPTER 5.....	53
5.1.	Design Process .....	53
5.2.	Design Proposal: <i>Shelter Module X</i> .....	59
5.3.	Design Limitations .....	67
5.4.	Discussion .....	68
6.	CHAPTER 6.....	70
	REFERENCES.....	73

## LIST OF FIGURES

<b>Figure 1.1.</b> Research methodology of the study .....	4
<b>Figure 2.1.</b> Disaster relief shelters.....	9
<b>Figure 2.2.</b> Modular paper partition solution of Shigeru Ban used for disaster victims .....	10
<b>Figure 2.3.</b> Overlapping stages of post-disaster relief shelters .....	12
<b>Figure 2.4.</b> Temporary housing as a core shelter example. a) primary building provides infrastructure and basic spatial needs b) secondary building as a permanent house .	14
<b>Figure 2.5.</b> Theory versus reality of disaster relief analysis.....	15
<b>Figure 2.6.</b> An incremental transitional shelter process compared with a multi-phased approach .....	16
<b>Figure 2.7.</b> Conventional sheltering process and construction systems.....	17
<b>Figure 2.8.</b> Advantages and disadvantages of transitional accommodation .....	18
<b>Figure 3.4.</b> Fire on shelter settlements: a) Lebanon b) Bangladesh c) Kenya.....	27
<b>Figure 3.5.</b> Roof types and effects of wind loads.....	29
<b>Figure 4.1.</b> Types of kinetic structures with variable mobility .....	34
<b>Figure 4.2.</b> Temporary shelters that commonly used in Turkey after disasters .....	
a) Mevlana Houses b) Containers used after Van 2011 Earthquake.....	39
<b>Figure 4.3.</b> Disassembled and assembled configurations of <i>Tentative Shelter</i> .....	40
<b>Figure 4.4.</b> Disassembled and assembled configurations of <i>Shelter Pack</i> .....	40
<b>Figure 4.5.</b> <i>Shelter 3800</i> .....	41
<b>Figure 4.6.</b> Shelter's exterior views a) <i>Liina Transitional Shelter</i> , b) <i>Pallet Shelter</i>	41
<b>Figure 4.7.</b> Compact configurations of shelters a) <i>Pallet Shelter</i> b) <i>Tentative Shelter</i> c) <i>Pallet Shelter</i> d) <i>Rapid Deployment Module</i> .....	42

<b>Figure 4.8.</b> <i>Global Village Shelter</i> a) Colored shelter option b) Deployment of the shelter c) Rapid deployment and numerous use of the shelter .....	43
<b>Figure 4.9.</b> The elevation of the <i>Shelter Proposal</i> shows the applied scissor mechanism.....	44
<b>Figure 4.10.</b> Assembly of the Disaster and Emergency Living Facility. ....	45
<b>Figure 4.11.</b> Deployment of the <i>Portable Shelter Proposal</i> a) compact configuration, b) deployment state, c) full deployed configuration .....	47
<b>Figure 4.12.</b> Transportation options for the <i>Portable Post-Disaster Home</i> : a)transportation by truck, b)distribution by car, c)relocation by human power.....	47
<b>Figure 4.13.</b> Deployment stages of the Deployable Yurt .....	50
<b>Figure 4.14.</b> Deployment stages of the Disaster Shelter .....	51
<b>Figure 4.15.</b> Using the same structural elements in diverse phases of relief and technical solutions for transitional sheltering.....	52
<b>Figure 4.16.</b> Using the same module in diverse phases of relief for transitional sheltering .....	52
<b>Figure 4.17.</b> Shelter unit combination from transitional sheltering to permanent housing .....	52
<b>Figure 5.1.</b> Physical model of Unit A.....	54
<b>Figure 5.2.</b> Unit A and its 4-modules combination .....	54
<b>Figure 5.3.</b> Deployment stages of Unit 1x1.....	55
<b>Figure 5.4.</b> Module combinations to create shelter units .....	55
<b>Figure 5.5.</b> Modelling studies of the Unit 3x3 .....	56
<b>Figure 5.6.</b> Plan layout of Unit A with module combination alternatives a) one module design with the long-sided entrance facing window opening, b) one module design with a short-sided entrance, c) 2-module combinations,d) 4-module combinations..	57
<b>Figure 5.7.</b> Plan layout of Unit 3x3 with foldable furniture a) living room with sofa, b) living room with folding bed open.....	58
<b>Figure 5.8.</b> Foldable plate hinge detail a) outside view, b) inside view, c) top view	58

<b>Figure 5.5.</b> Deployment stages of the <i>Shelter Module X</i> a) compact state; b) half deployed state; c) expanded form .....	59
<b>Figure 5.6.</b> Deployed configuration of the fully implemented shelter with indicated folding directions .....	60
<b>Figure 5.7</b> The physical model of proposal shelter perspective view .....	60
<b>Figure 5.8.</b> Perspective and front view of <i>Shelter Module X</i> physical model in deployed configuration.....	61
<b>Figure 5.9.</b> Transportation of the <i>Shelter Module X</i> a) half deployed state; b)demounted state by shelter package.....	61
<b>Figure 5.10.</b> Shelter package detail .....	62
<b>Figure 5.11.</b> Adjustable legs and wheels connection detail .....	62
<b>Figure 5.12.</b> Plan layout of Shelter Module X .....	63
<b>Figure 5.13.</b> The sectional perspective of shelter represents shelter life.....	64
<b>Figure 5.14.</b> The physical model of proposal shelter in deployed configuration.....	65
<b>Figure 5.15.</b> The physical model of proposal shelter without roof .....	65
<b>Figure 5.16.</b> Alternative module combination diagrams.....	66
<b>Figure 5.17.</b> Alternative module combination schemes for greater multifunctional use .....	66



## LIST OF TABLES

<b>Table 1.</b> Standards and technical requirements for transitional disaster relief shelters .....	22
<b>Table 2.</b> Classification of kinetic structures .....	34
<b>Table 3.</b> Evaluation of selected demountable temporary shelters .....	38
<b>Table 4.</b> Evaluation of relocatable temporary disaster relief shelters .....	43
<b>Table 5.</b> Evaluation of portable temporary shelters .....	46
<b>Table 6.</b> Evaluation of temporary disaster relief shelters has scissor & bar structures, foldable plate structures and their combinations.....	48



# CHAPTER 1

## INTRODUCTION

### 1.1. Motivation of the Study

Turkey is situated in a region prone to various natural disasters such as earthquakes, landslides, floods, and avalanches. These disasters frequently affect the country, causing significant devastation not only to the victims but also instilling fear of unpreparedness among all citizens. According to the hazard and exposure score of the sub-components of the Global Risk Management Index, Turkey ranks as the 10th most at-risk country. By the end of 2023, 75.9 million people were reported homeless according to the Internal Displacement Reports.

Organizations like Kızılay and AFAD, with the assistance of volunteers and government support, supply tents and other necessities to disaster-stricken areas. Various types of shelters have been used by these organizations: tent-typed shelters such as the “Kızılay Afet Çadırı” which can be assembled in 25 minutes, container-typed shelters, and prefabricated temporary shelters like “Mevlana Houses” which take hours to set up and were widely used after the 2011 Van earthquake.

Humanitarian organizations and governments strive to provide shelters for immediate use following disasters. Tent-type shelters are often preferred by organizations due to their affordability, ease of transportation, and quick installation, meeting the urgent need for thousands of shelters. However, while these shelters are convenient for short-term use, the need for more durable shelter solutions becomes apparent in the following weeks. Tent-type shelters fail to meet the evolving needs of disaster victims who must reside in temporary shelters for months and even years.

Considering the type of disaster, location, climate, and changing user needs over time, the “one size fits all” approach to sheltering proves inadequate and impractical in the later stages of the sheltering process.

The duration of sheltering begins the moment a disaster occurs and continues until livable, durable, and permanent housing options are provided for those affected (Shelter Centre, 2012). The disaster response process involves a comprehensive recovery approach spanning three interconnected periods: immediate relief, rehabilitation, and reconstruction (Corsellis & Vitale, 2005). This extended duration requires meticulous planning, as the need for sheltering persists until permanent living space is established.

Existing literature and field practices showcase several distinct shelter designs. However, most do not meet the requirements for providing adequate and habitable living spaces. This gap motivates to design adequate, habitable, durable, and portable disaster relief shelters that can last at least six months and be reused in various disaster situations, locations, and climate conditions.

## **1.2. Problem Definition**

In the existing practices, various types of temporary shelters are used after disasters, but most fail to meet the universal design standards and technical requirements set by humanitarian organizations (Sphere Association, 2018; IFRC, 2013). Thousands of shelters need to be delivered quickly, leading to the preference for small structures like tent-type shelters. In the following months, container-type shelters and prefabricated shelters are often provided to disaster-affected people. However, there is a distinction between short-term and long-term use of these shelter types. Tent-type shelters are not durable enough for long-term use, and only a limited number of prefabricated shelters can be transported to shelter settlements in the short term. In addition, these shelters require fieldwork and professional assistance for implementation.

As a result, relying on conventional shelter types can be a waste of resources, time, and labor. Therefore, an adequate shelter design with adaptive design solutions should be developed to respond to changing environmental conditions and user needs for both short-term and long-term use.

## **1.3. Objectives and Scope of the Study**

Kinetic structures offer the significant advantage of easy assembly and disassembly compared to container-type or prefabricated shelters, which require extensive

fieldwork and occupy large spaces. However, the use of kinetic structures in post-disaster relief shelters remains limited. Given these benefits, this thesis explores such structures.

This thesis aims to develop a kinetic temporary shelter featuring scissor linkages and foldable plates, which can be easily transported, stored, and deployed in post-disaster situations. The proposed shelter seeks to provide adequate shelter space in settlements and ensure a safe environment against secondary disasters.

#### **1.4. Methodology of Research**

The methodology employed in this thesis encompasses a qualitative research approach that integrates a critical review of literature on disaster relief shelters with simulation and modeling techniques to develop a kinetic disaster relief shelter (Figure 1).

The initial stage of the study involves a comprehensive review of relevant literature, employing bibliographic research to identify design standards and technical requirements for disaster relief shelters. This review encompasses the classification of kinetic structural systems based on their kinematic properties and the identification of specific parameters essential for evaluating the selected shelters. To gather relevant data, a diverse array of sources is consulted, including journal articles and conference papers, books, reports, and websites accessed through platforms such as Web of Science, Scopus, Google Scholar, and ResearchGate.

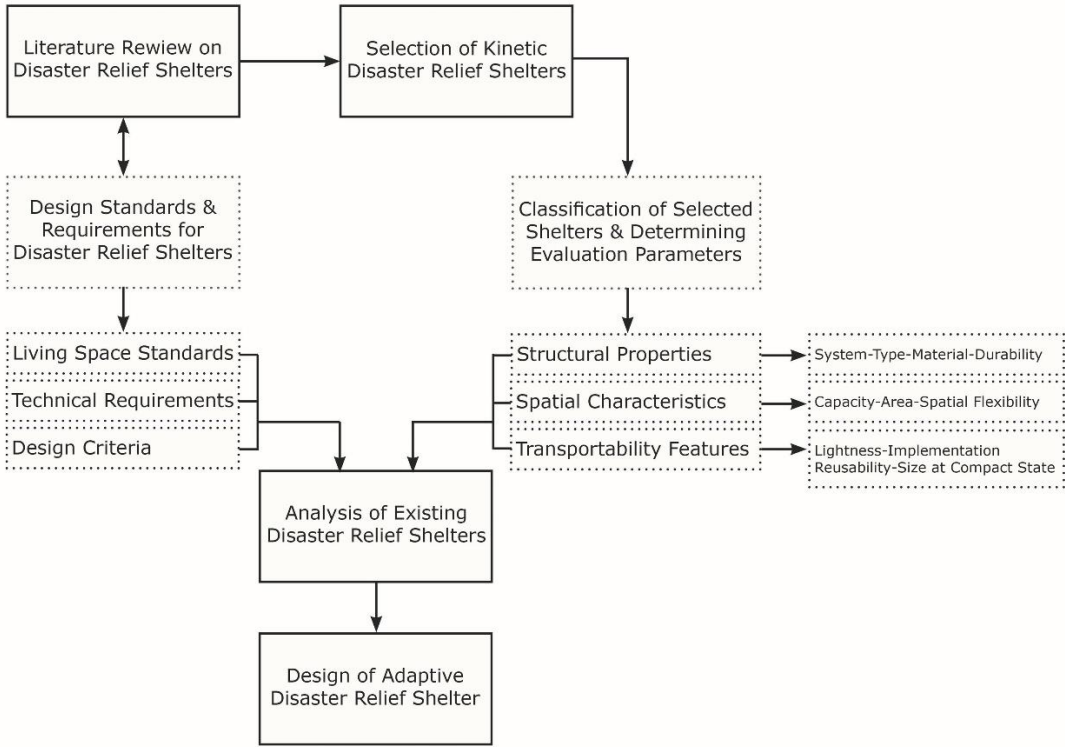
Subsequently, the study examines characteristics of temporary shelters, living space standards, technical requirements, and design criteria in alignment with temporary shelter standards (Corsellis & Vitale, 2005; Shelter Centre, 2012; AFAD, 2015; Sphere Association, 2018, UNHCR, 2021). Notably, the Sphere Handbook (2018), acknowledged as a leading international design standard offering comprehensive guidelines, plays a significant role in formulating tables and evaluating shelters.

Furthermore, kinetic structural systems used in architecture are classified into two main types based on their kinematic properties: structures with variable mobility and structures with variable geometry. Each category includes sub-groups distinguished by their unique movement and transformation capabilities. These characteristics, along with standards, requirements, and classifications, are instrumental in establishing parameters for selecting and analyzing the kinetic disaster relief shelters.

The thesis also delves into the latest designs and innovations in temporary shelters, incorporating patented examples and utility models for evaluation (AFAD, 2015; TMMOB Ankara, 2012). Selected shelters are analyzed across three main categories: structural properties, spatial characteristics, and transportability features. Findings from the analysis are synthesized into tables to facilitate comparative assessment among disaster relief shelters employing different types of kinetic structural systems.

The subsequent stage of the methodology centers on employing 3D modeling techniques to develop a kinetic disaster relief shelter. This approach allows for the exploration of diverse configurations and functionalities of the shelter, offering insight into its potential adaptability and flexibility. Leveraging insights gained from the literature review, several mechanism studies and shelter unit designs are examined and analyzed.

Ultimately, an adaptive disaster relief shelter, designated as “Shelter Module X,” has been developed following the established design criteria, requirements, and characteristics identified throughout the process.



**Figure 1.1.** Research methodology of the study

## **1.5. Significance of the Study**

Even though kinetic structures provide many advantages, the exploration of kinetic structures in temporary shelter design remains limited (Asefi & Sirus, 2012; TMMOB, 2012; Lee et al., 2013; Extremis Technology, 2014; Mira et al., 2014; Quaglia et al., 2014; Thrall & Quaglia, 2014; Seikaly, 2015; Kawuwa, 2017; TenFold Engineering, 2017; Gomez-Jauregui et al., 2018; Larsen et al., 2018; Alharthi, 2020; Arslan et al., 2021; Pérez-Valcárcel et al., 2021; Lee et al., 2022; Verzoni & Rais-Rohani, 2022). Existing studies primarily focus on developing new shelter types. However, there is no systematic study in the literature examining those proposals regarding their kinetic structural systems.

In the first stage of this study, kinetic disaster relief shelters are systematically analyzed based on their structural properties, spatial characteristics, and transportability features. This analysis offers insights into the current state-of-the-art in the field, emphasizing the potential of kinetic shelters to provide adaptable and flexible solutions. The findings obtained in this stage serve as a comprehensive guide for individuals or organizations interested in developing alternative temporary shelters, outlining the necessary standards and design requirements.

Building upon the insights gained in the initial analysis, the second stage of this study introduces a novel adaptive design for disaster relief shelters. This design addresses existing challenges associated with conventional shelter solutions. By proposing this adaptive design alternative, the study significantly contributes to the literature by not only systematically analyzing kinetic systems in disaster shelters but also presenting a practical solution that meets the necessary design criteria. This contribution underscores the significance of the study in advancing the field of disaster shelter design.

## **1.6. Outline of the Thesis**

This thesis is organized into six chapters:

Chapter 1 introduces the motivation, problem definition, objectives, scope, methodology, and the significance and contribution of the study.

Chapter 2 presents the sheltering process following natural disasters, reviewing and analyzing immediate responses. It explores the duration of sheltering, expected shelter types, phases, and approaches aimed at minimizing resource waste and minimizing harm to disaster-affected individuals. Temporary housing approaches are compared with traditional methods, followed by an overview of temporary shelter characteristics.

Chapter 3 establishes design standards and technical requirements by reviewing existing literature and guidelines. This review covers habitability standards and criteria for disaster relief shelters and prepares a guideline for subsequent evaluation and design proposal chapters. It identifies living space standards, technical requirements, and design criteria for disaster relief shelters.

Chapter 4 conducts a critical review using an evaluation table for disaster relief shelters, categorizing kinetic structures into two groups. It evaluates shelters categorized under structures with variable mobility (dismountable, relocatable, portable), and structures with variable geometry. The chapter compares 25 selected shelters, discussing their design features and spatial solutions.

Chapter 5 presents the design proposal and its development process. Various model studies and shelter units are explored, with selected models detailed in this chapter. The case study, *Shelter Module X*, is presented in depth, followed by a comparative discussion with existing examples.

Chapter 6 offers a conclusion for the entire thesis, summarizing key findings and proposing future directions for the design proposal.

## **CHAPTER 2**

### **SHELTERING PROCESS AFTER NATURAL DISASTERS**

Every year millions of people are displaced because of natural and man-made disasters such as earthquakes, floods, hurricanes, tsunamis, landslides, volcanic eruptions, fires, nuclear explosions, chemical or biological attacks, and conflicts. Because such disasters cause damage to the built environment, habitable living spaces should be provided to the people who lost their houses due to the disasters. Not only local and national governments but also humanitarian organizations respond immediately to provide temporary shelters and to meet the needs of disaster victims. Generally, tent-type shelters are distributed to the disaster victims although such shelters are not durable and convenient for long-term use. Since these shelters do not meet the habitability standards, there is a need to use alternative shelters such as container-type or prefabricated temporary shelters. However, they are not commonly used by humanitarian organizations due to the cost and logistics difficulties although they are durable for temporary accommodation.

Parallel to the devastating effects and increasing number of natural disasters in recent years, the necessity for temporary disaster shelters has increased (AFAD, 2018). Novel design solutions for temporary shelters have been developed by researchers and designers based on functionality and technical aspects. Habitability standards are generally dismissed even though their main purpose is to provide physically stable living spaces.

This chapter aims to investigate the sheltering process has been introduced which covers shelter definition, duration and phases of shelter, shelter types, and transitional approaches.

#### **2.1. Sheltering As a Disaster Response**

Before focusing on the habitability in temporary disaster shelters, it is required to comprehend the meaning of “shelter”, investigate the sheltering process and phases, and examine the shelter types and transitional approaches. There are numerous shelter

definitions, but the widely accepted definition is from the Sphere Association (2018): defined as a household living space, “shelter” contains the items to carry out daily activities as well as protecting the occupants from the outside. It also supports family and community life by providing essential needs that are dignity, security and access to livelihoods. Even though sheltering people means providing basic needs like a place to sleep at the very beginning of the disaster phases, such basic needs change in the following weeks and cover diverse notions which are called dignity, security, and access to livelihoods. Because people lose their belongings and relatives after the disaster, they are affected both physically and psychologically. Therefore, the shelter has a crucial role in the following process. Even if the sheltering process seems to be temporary, it covers different phases that require considering the habitability standards and needs to be well managed by humanitarian organizations and governments.

The first 72 hours after the disasters are crucial not only for search-and-rescue, life-saving medical triage and coordination but also for the arrangement of food, water, medicines, and shelter for disaster victims (AFAD, 2011). The disaster response should be following the phases of emergency relief, early recovery and medium to long-term recovery. Emergency and temporary shelters are mostly used in disaster settlements in the emergency relief and early recovery phases. However, those shelters may become permanent houses for disaster victims although they are convenient to be used for up to six months or one year.

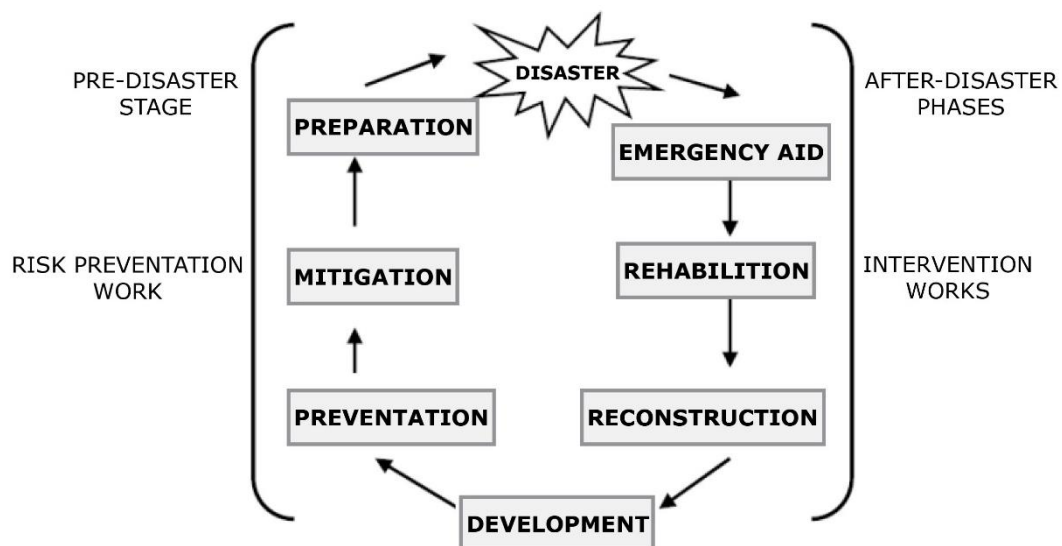
The sheltering process may take longer than planned because of several reasons such as continuation of aftershocks, duration of permanent housing construction, repairing time of damaged houses and transferring of disaster victims to permanent settlement areas. Reconstruction of the damaged buildings takes significant time and is a long process (Sey, 1987). Despite the advances in construction technology, it still takes time to get necessary permits and contracts from municipalities or governments. As the sheltering process extends, the temporality of sheltering habitat changes because the needs of people change over time.

## **2.2. The Duration and Phases of Shelter**

As the shelter duration extends, the phases overlap each other which may cause the use of an inconvenient type of shelter in the disaster settlement for an unintended period. This also affects the sheltering habitat. To provide a comfortable living space

for the disaster victims, a proper shelter should be selected which can meet the needs of the occupants. However, misunderstood terminologies about the shelter types and the transition of phases are common in the current literature (IFRC, 2013).

Post-disaster aid period consists of three interrelated stages: immediate relief period, rehabilitation period and reconstruction period (Figure 2.1). The primary purpose of these periods is to protect the lives and the safety of disaster victims in the long term. Divided into several different phases of operation to sustain itself as a transitional process, the immediate relief period consists of the phases of preparedness, contingency, transit, and emergency, which are the actions to take before a disaster. Called also as rehabilitation period, the immediate relief period includes care and maintenance phases. On the other hand, the reconstruction period consists of the durable solutions phase and exit-strategies phase, which aims to provide a permanent durable living environment to the disaster victims (Corsellis & Vitale, 2005).



**Figure 2.1.** Disaster relief shelters

Source: Redrawn by authors. Corsellis & Vitale, 2005; Çakır, 2007; Ergünay, 2009

FEMA (2005) suggests acting for a mitigation phase before the phases of operation to prevent estimated damages in houses, settlements and zones, e.g. digging water canals to redirect water and construction of permanent barriers to control flooding. Pre-planning has a crucial role in decreasing the vulnerability of people after the disaster, and the preparedness phase includes post-disaster settlement planning and housing stocks for estimated affected people and simulation of a disaster case to teach and learn

about hazardous cases which are not mitigated (Choi et al., 2020). The contingency phase is an organized action plan preparation and simulation to be followed in disaster cases which can reduce the vulnerability of disaster victims in the following stages, and it is prepared and actualized in coordination with humanitarian organizations and governments (Shelter Centre, 2012). In between the contingency and emergency phases, there is a transit phase which aims to gather information about the cultures, gender composition and vulnerabilities of disaster victims to maximize protection, habitability and safety during accommodation and includes other requirements for response readiness (Corsellis & Vitale, 2005). The emergency phase can be either ‘fast onset’ or ‘slow-onset’, which depends on the type of disaster, and both types need to be separately examined. The common consideration of these emergency phase types is to meet the immediate needs of disaster victims as a quick response. During the emergency phase, schools, sports centres and other usable public buildings, which are not damaged due to the disaster, are commonly used for accommodation. In this phase, tent-type shelters are provided by humanitarian organizations and governments. The habitability of these temporary accommodations is questioned in the current literature. For instance, Shigeru Ban questioned the chaotic disarray of temporary accommodation after the Japanese tsunami in 2011. Ban proposed a simple solution by creating partitions with cardboard paper tubes and white curtains which gives the evacuees at least a sense of individual space (Figure 2.2). This solution has widely been used in several countries for the same purpose with some additions. The approach of Shigeru Ban indicates the problems of temporary accommodation which need to be examined: habitability, privacy, dignity, adequacy, sustainability and other problems like noise and hygiene.



**Figure 2.2.** Modular paper partition solution of Shigeru Ban used for disaster victims

Source: Voluntary Architects’ Network, 2011

After covering the immediate needs of the emergency phase, the care and maintenance phases of the rehabilitation period start. In this stage, humanitarian organizations and governments have diverse roles aiming to provide food and water distribution, sanitation and health care, and planned settlements for temporary or long-term accommodation in coordination with each other. The flow and increase of displacement are expected to be controlled or managed in this stage, which can be the opposite (Corsellis & Vitale, 2005). However, the contingency phase of the operation helps to manage the number of displaced people with variable sub-divisions like age, gender and disability. It is expected to help the management of this care and maintenance phase through the provided reports.

The longest period is the reconstruction period which directly affects the shelter duration. Durable solutions and exit-strategies operations are actualized in this period. The displacement is expected to end in this period. For instance, UNHCR (2001) suggested three possible durable solutions for refugees which are as follows: returning to their home country if the conditions are available, integration with the host community which can be a foreign country for displaced people, and resettlement option in another country that is not affected directly by disasters or conflicts. Corsellis & Vitale (2005) considered these solutions for all types of displacements as 'integration within the area of displacement'. Therefore, it has a wider inclusion and an emphasis on the habitability of displacement settlements. When durable solutions and a planned stable living environment are achieved, the exit-strategies phase of operation starts which aims to transfer learning outcomes from the case as skills, abilities, and adequacy organizations, and recycling used equipment, shelters, and such elements for another case if possible.

Tent-type shelters are not mostly reusable for other disasters because they are not durable and not adaptable for different cases of disasters. Using the same tent-type shelters for every disaster type and long-term stay creates habitability problems. Because the design solutions that are not adaptive and durable are still in use and the displacements increase rapidly, the researchers and designers attempt to fill the gap in the literature by developing new shelter solutions. Particularly, temporary solutions need to be developed because temporary accommodation is the longest period of stay which starts with the emergency phase and ends with the delivery of core shelters or

permanent houses (Félix et al., 2015). There is a need to develop alternative solutions to meet the habitability standards while designing temporary shelters.

### 2.3. Shelter Types and Transitional Approaches

As the reconstruction of damaged houses and construction of a permanent stable living environment takes months even years, temporary accommodation becomes a need for the displaced people. From the first day that disaster occurs to the day the permanent living area is provided, this is called the shelter duration (Shelter Centre, 2012). Temporary accommodation is the longest duration because it contains emergency shelter, temporary shelter, and temporary housing periods, which are used until the permanent houses are built (Johnson, 2002).

Shelter duration is divided into phases where diverse shelter types are used. These shelters differ in terms of their spatial characteristics and user needs. The transition between the sheltering phases needs to be well managed and designed due to its direct effect on the users. Emergency shelters, temporary shelters, transitional shelters, progressive shelters, core shelters, and permanent housing are the shelter types classified by Sphere Association (2018) and represented by IFRC (2013), which have been used in the transitional shelter duration (Figure 2.3). Briefly, these shelters are defined as follows.

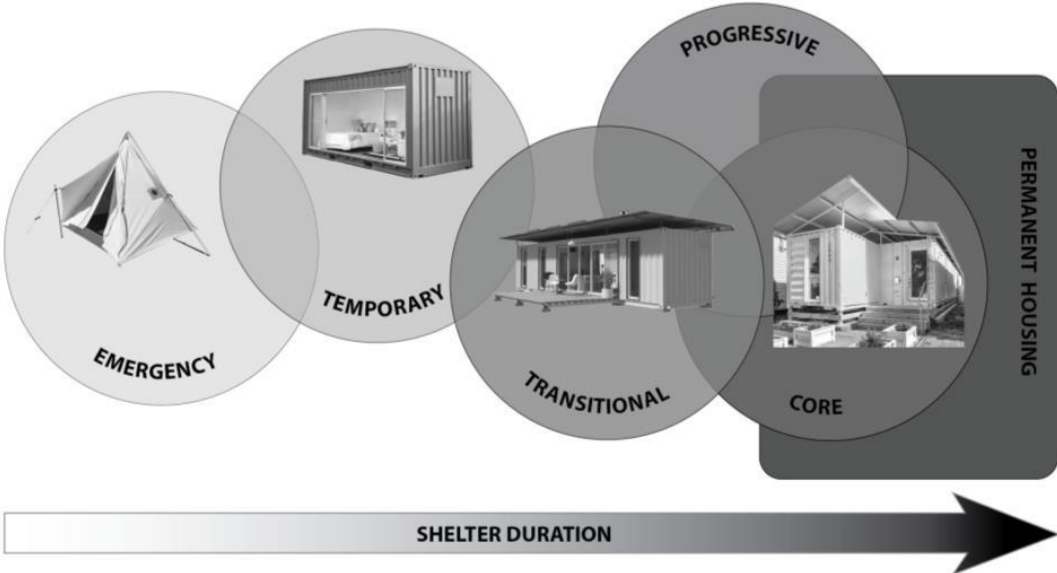


Figure 2.3. Overlapping stages of post-disaster relief shelters

Source: Redrawn by authors (IFRC, 2013; Shelter Centre, 2012)

- **Emergency Shelters:** It is the first type of shelter used immediately after the disaster, which is suitable for the use of a certain time such as a week, and is not recommended to be used for a long time. Emergency shelters provide a living environment immediately after the disaster occurs, which is suitable for short-time usage. Thus, this type does not include service integrations such as kitchen, bathroom and toilet. Also, users do not have enough space to carry out their daily routines in the emergency shelters. Thousands of emergency shelters can be used just after one disaster; therefore, these shelters need to be easy to store, transport and low-cost as well as provide 3.5m<sup>2</sup> per person which is the minimum living area standard (Sphere Association, 2018).
- **Temporary Shelters:** As called temporary, it is suitable for short-time use and not recommended to exceed 6 months. It is expected to be easy to construct, low cost and reusable. Temporary shelters and emergency shelters are diverse due to the space inclusions. Temporary shelters provide service integration; therefore, more living areas per person can be created so that the disaster victims can continue their daily routines like cooking, reading, working and studying. This feature of temporary shelters creates an important difference and makes shelter duration more habitable for the users.
- **Transitional Shelter:** It can be rapidly upgraded within the context of construction location and materiality; this may sometimes need to be adjusted by the users.

Temporary shelters are used as transitional shelters or vice versa; therefore, they are also called T-shelters. However, temporary shelters are not required to be used in permanent housing like transitional ones. Since temporary shelters are designed to be reused, and re-located, they are expected to be the most adaptive shelter in variable disasters. Transitional shelters have been used during the process of securing land tenure and reconstruction for shelter users. These shelters can be resold, recycled or reused for permanent houses. This design process should continue in cooperation with the users, but it can take years. Moreover, these shelters can be moved to permanent housing locations from temporary settlements (IFRC, 2013). Regarding this, there are recycling methods such as material, product and feedstock recycling and alternative destinies for temporary shelters and housings which have ceased to be used (Arslan, 2007). Demolishing is the most wasteful option whereas relocating, storing or

upgrading for other uses can be adaptive and sustainable options. On the other hand, selling to increase the budget for permanent construction can be another alternative. However, not taking any action or abandoning these shelters when permanent residences are ready for use should not be an option for such shelters. Because there are many options and solutions for the sustainability of these structures (Askar et al., 2019).

- **Progressive Shelters:** This type of shelter can be advanced to permanent structures in terms of their structural characteristics and detailing. In diverse relief phases, the same structural elements can be used through technical solutions regarding structural improvement and reconfigurations. In this way, shelters can be improved to sustain a complete sheltering process.
- **Core Shelters (One-room shelters):** It is a permanent living space solution and is seen as the beginning of a large permanent space solution. Firstly, building infrastructures and living spaces as the core of permanent houses, then spatially growing by adding other necessities (Figure 2.4).
- **Permanent Housing:** Reconstructed or newly constructed for long-term use, it can be defined as a stable and permanent living environment. The settlements are decided and guided by governments, mostly governments support reconstruction for permanent housing after natural disasters. Disaster victims sometimes may not be willing to leave their neighbourhoods even if they live hazards in there. However, they need to leave there and stay in secure lands matter temporary or permanent. Then, permanent living areas need to be provided while the permanent housing process or transitional housing starts.



**Figure 2.4.** Temporary housing as a core shelter example. a) primary building provides infrastructure and basic spatial needs b) secondary building as a permanent house

Source: Aravena, 2014

If the shelter duration is not transitional, tent-type emergency shelters are used for months or even years. There are many cases where people live in such tents for more than five years. This demonstrates that the theory and reality of disaster relief can be different (Figure 2.5) (Dialameh, 2017). There is an approach aiming to close this difference: incremental housing. In this approach, the focus is on the process of sheltering not the shelter type or the product. It offers small changes during the transition of shelter phases to meet the changing needs of users (Askar et al., 2019).



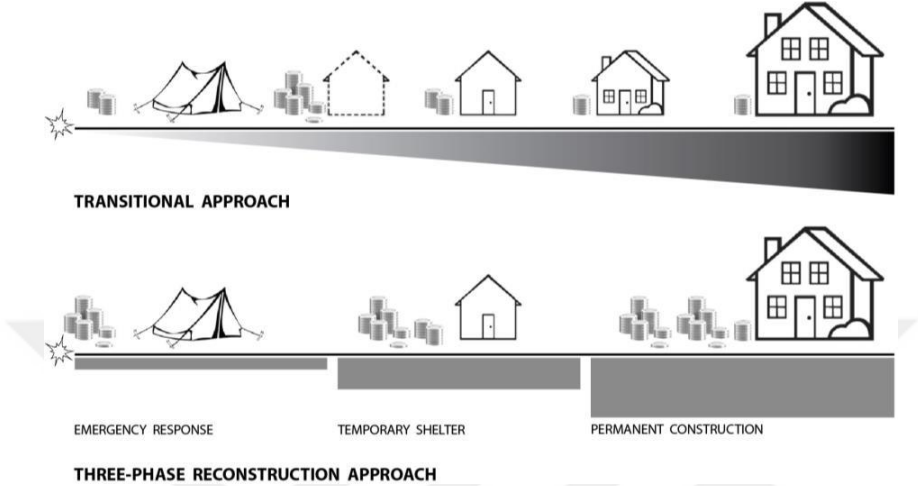
**Figure 2.5.** Theory versus reality of disaster relief analysis

Source: Dialameh, 2017

In each phase of shelter duration, using different types of shelters is a necessity because the needs are changing, and they become unavailable to meet the user's needs. However, it is a waste of cost, time and workforce since people work against time to provide safe spaces for disaster victims (Shelter Centre, 2012). In the transition between shelter types with incremental architecture, the cost and time are saved (Figure 2.6). The contact between users and humanitarian organizations needs to be well managed by consultations to understand future needs and to develop permanent solutions. Thus, the sheltering process should be advanced with the users while focusing on the next stage which is a permanent reconstruction (Wagemann & Moris, 2018).

Transitional approaches in shelter duration make shelter settlements more habitable due to the fewer changes in structure and affect the living environment much less compared to the conventional three-phase reconstruction. Moreover, transition aims to carry and upgrade the duration less vulnerable state for the users and relates to the habitability conditions. Even if temporary shelters and transitional shelters can be seen

as a waste of cost due to their use in temporary situations, the reconstruction of disaster-affected community living settlements through the incremental transitional shelter process can be more cost-effective over time (Shelter Centre, 2012; Karaođlan & Alaçam, 2018). The temporary shelters need to be perceived and designed as long-term products, which are reused several times in diverse conditions for even years.



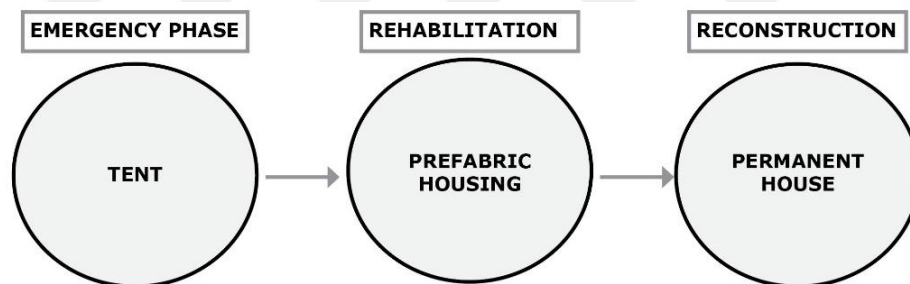
**Figure 2.6.** An incremental transitional shelter process compared with a multi-phased approach

Source: Redrawn by authors. (Shelter Centre, 2012)

**2.4. Characteristics of Temporary Shelters**

Temporary shelters can cover the stages in which emergency and transitional shelters are used due to the extended sheltering periods if they meet spatial needs and technical requirements. Unlike emergency shelters, temporary shelters are designed to be used for up to six months and provide essential amenities such as sleeping, bathing, and cooking facilities. In cases where transitional shelters cannot be utilized due to settlement policies, they are referred to as temporary shelters, highlighting the overlapping terminologies used in the context of shelters. However, employing various types of shelters throughout the sheltering process presents more drawbacks than benefits. Each type of shelter possesses distinct spatial and technical characteristics to fulfill specific needs, resulting in increased overall costs. Temporary shelters are expected to be cost-effective, easily constructible, relocatable, and reusable, while transitional shelters should offer rapid upgradeability.

Once temporary shelters have been used for six months, they can undergo various actions to prolong their life cycle, including repairs, relocation to permanent settlements, or expansion to meet additional needs until permanent dwellings are constructed. The literature emphasizes the importance of extending the life cycle of these shelters through measures such as space additions, repairs, reuse in subsequent stages, and relocation to permanent or safer shelter settlements (Arslan, 2007; Askar et al, 2019). Even if temporary shelters are not intended to become permanent houses, they can be upgraded to accommodate different stages of the sheltering period. The incremental transition approach suggests using the same shelter and making minor modifications to meet the evolving needs of shelter users (Wagemann & Moris, 2018). This approach allows for the continued use of the shelter in the same location and habitat, thereby protecting the mental health and comfort of disaster victims (Choi et al, 2020). Furthermore, adopting this approach can lead to reduced costs during the sheltering period compared to the conventional three-phase reconstruction approach, where temporary shelters are used after emergency response until permanent houses are built (Figure 2.7).



**Figure 2.7.** Conventional sheltering process and construction systems

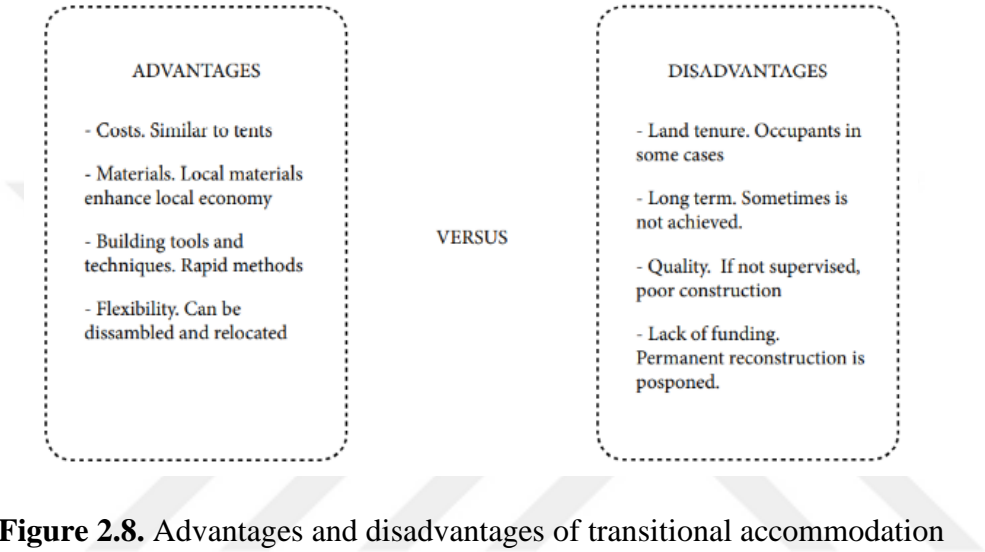
Source: Redrawn by authors. (Çakır, 2007; Ergünay, 2009)

The fundamental advantages provided by following the incremental transition approach are the cost that is similar to tents, the building methods tools and techniques that encompass rapid methods, flexibility due to disassembly and relocation, and the use of local materials to support sustainability and cost-effective solutions.

On the other hand, for transitional accommodations, land tenure can be problematic. Sometimes transitional accommodation is not achieved and lasts long term. The quality of transitional shelters needs to be well supervised and avoid poor construction.

Mostly, such shelters are seen as temporary and constructed as poor-quality products. Similarly, due to a lack of funding, permanent construction can be postponed.

To address the need for adaptability and relocatability, designers and researchers have explored new design solutions for temporary shelters. They have started using kinetic structural systems in temporary shelter designs since they offer formal transformability, spatial flexibility, rapid assembly, and disassembly, adaptability to changing conditions, and ease of transportability (Figure 2.8).



**Figure 2.8.** Advantages and disadvantages of transitional accommodation

Source: Wagemann, 2012

## **CHAPTER 3**

### **DETERMINATION OF DESIGN STANDARDS AND TECHNICAL REQUIREMENTS**

Universal standards, technical requirements, and structural capabilities are prioritized in the selection and evaluation of temporary shelters.

#### **3.1. Habitability in Temporary Shelters**

Habitability means creating an environment where people can live for a long term with safety/security, comfort, and dignity. Habitability has four sub-categories such as safety, health, sociality and comfortability (Kim et al., 2021). In terms of safety, the shelter should be able to protect the users from weather conditions and prevent possible risks such as theft or secondary disasters (e.g. fire in the shelter area). Fire is the most common secondary disaster in disaster settlements. There are some standards for the prevention of the fire such as using fireproof materials, keeping certain distances between the shelters, and avoiding tent-type or container-type camps where thousands of temporary shelters are placed at a close distance to each other (Shelter Centre, 2012).

The health sub-category can be achieved with cleaning and sanitary zones. In addition, self-isolation areas can be added to the temporary settlement sites against possible infectious diseases and prevent their spread in the area. Further, sanitary areas can be added at the entrances of the settlements to protect the area from the external environment. The inability to obtain healthy drinking water after natural disasters such as earthquakes causes an increase in infectious diseases. Special precautions should be taken against communicable diseases after earthquakes. For instance, the disaster management program implemented after the earthquake occurred in Van in 2011 to prevent water-borne infectious diseases (Bayram et al., 2014).

On the other hand, the sociality category aims to make the shelter environment accessible for all users, including children, the elderly, and handicapped people. There is a need to include community areas in the disaster settlements for the people to rest,

eat, and spend time with other people. The use of such spaces can reduce the stress level of shelter users.

The comfortability depends on whether each person in the shelter can carry out the domestic activities at an optimum level. Based on the shelter standards (Sphere Association, 2018; IFRC, 2013), a minimum of 3.5m<sup>2</sup> is required for each person for a living space that excludes cooking, bathing, and sanitation. In cold climates or the settlement in urban settings, it is up to 4.5m<sup>2</sup> - 5.5m<sup>2</sup>. The internal floor-to-ceiling height should be at least 2m while it is 2.6m in hot climates. Moreover, private spaces for individuals should be provided using dividers or separators. Furthermore, indoor thermal comfort should be obtained with a proper cooling and heating system, humidity management, natural ventilation and daylight.

Habitability standards protect the dignity of users throughout their stay. While developing the layouts of shelters and settlements, they should be designed with possible service integrations considering the users' future needs. For instance, there can be a need for childcare units in the first month of shelter duration, but a need for kindergarten or primary school may emerge in the following stages. Thus, these spaces need to be spatially flexible or adaptable to diverse functions.

### **3.2. Habitability Standards and Criteria for Disaster Relief Shelters**

Habitability standards protect the dignity of users throughout their stay. While developing the layouts of shelters and settlements, they should be designed with possible service integrations considering the users' future needs. For instance, there can be a need for childcare units in the first month of shelter duration, but a need for kindergarten or primary school may emerge in the following stages. Thus, these spaces need to be spatially flexible or adaptable to diverse functions.

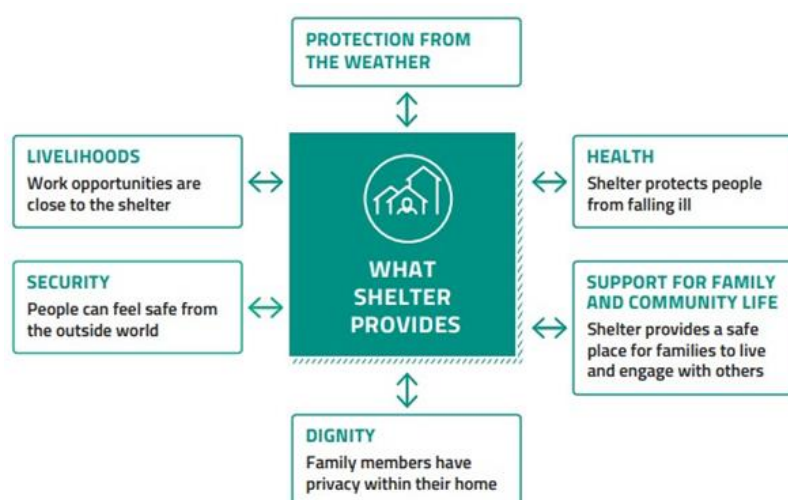
Unlike the terminology used for permanent buildings, emergency architecture employs distinct terms due to its temporary nature, often arising immediately after disasters. Although 'house' and 'home' may appear similar, their differentiation hinges on criteria related to user comfort, privacy, and dignity, all of which contribute to the habitability of these living environments.

Ensuring the physical and psychological well-being of shelter occupants can be achieved through a well-organized sheltering process and the provision of suitable

shelters. Given that sheltering aims to mitigate the vulnerability of disaster victims, considering the broader impact, the primary focus should be on the rehabilitation and improvement of conditions for both the affected communities and individuals residing in disaster settlements (Vaccari et al., 2021).

The essential requirements to ensure the adequacy of a disaster relief shelter encompass the following criteria:

- Ensuring sufficient privacy for users
- Providing a safe and secure living environment
- Guaranteeing the stability of shelter tenure
- Ensuring ease of physical access for both users and ongoing service vehicles
- Establishing structural stability and durability
- Adequate provision of natural light and as well as temperature control
- Proper air circulation through either natural or mechanical means of ventilation
- Providing fundamental infrastructure such as electricity, water supply, sanitation, and waste management facilities
- Maintaining a suitable and healthy living environment
- Placing shelter settlement in proximity to the daily routines of the users
- Furthermore, it is imperative that these criteria have met while maintaining affordability (UN General Assembly, 1996).



**Figure 3.1.** The chart shows what a shelter provides.

Source: Sphere Association, 2018.

The definitions of adequacy can vary significantly, and these indicators may occasionally conflict with each other. Nevertheless, there is a consensus, particularly in the context of long-term disaster recovery, that achieving a “one-size-fits-all” standard of adequacy is practically unattainable (Hurkmans, 2018). From this standpoint, it becomes evident that the conditions of disaster settlements and the requirements of their inhabitants are highly contingent on various factors, including the type and location of the disaster, as well as the extent to which the society has been impacted by it. Furthermore, these conditions and needs can evolve.

### 3.3. Living Space Standards, Technical Requirements and Design Criteria for Disaster Relief Shelters

To create habitable living spaces to settle disaster relief shelters, it is crucial to design temporary shelters by considering standardized parameters, which are presented in transitional sheltering guidelines. Since temporary shelters intend to be used for up to 6 months, they need to be designed like transitional shelters as well to meet changing user needs. Detailed living space standards, technical requirements, and design criteria for disaster relief shelters are outlined in Table 1 (Corsellis & Vitale, 2005; Shelter Centre, 2012; AFAD, 2015; Sphere Association, 2018, UNHCR, 2021).

**Table 1.** Standards and technical requirements for transitional disaster relief shelters

<b>Living Space Standards</b>	<i>Minimum living space per person</i>				3.5m <sup>2</sup> including eating, bathing and sanitary		4.5m <sup>2</sup> - 5.5m <sup>2</sup> in cold climates	
	<i>Minimum internal floor-to-ceiling height</i>				2m		2.6m in cold climates	
	<i>Indoor areas</i>	thermal comfort	fire resistance	water resistance	humidity management	natural ventilation daylight	safety security	privacy dignity
<b>Technical Requirements</b>	<i>Fire safety</i>		30m firebreaks per built-up 300m in shelter settlements					
	<i>Supplying basic infrastructures and needs</i>		water tanks	sanitaries	electricity	bathroom	food supplies	healthcare supplies
<b>Design Criteria</b>	durability	reusability	non-toxic materiality	lightness	implementation	storage	transportability	feasibility and cost

Source: Author

### 3.3.1. Living Space Standards

As indicated by the Sphere Association (2018) and UNHCR (2021), the minimum area required for a living space per person in a temporary shelter should be 3.5m<sup>2</sup>, excluding dedicated spaces for cooking and bathroom facilities. However, the living space per person should be increased to a range of 4.5m<sup>2</sup> - 5.5m<sup>2</sup> in cold climates, which includes the spaces for cooking, bathing, and sanitation facilities. Temporary shelters should protect the users from extreme weather conditions while providing user comfort through natural ventilation and daylighting the indoor areas.

The minimum internal floor-to-ceiling height should be 2m in temporary shelters. However, in hot climates, it should be 2.6m for air circulation. Temporary shelters should also provide privacy, safety, and security, which are essential requirements to maintain daily life for shelter users as much as possible. Moreover, complementary facilities should be considered in and around the shelter because providing designated spaces for cooking, bathing, and sanitary allows people to undertake daily activities.

There are several criteria for indoor area design as follows:

- **Thermal comfort:** The shelter materials not only influence the interior environment but also play a crucial role in providing thermal comfort and protection against the elements, as highlighted by the Sphere Association (2018) (Figure 3.2).

In colder climates, where maintaining warmth is paramount, insulation becomes a critical consideration. Applying insulation layers to both the interior and exterior surfaces of the shelter is an effective strategy, as recommended by the International Organization for Migration (IOM, 2012). These insulation layers act as a thermal barrier, preventing heat loss and helping to maintain a comfortable temperature inside the shelter. Adequate insulation is vital for safeguarding the health and well-being of shelter occupants, particularly in regions where extreme cold can pose significant risks.

Conversely, in hot and arid regions, lightweight materials with sufficient insulation are the materials of choice. These materials help manage the challenges posed by intense heat and solar radiation. They contribute to maintaining a cooler interior environment by reducing heat transfer from the exterior to the interior. Lightweight materials are

also advantageous for ease of transport and assembly, making them practical choices for shelter construction in resource-limited disaster-affected areas.



**Figure 3.2.** Thermal insulation in the face of changing conditions in temporary shelters

Source: Dialameh, 2017

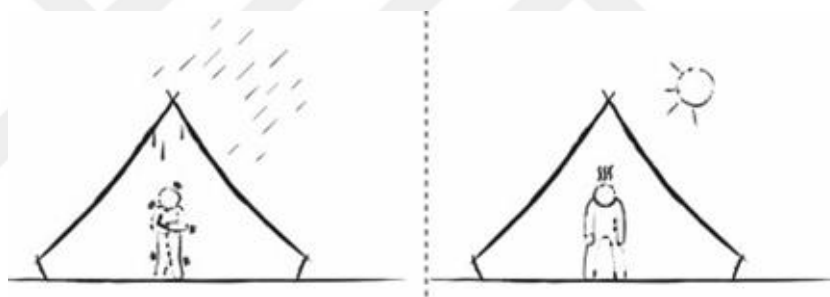
- **Fire resistance:** Fire resistance is a paramount consideration in the design and construction of temporary shelters, especially in disaster-prone regions where the risk of fire can pose a significant threat to vulnerable populations, particularly those who may have difficulty evacuating swiftly. The safety and well-being of shelter occupants must be a top priority, and this includes safeguarding them from the devastating impact of fires that can occur in densely populated shelter settings.

There is a pressing need for the establishment of fire breaks or fire-resistant barriers within the shelter settlements. These measures can help reduce the risk of fire spreading rapidly and provide additional time for evacuation and emergency response. Another critical aspect of fire safety in temporary shelters is the evaluation of the fire resistance of the materials used in their construction. Assessing the fire resistance properties of these materials is essential to determine their suitability in disaster-prone areas. Materials that can withstand or resist fire for a sufficient duration are preferable, as they provide vital protection to shelter occupants and help prevent the rapid spread of fires within the settlement.

- **Water resistance:** Water infiltration can pose a significant challenge to the habitability and structural integrity of temporary shelters, particularly in regions prone to heavy rainfall or flooding. Effective strategies for preventing water penetration are essential to ensure the safety and comfort of shelter occupants.

One critical consideration in shelter design, as emphasized by the International Organization for Migration (IOM, 2012), is proper insulation and moisture protection. Insulation helps maintain a comfortable indoor climate by preventing temperature extremes and reducing condensation inside the shelter. Shielding the shelter from ground moisture and ensuring a waterproof roof are essential components of this strategy. Waterproofing materials and techniques can help create a barrier against moisture infiltration, protecting shelter occupants and their belongings from dampness and potential waterborne diseases.

Furthermore, elevating the shelter off the ground and establishing proper drainage systems around the shelter, as recommended by the International Federation of Red Cross and Red Crescent Societies (IFRC, 2013), are crucial strategies for mitigating the effects of accumulated rainfall and flooding. Elevating the shelter not only prevents ground moisture from seeping into the structure but also ensures that floodwater does not inundate the living space, preserving the safety and well-being of occupants.



**Figure 3.3.** Water resistance and heat protection in temporary shelters

Source: Dialameh, 2017

- **Humidity Management:** In warm and hot climates, humidity becomes problematic, and the shelter needs to be designed by considering that issue.
- **Natural Ventilation:** To ensure a healthy and comfortable indoor climate within temporary shelters, it is essential to provide shaded and well-ventilated areas, as highlighted by the International Federation of Red Cross and Red Crescent Societies (IFRC, 2013). This consideration is particularly important for maintaining the well-being of shelter occupants, as it helps regulate temperature and air quality.

In regions with hot and arid climates, enhancing air movement is a key strategy for improving comfort. This can be achieved through the use of higher ceilings and the incorporation of verandas, as recommended by the International Organization for Migration (IOM, 2012). These design elements promote natural ventilation and create a cooler and more pleasant living environment.

Optimizing airflow is further achieved by strategically positioning openings on opposing walls at high and low levels. This cross-ventilation system facilitates the exchange of air, reducing indoor temperatures and enhancing comfort. However, in extremely cold climates, where maintaining warmth is a priority, ventilation should be minimized to conserve heat.

- **Natural Daylighting:** Natural daylighting is a fundamental aspect of shelter design that can significantly enhance the living conditions and well-being of shelter occupants. It goes beyond just providing illumination; it fosters a sense of normalcy, promotes productivity, and contributes to a positive and uplifting environment within the shelter. To ensure the safety and privacy of shelter users, small windows are often strategically positioned above eye level. This design approach offers the dual benefit of allowing natural daylight to filter into the shelter while maintaining a level of privacy and security. It creates a balance between the need for illumination and the need to safeguard the personal space of shelter occupants, particularly in densely populated shelter environments. Thin and tall windows are often preferred for their ability to maximize the ingress of natural daylight. Their vertical orientation allows sunlight to penetrate deeper into the shelter, effectively illuminating a larger area. This design choice helps reduce the reliance on artificial lighting during the day, which can lead to energy savings and contribute to the overall sustainability of the shelter.
- **Safety and Security:** Providing individuals with a secure and safe haven is a fundamental aspect of designing temporary shelters, as emphasized by the Sphere Association (2018). These shelters serve as a refuge not only for the occupants but also for their precious belongings, and safeguarding both is of utmost importance. To achieve this, it is imperative to incorporate features such as lockable windows and doors within the shelter's design. These security measures not only deter potential theft but also help protect residents from

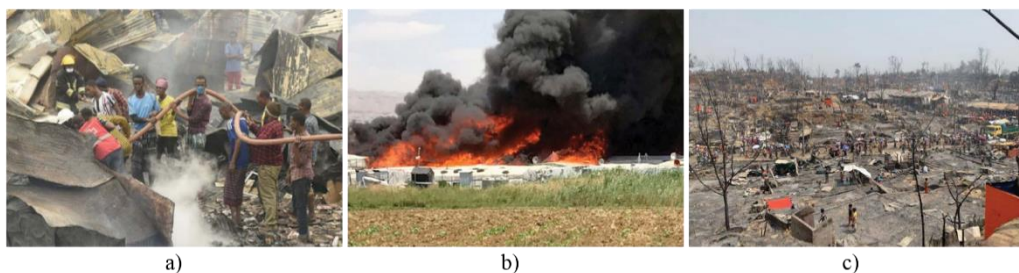
potential risks such as assault or intrusion, ensuring their physical safety and peace of mind.

- **Dignity and Privacy:** The concept of privacy holds an equally pivotal role in the design of temporary shelters. Beyond physical safety, preserving the dignity and privacy of shelter users is a fundamental human need. To address this, the shelter should include provisions for creating private spaces within its confines. The strategic use of various compartments or partition walls can help create separate areas, allowing residents to maintain their personal space and engage in daily activities without feeling exposed or vulnerable.

### 3.3.2. Technical Requirements

Meeting technical requirements is as important as living space standards, encompassing aspects like fire safety, technical performance, and the provision of basic infrastructure and necessities. Shelter settlements should be chosen considering adequate and accessible places in terms of basic facilities for shelter users. Natural ventilation and daylight are the needs and preferences to provide habitable indoor space for temporary shelters. The parameters such as fire safety, sanitary, food, and healthcare supplies positively affect the performance of shelters.

- **Fire Safety:** 30m firebreaks per built-up 300m in shelter settlements. There is a high potential for secondary disasters in disaster settlements and fire is the common disaster. Therefore, fire safety is crucial to avoid such risks in settlements. There are many devastating examples of fire in settlements (Figure 3.4).



**Figure 3.4.** Fire on shelter settlements: a) Lebanon b) Bangladesh c) Kenya

Source: Dialameh, 2017

- **Supplying Basic Infrastructures and Needs:** At the beginning of the shelter duration, generally, the provided sanitary, bathrooms, and even sleeping zones are shared with the disaster community while water tanks and food supplies are placed in the shelter settlement. Such needs can be provided like that for one week, but then private sleeping zones, bathrooms, and personal spaces need to be provided. In that way, users can be motivated to turn back their daily routines like cooking, working, or even just sitting in their personal space. Provided areas can be close one to another, but the gender, age and needs need to be well analyzed to place zones such as healthcare units or kinder gardens. After entering shelter settlements, users need to be able to feel secure and peaceful. Over time, users protect their dignity and privacy in such secured settlements. Since electricity and water tanks need to be provided by the beginning of accommodation, shelter settlements should be prepared for these infrastructures. Healthcare supplies can be part of shelter settlement and serve for the long term. Shelters and offices for healthcare workers should be provided in the settlement.

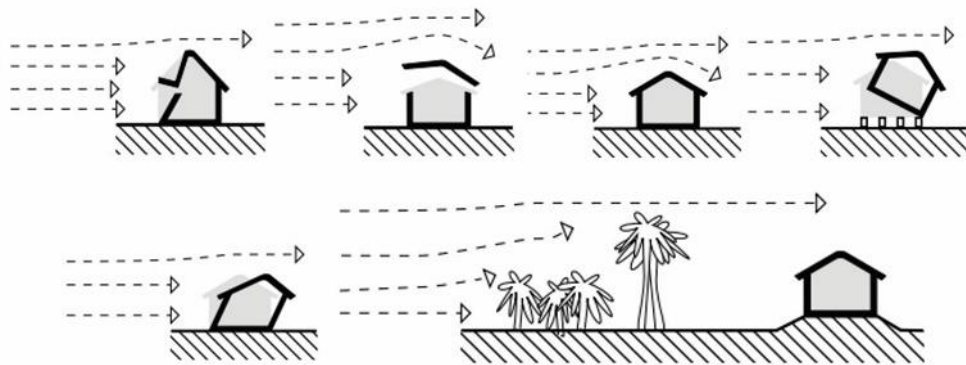
### 3.3.3. Design Criteria

Design criteria include durability, non-toxic materiality, transportability, implementation, reusability, lightness and storage, feasibility and cost, expandability and spatial flexibility constitute the principles of designing an adequate temporary shelter.

- **Durability:** Ensuring the durability of temporary shelters is paramount to their effectiveness in providing safe and stable living conditions over the planned duration of use. The concept of durability extends beyond merely withstanding the test of time; it encompasses the shelter's ability to endure the challenges posed by a range of environmental factors (IFRC, 2013; AFAD, 2015). These factors include, but are not limited to, the load-bearing capacity of the structure and its resilience in the face of ever-changing weather conditions.

In the selection of construction materials, careful consideration must be given to the potential impact of extreme weather events, such as storms, heavy rainfall, extreme temperatures, and seismic activity. The choice of materials, their quality, and the

construction techniques employed all play a pivotal role in determining the shelter's longevity and its ability to maintain structural integrity under adverse circumstances. Specifically, the shelter's capacity to withstand wind loads, which may act from various directions, is of critical importance. Ensuring that the shelter remains steadfast even when subjected to strong winds not only guarantees the safety of its occupants but also enhances the shelter's overall utility and effectiveness in disaster-stricken areas.



**Figure 3.5.** Roof types and effects of wind loads

Source: Corsellis & Vitale, 2005

- **Non-Toxic Materiality:** When developing temporary shelters, durable materials should be selected for structural durability in long-term use, but the transportation and installation features of temporary shelters should not be dismissed as well. The lightness of temporary shelters can be achieved by using light material in the structure and cladding. A critical issue in material selection especially for cladding is that the material must be non-toxic for the users and environment. Off-gassing is an issue for material selection. For instance, FEMA trailers used after the Katrina disaster in 2005 were made of formaldehyde material; thus, they were toxic trailers with the off-gassing problem.
- **Transportability:** Ensuring the swift deployment of shelters to their intended locations is a critical consideration in disaster response efforts (Perez Valcarcel et al., 2021). To facilitate rapid transportation, these shelters must be designed to be compact and lightweight. This not only expedites the logistics of moving them but also aligns with the carrying capacity of vehicles. By adhering to the

constraints of the vehicles, multiple shelters can be efficiently transported and distributed simultaneously, optimizing the delivery of much-needed aid to disaster-stricken areas.

Carefully addressing these transportability features in the design and production of temporary shelters, can enhance their response capabilities, enabling the timely delivery of essential shelter solutions to those in urgent need during times of crisis.

- **Implementation:** The demand for temporary shelters in the aftermath of a disaster can be staggering and highly unpredictable. Disasters often strike with little warning, leaving communities in urgent need of safe and secure housing solutions. This unpredictability necessitates the development of rapid assembly strategies for these shelters, as highlighted by the International Organization for Migration (IOM, 2012).

Traditional construction methods, which are often time-consuming and labor-intensive, may not be feasible in such high-pressure situations. Hence, innovative approaches are required to provide shelter quickly and efficiently. One such approach involves the use of kinetic structural systems, which can significantly expedite the assembly process compared to conventional building techniques.

- **Reusability:** Typically intended for short-term occupancy, spanning from just a few months to several years, temporary shelters have a unique design challenge that requires them to be not only functional but also adaptable and sustainable in their construction.

One of the key principles guiding the design and material choices for these shelters, as advocated by the International Organization for Migration (IOM, 2012), is adaptability and reusability. The use of materials that can be easily reused or relocated contributes to the sustainability of these structures. Such adaptability extends the lifespan of the materials and reduces waste, making them not just a short-term solution but also a resource that can be efficiently employed in future disaster scenarios.

The notion of adaptability also pertains to the shelter's capacity to evolve with the changing needs of its occupants. As disaster-affected communities progress towards recovery and reconstruction, these shelters may serve as a temporary base that can be adapted to meet evolving requirements. This adaptability ensures that these structures remain relevant and useful for as long as they are needed.

- **Lightness and Storage:** Compactness in shelter design is essential for various reasons, especially for storage. Before deployment, shelters often need to be stored in limited space, making it imperative that they occupy as little room as possible. By designing shelters that can be safely reduced in size for storage, humanitarian organizations and governments can stockpile a larger number of units within a given space. This strategic compactness and lightness ensures that a substantial reserve of shelters is readily available and can be quickly mobilized in response to a disaster, meeting the immediate needs of affected populations.

Because the magnitude and impact of a disaster can be highly unpredictable, it is often challenging to anticipate the exact number of shelters required in its aftermath. To ensure efficient storage, shelters should be designed and constructed with compactness and lightness in mind. Large, bulky shelters are impractical for pre-disaster storage, as they demand substantial space and resources. Instead, the focus should be on developing shelters that can be efficiently packed and stored in large quantities without taking up excessive room.

Furthermore, compactness also influences the economics of transportation. Smaller and lighter shelter units can be compressed into their compact state, allowing for the simultaneous transportation of a greater number of units using fewer resources. This not only reduces transportation costs but also minimizes the environmental impact associated with moving these shelters to disaster-affected areas.

- **Feasibility and Cost:** To design feasible and cost-effective disaster relief shelters, expandability features and spatial flexibility of shelters need to be considered. The ability to configure shelter units in various ways both individually and as settlements allows for the optimization of available space and resources.
- **Expandability:** It addresses the need for shelters to adapt to changing requirements. During a disaster response, the demand for shelter units may fluctuate, and some areas may require larger accommodation than others. Shelters that can expand when needed offer a versatile solution to address these dynamic needs, ensuring that resources are allocated efficiently and that shelter solutions are tailored to the specific conditions on the ground.

- **Spatial Flexibility:** This criterion represents a cornerstone in the design of temporary shelters and settlements, offering a dynamic approach that greatly enhances their adaptability and functionality. This concept encompasses two fundamental aspects: the adaptability of individual shelter units and the versatility in configuring entire shelter settlements. At the unit level, spatial flexibility empowers designers to create shelters with multifunctional spaces. This means that the interior layout can be adapted to serve a variety of purposes within the same unit. For example, during the initial phase of disaster response, a shelter may primarily function as a sleeping area. Still, as the situation evolves, it can be reconfigured to accommodate other essential activities like cooking, bathing, or communal gathering spaces. This adaptability ensures that the shelter remains relevant and useful throughout the various stages of disaster recovery. Moreover, spatial flexibility extends to the arrangement of shelters within a settlement. Different settlement layouts can be tailored to the specific needs of the community and the terrain, ensuring that the shelter site can adapt to the unique challenges posed by each disaster scenario. This adaptability also enables efficient land use, helping to minimize the environmental impact of temporary settlements.

Aforementioned criteria have been determined based on the shelter standards and requirements. In fact, shelter design should be beyond the standards since the current and future needs of users should be considered during the sheltering period. All criteria are interrelated; thus, there is no single criterion for the level of habitability. These multiple criteria can combine to create the requirements for adequate shelter. Such characteristics can be evaluated together to investigate the habitability of a temporary shelter. Therefore, it can be claimed that habitability depends on the spatial, structural, and technical properties of temporary shelters. Shelter designs can be discussed as having a high level of habitability as they meet multiple certain criteria.

## **CHAPTER 4**

### **REVIEW OF TEMPORARY DISASTER RELIEF SHELTERS**

The structural stability and durability of temporary shelters are important in terms of withstanding external forces and resisting extreme environmental conditions. In case of more durable shelters are used through the sheltering process, the cost can decrease. Since these shelters can also be used later thanks to their structural stability and durability, such properties make these shelters much preferable. Although the use of durable materials and structures in shelter design increases the cost of units, it is a cost-effective solution in the long term. Therefore, durable shelters can be a feasible solution.

Mobility is another important feature in shelter design because shelters must have a certain level of movement to adapt to changing conditions and needs, which can be achieved using kinetic structural systems (Cerrahoğlu & Maden, 2020). The structural system and mobility are the essential sub-criteria of the examination in this paper since they provide shelter in variable locations.

#### **4.1. Classification of Kinetic Structural Systems**

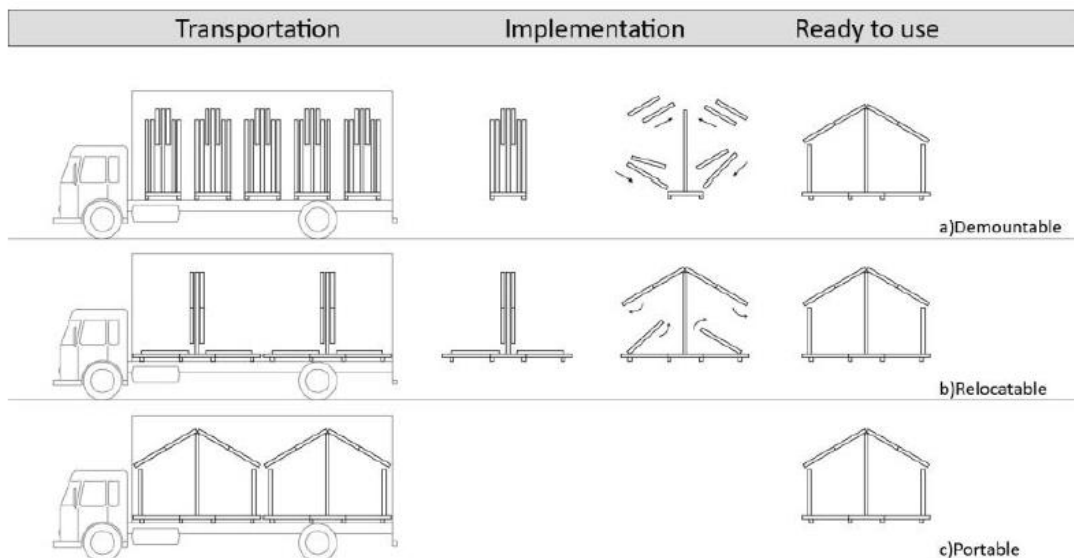
Kinetic structures can be classified under two main categories as shown in Table 2: structures with variable mobility and structures with variable geometry (Zuk & Clark, 1970; Kronenburg, 2003; Maden, 2019). The first type is divided into three main categories such as demountable, relocatable, and portable. The second type is divided into four main categories and scissors & bars structures, foldable plates structures, tensegrity structures and deformable structures. These categories are briefly explained below.

**Table 2.** Classification of kinetic structures

Kinetic Structures				
<i>Structures with variable mobility</i>	Demountable Structures	Relocatable Structures	Portable Structures	
<i>Structures with variable geometry</i>	Scissors & Bars Structures	Foldable Plate Structures	Tensegrity Structures	Deformable Structures

Source: Author

- Demountable Structures:** These structures consist of pre-fabricated elements that can be stored in parts, transported as a complete package, and quickly assembled or demounted at the site (Figure 2a). Since smaller parts are used in such structures, the assembly process can become complex for users and professional assistance can be needed.
- Relocatable Structures:** Such structures are composed of transportable modular parts that are generally dry-assembled at the site. These examples are mostly easy to assemble, but their parts can be heavier to assemble by manpower in some additional carriers can be needed to build up.
- Portable Structures:** Portable ones are transported in one piece for instant use (Figures 2b and 2c). Mostly, such structures do not need site work and are ready to use thanks to their wheels or adjustable legs below their slab.



**Figure 4.1.** Types of kinetic structures with variable mobility

Source: Author

The mobility of shelters not only provides reusability and ease of transportation but also reduces the assembly time and required labor in implementation. The shelters can easily be assembled without the need for professional assistance. Since it is easy to store, transport and assemble such movable shelters, it provides an advantage in changing the place of shelter that may be needed during the sheltering process. Moreover, it increases the transport and storage capacities of the shelters to be used in different disasters. When the shelter period is over, they can be stored and reused in other disasters as they are durable. These advantages pave the way for the shelters to be sustainable and adaptable. These properties construct the transportability features category in the evaluation table of this research.

The second type structures with variable geometry can be reviewed under four main categories.

- **Scissors and Bar Structures:** Scissor structures are composed of primary scissor units or loops (Sarısayın et al, 2022), whereas bar structures can be built using any element. Both types provide advantages regarding transformation, transportation, and storage, but their systems may become complex if they consist of numerous elements and joints. Since systems can be developed and designed for compact and deployed configurations, these can be assembled in minutes. For instance, portable shelters developed with scissors and bars structural systems can be deployed from one side by just pulling and opening the system. There are several novel classifications for scissor and bar structures but using them as the structure of temporary disaster relief shelters is not common.
- **Foldable Plate Structures:** These structures are composed of plate elements rotating relative to their adjacent plates. Mostly hinges are used to adjust panels from one to another. There are many techniques to design such structural systems, but the OPT technique comes to the fore. It suggests diverse techniques to design foldable plates considering the thickness of the panels while several hinge places are suggested as well.
- **Tensegrity Structures:** Such structures consist of bar elements and cables, which are rarely used in kinetic architecture but commonly used in tent-typed shelters.

- **Deformable Structures:** These structures also called membrane and pneumatic systems mostly used to cover large spans such as enclosing open theatres and stadiums.

The shelters that do not meet the criteria of aforementioned habitability and technical requirements have been eliminated. Thus, they have not been included in this evaluation. The temporary shelters developed considering the standards and requirements of humanitarian organizations have been selected for this research. Based on the given living space standards, technical requirements and design criteria regarding habitability standards, evaluation parameters are conducted. Then the selected shelters were evaluated in terms of the parameters presented below.

- **Structural properties:** system, mobility/movement, material, and durability
- **Spatial characteristics:** capacity, area, and spatial flexibility
- **Transportability features:** lightness, implementation, reusability, and storage

Having mobility in terms of changing location or movement in terms of formal change in the structural systems of temporary shelters is essential since it allows adapting to the evolving conditions and user needs during the sheltering process. Therefore, mobility and movement have been determined as the selection criteria for temporary shelters to be used in the evaluation. As material criteria, non-toxic materialized shelters are selected, in which the use of durable and sustainable materials for constructing shelters is taken into account for selection. Durability criteria are related to the use of durable materials as well as the resilience of the shelters in diverse cases and multiple times of reuses.

In the spatial characteristics section, the capacity of shelters as how many people it can accommodate and its provided enclosed space is compared in terms of minimum living space standards while such shelters' spatial flexibility is analyzed as the potential of serving more people in the same shelter with expansions or using more of the same modular shelter.

The transportability features are directly related to the transportation capacity of temporary shelters. The transportation capacity can be compared and analyzed regarding the lightness and storage capacity of the shelters, which is related to compactness; lightweight and more compact shelters can be stored much more easily and numbered than heavier materials and bulky designs. If in the same storage area

larger number of shelters can be stored, more shelters can be transported at once therefore transportation time will be decreased. The systems of the shelters can make shelters quickly assembled and implementation time could be just minutes, especially in portable ones. As the number of shelter parts increases, the implementation time will be increased. While portable shelters mostly do not need site or additional implementation due to being ready to use, relocatable shelters need to be assembled which consist of larger parts.

Demountable shelters have smaller parts which may cause the need for professional assistance in the implementation of the shelter. In that case, implementation time increases, and the use of thousands of shelters in a very short assembly time of emergency cases can be impossible due to the needed workforce. These sections may be indirectly related to the habitability category due to the reusability feature while they are interrelated directly with the mobility of structural properties.

The existing literature on the topic has been reviewed, and shelter examples having variable mobility and variable geometry have been chosen, which are proposed by researchers, designers, humanitarian organizations, and engineering companies. Those examples have been analyzed and compared regarding their structural properties, spatial characteristics, and transportability features.









#### **4.2. Evaluation of Kinetic Structural Systems Having Variable Mobility**

Several types of temporary shelters exist as tents, containers, modular units, and trailers which vary in comfort levels for users. In this research, 17 different temporary shelters have been selected regarding their mobility degrees: demountable shelters, relocatable shelters, and portable shelters. There are 8 demountable, 5 relocatable and 5 portable shelters are selected and evaluated. Demountable ones are *AbleNook*, *Liina Transitional Shelter*, *Rapid Deployment Module*, *Tentative*, *Shelter Pack*, *Hex House*, *Shelter 3800*, and *Pallet Shelter* (Table 3). Relocatable ones are selected as *Global Village Shelter*, *the Shelter Proposal*, *Life Shelter*, *Disaster and Emergency Living Facility*, and *Hush Shelter* (Table 4). Lastly, portable ones are *Cardborigami*, *Exo Shelter*, *the Portable Shelter Proposal* and *the Portable Post-Disaster Home* (Table 5).

#### 4.2.1. Evaluation of Selected Demountable Temporary Shelters

Demountable shelters have widely been used in the existing disaster settlements. There are eight demountable shelters among the selected examples (Table 3). It is obvious that the designers consciously made the shelters demountable because shelter parts can be damaged less, and the damaged parts can easily be repaired. Besides these advantages, demountable temporary shelters can be modular and spatially flexible. *AbleNook*, *Hex House*, *Liina Transitional Shelter*, and *Rapid Deployment Module* examples are demountable and modular, which can be expanded by combining the modules so that they have spatial flexibility. However, even if *Tentative*, *Shelter Pack*, *Shelter 3800*, and *Pallet Shelter* examples are demountable, they are not modular shelters and are not spatially flexible.

**Table 3.** Evaluation of selected demountable temporary shelters

PROJECTS		STRUCTURAL PROPERTIES				SPATIAL CHARACTERISTICS			TRANSPORTABILITY FEATURES				TECHNICAL REQUIREMENTS				
NAME	EXTERNAL VIEW	SYSTEM	TYPE	MATERIAL	DURABILITY	CAPACITY	AREA	SPATIAL FLEXIBILITY	LIGHTNESS	IMPLEMENTATION	REUSABILITY	SIZE AT COMPACT STATE	FIRE RESISTANCE	WATER RESISTANCE	THERMAL COMFORT	DAYLIGHTING	VENTILATION
AbleNook 2011		Aircraft-grade aluminum structural framing, SIPs	DEMOUNTABLE	Aircraft-grade aluminum, SIPs	> 1 YEAR	2 people	21 sqm	YES: Modular units can be combined	Lightweight	2 hours by 2 people	YES	As kit of parts or modules No size specified	YES	YES	YES	YES	YES: Windows are used
Liina Transitional Shelter 2011		Wooden frames w/ prefabricated sandwich panels	DEMOUNTABLE	Finish wood/wood-based materials, prefabricated sandwich panels, phenolic/SLX, w/wood-fibre insulation	> 1 YEAR	5 people	18 sqm	YES: Modular and can be combined	Lightweight	6 hours by 2 people	YES	One unit as kits of parts	YES	YES	YES	YES	YES: Windows are used
Rapid Deployment Module 2013		A series of universally sized interlocking SIPs	DEMOUNTABLE	Vented fabric canopy roof, structural whiteboards	> 1 YEAR	2 people	12 sqm	YES: Modular and can be combined	Heavy	< 1 hour by 2 people	YES	One unit as kits of parts	-	-	YES	YES	YES: Passive cooling & heating
Tentative		Pieces of structure come together in the area	DEMOUNTABLE	Fiberglass panels	> 1 year	8 sqm	disaster shelter	NO	Lightweight	Not found	YES	One unit as kits of parts compact size = 30 cm	YES	YES	YES	YES	YES
Shelter Pack		Pieces of structure come together in the area	DEMOUNTABLE	plastic frame	> 6 months	12 sqm	disaster shelter	NO	Lightweight	3 hours by 2 people	YES	One unit as kits of parts compact	YES	YES	YES	YES	YES
Hex House 2017		SIPs form a rigid structural shell	DEMOUNTABLE	SIPs, glue-laminated beams	> 1 YEAR	2 people	47 sqm	YES: Units can be combined	Lightweight	5-8 days by 5 people	YES	Kit of parts flat pack	YES	YES	YES	YES	YES: Passive cooling
Shelter 3800 2017		Compact and lightweight steel panels and frame	DEMOUNTABLE	Steel-wood	> 1 YEAR	16 people only sleeping	23 sqm	NO	Heavy	8 hours by 6 people	YES	<20 kg Components 1 unit package 500 kg	YES	YES	YES	YES	NO
Pallet Shelter 2012		SIPs	DEMOUNTABLE	SIPs	> 1 YEAR	2 people	9 sqm	NO	Heavy	4 hours by 3 people	YES	One unit as kits of parts	YES	YES	YES	YES	YES: Windows are used

Source: Author

The built examples of demountable shelters are made of structural insulated panels, fiberglass shells, steel, wooden or plastic structural frames. These are rigid and reinforced materials in universal standards, which make shelters easier to disassemble into smaller but durable parts. However, dismantling a shelter into pieces to store more shelter in less space brings disadvantages. One of the disadvantages is that they cannot assemble rapidly. The diversity and amount of shelter parts can slow down their implementation time and require more labor work. Reusing the shelters constantly as assembling and disassembling may damage the material, structure, and joints. For this reason, shelters need maintenance and repair, which increases the total cost.

Demountable shelters occupy less space for storage as they can be dismantled into smaller parts and transported by packing those small parts. However, small structural elements increase the implementation time, labor requirement, and complexity of the structure. In addition, reusing such shelters may cause deformation or damage in structural components and joints; thus, requiring renewal and repair.

In Turkey, prefabricated houses such as containers have been widely used after disasters (Figure 4.2). Such shelters are heavy and contain large spaces. Therefore, it takes much time to arrive at shelter sites. Also, such shelters need fieldwork and infrastructure work. Because such disadvantages of the conventional type of demountable shelters (e.g., tents, container-type shelters, and prefabricated structures) outweigh their advantages, they have not been included in this evaluation.



**Figure 4.2.** Temporary shelters that commonly used in Turkey after disasters

a) Mevlana Houses b) Containers used after Van 2011 Earthquake

Source: Kızılay, 2024

Made of non-toxic materials, most of the selected shelters are composed of reusable materials like steel, wood, and glass. The selected demountable shelters have been prefabricated and transported as a kit of parts. Thus, the implementation time is longer than the relocatable and portable shelters.

*AbleNook* and *Shelter Pack* can be implemented in 2 hours by two people. The implementation time of the *Tentative* shelter is not specified, but it may take 2 or 3 hours for two people since it is similar to the mentioned two shelters. *Pallet Shelter* can be implemented in 4 hours by three people while *Liina Transitional Shelter* needs 6 hours of work by two people and *Shelter 3800* needs 8 hours of work by six people.



**Figure 4.3.** Disassembled and assembled configurations of *Tentative Shelter*

Source: Designnobilis, 2015



**Figure 4.4.** Disassembled and assembled configurations of *Shelter Pack*

Source: Designnobilis, 2015

On the other hand, the implementation of the *Rapid Deployment Module* takes less than one hour by two people which makes it the easiest and fastest example among the demountable shelters. *Shelter 3800*'s implementation needs more workforce because its components are heavier than other examples even if they are lighter than 20kg. Because the entire unit package is 500kg, this shelter has the highest transportation cost and the most labor requirement. In contrast, components of *Hex House* are light enough to be able to be carried by one or two people. However, *Hex House* can be installed in 5-8 days by five people because it has numerous components and needs

fieldwork for the infrastructure and foundation. *Shelter 3800* has an adjustable foundation that allows use on sloping and rugged terrain.



**Figure 4.5.** *Shelter 3800*

Source: Ice-Age, 2017

Considering the habitability criteria, it can be said that the aforementioned demountable temporary shelters have privacy except for the *Liina Transitional Shelter* and *Pallet Shelter* because these examples have large windows. If possible, the shelter windows should be higher than eye level and not too wide to provide privacy against being seen from outside who pass in front of the shelter.



**Figure 4.6.** Shelter's exterior views a) *Liina Transitional Shelter*, b) *Pallet Shelter*

Source: a) Aalto University Wood program, 2011; b) Pallet Shelter, 2022

All demountable examples except *Shelter 3800* have variable service integrations. *AbleNook*, *Tentative*, *Shelter Pack*, *Hex House*, and *Liina Transitional Shelter* have a

kitchen. *AbleNook*, *Hex House*, *Pallet Shelter*, and *Rapid Deployment Module* have electricity integration which works by solar panels, and heating and cooling systems are embedded into these shelters. *Hex House* also has passive cooling, rainwater harvesting, electricity generation with solar panels, and a biogas production system from user waste with composting.

The standard living area per individual and thermal comfort are provided in *AbleNook*, *Shelter Pack*, *Hex House*, *Liina Transitional Shelter*, *Pallet Shelter*, and *Rapid Deployment Module*. Some shelters have living areas beyond the standard. For instance, *AbleNook* has a 21m<sup>2</sup> living space for two people while *Hex House* has 47m<sup>2</sup> for two people. The living area for two people is 9m<sup>2</sup> in *Pallet Shelter* and 12m<sup>2</sup> in *Rapid Deployment Module*. *Liina Transitional Shelter* has an 18m<sup>2</sup> living space for five people which is at the limit of standards with this capacity. If fewer people use this shelter, it would be more habitable for the users and beyond the living area per individual standard which is 3.5m<sup>2</sup>. All the selected built demountable temporary shelters accomplish the technical requirements determined by humanitarian organizations which are fire and water resistance, daylight and natural ventilation. However, *Shelter 3800* does not provide natural ventilation.

Since these shelters are disassembled into smaller pieces, more than one can be transported at the same time (Figure 4.7). Shelter parts have an important role in terms of high portability, each part must be designed according to transportation options. Trucks and trailers are generally used.








**Figure 4.7.** Compact configurations of shelters a) *Pallet Shelter* b) *Tentative Shelter* c) *Pallet Shelter* d) *Rapid Deployment Module*

Source: a) *Pallet Shelter*, 2022, b-c) *Designnobis*, 2015, d) *Rapid Deployment Module*, 2013

#### 4.2.2. Evaluation of Selected Relocatable Temporary Shelters

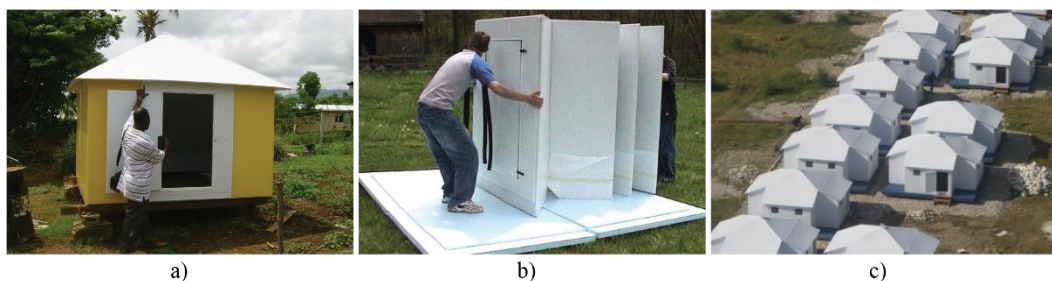
The relocatable built examples are the *Global Village Shelter*, *Life Shelter*, the *Shelter Proposal*, *Hush Shelter*, and the *Disaster and Emergency Living Facility* (Table 4). The structure of the *Global Village Shelter* is made of triple wall fiber-cardboard corrugated while the *Life Shelter* has panels with steel reinforcement as a structural system. They are not spatially flexible but durable for more than six months thanks to their durable materials, structures, and proper insulations. Requiring 16 hours of fieldwork, *Life Shelter* can be relocated and reused as one piece in different disasters.

**Table 4.** Evaluation of relocatable temporary disaster relief shelters

PROJECTS	STRUCTURAL PROPERTIES					SPATIAL CHARACTERISTICS				TRANSPORTABILITY FEATURES			TECHNICAL REQUIREMENTS				
	NAME	EXTERNAL VIEW	SYSTEM	TYPE	MATERIAL	DURABILITY	CAPACITY	AREA	SPATIAL FLEXIBILITY	LIGHTNESS	IMPLEMENTATION	REUSABILITY	SIZE AT COMPACT STATE	FIRE RESISTANCE	WATER RESISTANCE	THERMAL COMFORT	DAYLIGHTING
Global Village Shelter 2002		Triple-wall fiber-board composite	RELOCATABLE	Triple-wall fiber-board composite	> 6 MONTHS	2 people	7 sqm	NO	Lightweight	< 1 hour by 2 people	YES	One unit as kits of parts	YES	YES	NO	YES	NO
Bayeth - Shelter Proposal 2010		Container structure w/ steel expansion solution	RELOCATABLE	Steel, PVC panels, textile	Materials are durable but cannot be assured time	2 people	10qm	YES: Units can be combined	Heavy	< 1 hour by 1 person	YES	One unit package = 280x233x240cm	YES	YES	YES	YES	YES: Windows are used
Life Shelter 2006		Panel reinforced w/ steel	RELOCATABLE	Waterproof cement cladding, roof, stone wool insulation boards reinforced with steel	> 2 year	5 people	18 sqm	NO	Lightweight (panels)	16 hours by 2 people	YES	One unit as kits of parts but as whole unit when reused - 36shelters	YES	YES	NO	NO	NO
AFAD - Disaster and Emergency Living Facility 2005		Modular system with insulated plates and tensioning belt	RELOCATABLE	Polyurethane plastic on walls and roof, fiberglass and polyester in pallet floor w/ adjustable legs and covering plates	> 1 year	1 person	3.5qm	YES: Modules can be combined	Lightweight	20 mins by 3 people	YES	As one module package Non-specified size 12 modules can be carried at once	-	YES	YES	YES	YES: Windows are used
Hush Shelter 2008		Wooden framed walls are produced as foldable	PORTABLE	Wooden plates insulated walls	> 1 YEAR	-	~9sqm	YES: Units can be combined to each other from different sides of shelter	Lightweight	< 1 hour by one person	YES	One compact unit	YES	YES	YES	YES	YES

Source: Author

In contrast, *Global Village Shelter* is composed of two pieces: a folded wall and a folded roof made of triple wall fire-cardboard plates. Assembled in less than an hour by two people, *Global Village Shelter* is lighter than *Life Shelter* and can be relocated as one unit. These shelters are feasible because of cost, reusability, and ease of transportation and storage.

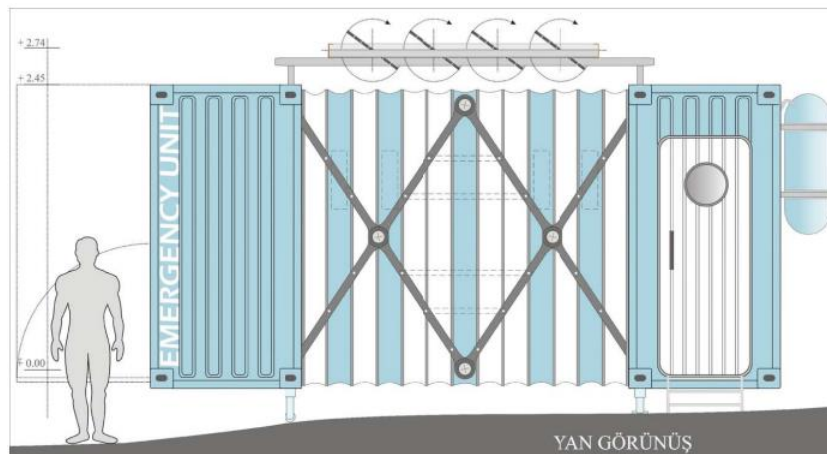


**Figure 4.8.** *Global Village Shelter* a) Colored shelter option b) Deployment of the shelter c) Rapid deployment and numerous use of the shelter

Source: Ferrara Design, 2002

The standard living area per individual and the privacy of users are provided in both examples. *Global Village Shelter* and *Life Shelter* are not spatially flexible and do not provide service integrations. However, these deficiencies can be solved by well-designed and managed shelter settlements where sanitary zones and service integrations are placed by following the habitability criteria and shelter settlement guidelines. The mentioned two shelters are fire-resistant and water-resistant, but they do not have thermal comfort or natural ventilation. *Global Village Shelter* has daylight access to interior space, but the *Life Shelter* does not have it.

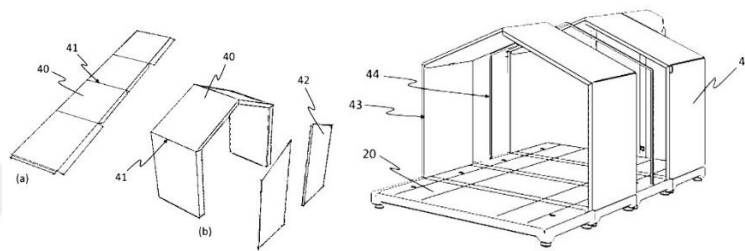
The *Shelter Proposal* developed by Beyatlı (2010) is a relocatable container structure designed which reuses waste materials as components and use new materials only for the scissor-like elements. Unlike conventional container-type disaster shelters, it occupies less space in its compact configuration than a container since it is expandable. The shelter is composed of scissor-like elements and panels, and it can be stored in parts and assembled at the site. Therefore, it is easier to transport and store the shelter than the other conventional container-type shelters. In this shelter, PVC panels and accordion textile material are used for walls and roofs, and steel is used for structural elements and adjustable legs. Using the waste container structure makes it cost-effective and provides material savings. Having a 10m<sup>2</sup> living area for two people, the *Shelter Proposal* is spatially flexible since it allows combining two units from the sides of the shelter.



**Figure 4.9.** The elevation of the *Shelter Proposal* shows the applied scissor mechanism.

Source: Beyatlı, 2010.

The *Disaster and Emergency Living Facility* has a modular system consisting of polyurethane plates used for walls and roof, fiberglass and polyester for the slab, and it has a tension belt to increase structural durability. Its adjustable legs allow the shelter to keep flat and to be used even on sloping terrain. The wheels under its adjustable legs make it easier to move for implementation, which can be locked via latches on its wheels to keep the shelter in place. One of the modules of the shelter is 3.5m<sup>2</sup>, which equals the minimum area for the living space standard per person. However, it can be expanded by module additions because its slab is designed like a pallet.



**Figure 4.10.** Assembly of the Disaster and Emergency Living Facility.

Source: AFAD, 2015.





*Hush Shelter* is the most advantageous portable shelter among these examples since it has foldable wooden framed walls that can be combined for additional needs. It is durable for more than one year, low-cost and able to be transported as one pack of units. The disadvantage of *Hush Shelter* is that it does not have service integration like a kitchenette. *Hush Shelter* has folded walls made of wooden plates. The standard living area per individual is provided in *Hush Shelter* while it is developed as water-resistant and fire-resistant, and provides thermal comfort, adequate daylighting, and natural ventilation.

Both of the examined relocatable shelters are durable enough to be used for more than one year and meet the technical requirements of fire and water resistance, thermal comfort, daylighting, and natural ventilation. They can be implemented rapidly. The *Shelter Proposal* can be implemented in less than one hour by one person, whereas the *Disaster and Emergency Living Facility* can be assembled in 20 minutes by three people. Multiple shelters can be transported on trucks. Considering their sizes, it can be said that they may provide habitable living environments for users for long-term use.

### 4.2.3. Evaluation of Selected Portable Temporary Shelters

The portable built shelters are *Cardborigami*, *Exo Shelter*, *Portable Shelter Proposal*, and the *Portable Post-Disaster Home* (Table 5). All these examples can be transported easily as a whole structure. *Cardborigami* is made of folded coated cardboard durable only for two or three weeks and does not have spatial flexibility. *Exo Shelter* has a honeycomb composite shell as a structure which is durable for more than one year, but it is not spatially flexible.

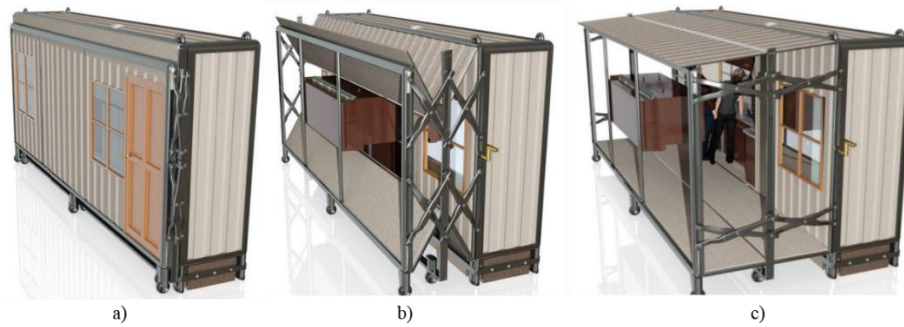
**Table 5.** Evaluation of portable temporary shelters

PROJECTS	EXTERNAL VIEW	STRUCTURAL PROPERTIES				SPATIAL CHARACTERISTICS			TRANSPORTABILITY FEATURES				TECHNICAL REQUIREMENTS				
		SYSTEM	TYPE	MATERIAL	DURABILITY	CAPACITY	AREA	SPATIAL FLEXIBILITY	LIGHTNESS	IMPLEMENTATION	REUSABILITY	SIZE AT COMPACT STATE	FIRE RESISTANCE	WATER RESISTANCE	THERMAL COMFORT	DAYLIGHTING	VENTILATION
<i>Cardborigami</i> 2010		Folded - coated cardboard	PORTABLE	Folded - coated cardboard	2-3 WEEKS	1 person	2 sqm	NO	Lightweight	< 1 hour by 2 people	YES	One folded unit	YES	YES	NO	NO	NO
<i>Exo Shelter</i> 2014		Honeycomb composite rigid shell	PORTABLE	Honeycomb composite	> 1 YEAR	4 people	9 sqm	NO	Lightweight	< 1 hour by 4 people	YES	One unit or as 3 parts	YES	YES	NO	NO: Artificial lighting	NO: Air conditioning
<i>Uçar - Portable Shelter Proposal</i> 2015		Container structure w/ steel expansion solution	PORTABLE	Steel, PVC panels	Materials are durable but cannot be reused @ time	4 people	18sqm	YES: Expands by changing dimensions of scissors & panels	Heavy	2 mins by 2 people	YES	One unit package = 120x60x270cm	YES	YES	YES	YES	YES: Windows are used
<i>Dialamath - Portable Post-Disaster Home Proposal</i> 2017		Steel frame, wooden beams, plywood panels	PORTABLE	Steel, wood, plywood	Materials are durable but cannot be reused @ time	4 people	20sqm	YES: Expandable units	Heavy	2 mins by 1-2 people	YES	One unit package = 215x350x380cm	NO	YES	YES	YES	YES: Windows are used

Source: Author

The mentioned portable shelters are lightweight and can be transported, reused, and installed easily by the users. *Cardborigami* is deployable, easy to store occupy less space in their folded stages, and is designed to be used for several days by homeless people. The designers of *Exo Shelter* solved the storage problem by the form of a shelter. *Exo Shelter* has portable power generation, artificial lighting, and air conditioning which are not seen in any other built examples of this research. However, *Exo Shelter* is heavier and more expensive than other portable shelters. Because *Cardborigami* has 2m<sup>2</sup> per person, and *Exo Shelter* provides 9m<sup>2</sup> of living space for four people, they are not convenient for long-term use. Thermal comfort, daylighting, and natural ventilation are not provided in *Exo Shelter* and *Cardborigami* although they are fire-resistant and water-resistant. All the examined built portable examples can be assembled in less than one hour and can be carried by only one person or two people.

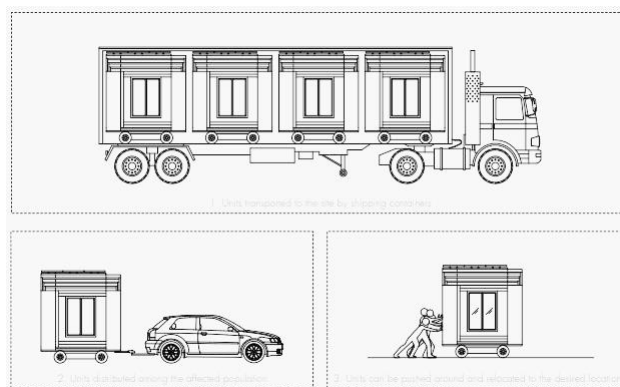
The *Portable Shelter Proposal* developed by Uçar (2015) is a container-type structure composed of scissor-like elements and PVC panels as in the relocatable shelter designed by Beyatlı. This shelter has more expansion capability, and it can be transported in one piece in its compact state. It occupies less space for storage.



**Figure 4.11.** Deployment of the *Portable Shelter Proposal* a) compact configuration, b) deployment state, c) full deployed configuration

Source: Uçar, 2015

In the *Portable Post-Disaster Home*, steel and wooden frames are used for the structural components, and plywood panels are used for the walls. Wooden beams are preferred on the slab and walls to reduce the shelter cost, whereas steel frames are used for the shelter skeleton. Both selected portable shelters are durable enough to be used for more than one year. The *Portable Shelter Proposal* meets all technical requirements, while the *Portable Post-Disaster Home* meets the requirements except fire resistance. When the living areas are compared, it is seen that the *Portable Shelter Proposal* provides 18m<sup>2</sup> for four people while the *Portable Post-Disaster Home* has 20m<sup>2</sup>. Although these portable shelters are heavy, their implementation takes 2 minutes by one or two people since they can be expanded by just pulling one side of the shelter to make it ready for use.



**Figure 4.12.** Transportation options for the *Portable Post-Disaster Home*: a) transportation by truck, b) distribution by car, c) relocation by human power

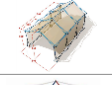
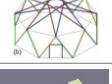






Source: Dialameh, 2017

### 4.3. Evaluation of Kinetic Structural Systems Having Variable Geometry

Three shelters having scissor and bar structural systems (*Gable Roof Proposal*, *Deployable Yurt Proposal*, and *Deployable Scissor Arch Proposal*), one shelter consisting of scissor and foldable plate structures' combination (*TenFold Engineering TF64*), three shelters composed of foldable plates structures (*Transformable Shelter Proposal*, *Hush Shelter-2*, and *the Disaster Shelter*), and one temporary shelter constructed by deformable structure (*Weaving a Home Shelter*) have been selected and evaluated .

After examining the shelter examples having variable mobility, the temporary shelters having the capability of changing their geometries have been analyzed (Table 6). The search for adaptive structural solutions to store, assemble, and transport shelters has led designers to develop temporary shelters that can transform their shapes from compact shapes to expanded forms. Features such as lightness, flexibility, rapid erection and dismantling, reusability, ease of storage, and transportability can be accomplished using kinetic systems in shelter design.

**Table 6.** Evaluation of temporary disaster relief shelters has scissor & bar structures, foldable plate structures and their combinations.

PROJECTS		STRUCTURAL PROPERTIES				SPATIAL CHARACTERISTICS			TRANSPORTABILITY FEATURES			
NAME	EXTERNAL VIEW	SYSTEM	TYPE	MATERIAL	DURABILITY	CAPACITY	AREA	SPATIAL FLEXIBILITY	LIGHTNESS	IMPLEMENTATION	REUSABILITY	SIZE AT COMPACT STATE
Valcárcel et al. Gable Roof Proposal 2021		Deployable cylindrical vaults with reciprocal scissor linkages	SCISSOR	Aluminum tubes, fabric	-	-	73qm	YES: Units can be combined and deploy together	Lightweight	Easy to assemble, no time specified	YES	As kit of parts or modules No size specified
Valcárcel et al. Deployable Yurt Proposal 2021		Reciprocal structures w/ triangular frames	BAR	Aluminum tubes, sloping pillars	-	-	76qm	YES: Modules can be combined	Lightweight	Easy to assemble, no time specified	YES	As one compact module No size specified 24-30 modules can be carried at once
Asefi & Sirus Transformable Shelter Proposal 2012		Steel frame w/ sliding mechanism	PLATE	Steel frames & curved plates	-	-	50qm	YES: Modular and can be combined	Lightweight	< 1 hour by 2 people	YES	Compact modular units No size specified
Mira et al. Deployable Scissor Arch Proposal 2014		Scissor arch	SCISSOR	Aluminum, membrane	-	4 people	14qm	YES: Units can be expanded & transformed	Lightweight	2 hours by 3 people	YES	Fully folded unit No size specified
Seikaly - Weaving a Home Shelter 2015		Deformable self-deploying system	DEFORMABLE	Fabric & plastic members	-	3 people	20 sqm	YES: Units can be combined	Lightweight	Easy to assemble, no time specified	YES	Fully folded unit No size specified
TMMOB Disaster Shelter 2012		Foldable plates & panels w/ hinges	FOLDABLE PLATE	MDF plates, panels & L-shaped water-protective components w/ white lacquer coating	> 1 year	2 people	~9qm	YES: Panels can be removed & another unit can be combined w/ hinges	Lightweight & has wheels to carry	< 1 hour by one person	YES	As one compact module = 30x30x260cm 45 modules can be carried at once
TenFold Engineering TF64 2017		Modular, self-deploying system	SCISSOR & FOLDABLE PLATE	Steel, insulated panels	> 1 year	6 people	68qm	YES: Units can be combined, expandable units	Heavy	In minutes by one person	YES	10.4sqm compact unit
Extremis Technology Hush Shelter-2 2014		Foldable plates w/ hinges	FOLDABLE PLATE	Wooden insulated walls	> 1 year	-	19qm	YES: Units can be combined	Heavy	2 hours by one person	YES	Compact folded unit No size specified

Source: Author

For the evaluation, six deployable temporary shelters have been selected, which are the *Weaving Home Shelter* by Seikaly (2015), the *Transformable Shelter* by Asefi & Sirius (2012), the *Gable Roof*, and the *Deployable Yurt* by Pérez-Valcárcel et al (2021), the *Deployable Scissor Arch* by Mira et al (2014), the *TF-64* by TenFold Engineering (2017). Also, foldable examples such as the *Hush Shelter-2* by Extremis Technology (2014) and the *Disaster Shelter* by TMMOB Ankara (Union of Chambers of Turkish Engineers and Architects, Ankara Branch; 2012) have been examined.

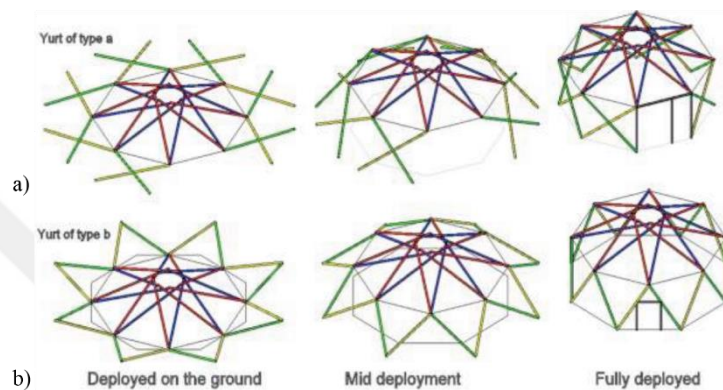
The *Weaving Home Shelter* has a deformable structure and is composed of structural fabric with plastic members. Being capable of folding itself across a central axis, the shelter has operable windows that can control air circulation. There is a space for the water collector that supplies electrical energy for the waving action of the shelter. The shelter has a 20m<sup>2</sup> living space for three people, but it can be expanded by combining units. It is lightweight due to its materiality, easy to assemble, and can be stored as folded. Also, this shelter meets all technical requirements.

The *Transformable Shelter* has scissor and foldable plate structures composed of steel-framed modules with a sliding mechanism. The shelter is easy to assemble, store, and transport due to its lightweight structural system. It can be assembled by two people in less than an hour. Having a sliding mechanism, the shelter provides variable geometries changing the configurations only along the horizontal direction. The shelter can cover 50m<sup>2</sup> by expanding, which allows it to be used for various functions.

The *Gable Roof* is composed of reciprocal scissor linkages, whereas the *Deployable Yurt* has reciprocal bar structures. The *Deployable Scissor Arch* is comprised of polar scissor units, and the shelter is covered by a fabric membrane. These three examples demonstrate the structural investigations and possible applications of scissor linkages and bar structures in shelter design proposals. The designers of these structures explored the structural limits of the proposed mechanisms and conducted several analyses for durability. Because such structures are durable and provide ease of storage, transportation, and implementation, they are promising for further applications even if technical requirements have not been accomplished yet.

Since these shelters can cover large spaces, they are adequate even for larger families, although the designers did not mention the number of occupants. The *Gable Roof* covers 73m<sup>2</sup>, which can be expanded on both horizontal sides of the shelter.

Likewise, the *Deployable Yurt* encloses 76m<sup>2</sup> thanks to its reciprocal scissor structures (Figure 4.13). Compared to these shelters, the *Deployable Scissor Arch* is smaller since it covers only 14m<sup>2</sup> and serves four people. However, larger spaces can be covered with module combinations. These three structures provide various geometric configurations and can be used as temporary shelters in the long term. Even though these examples are composed of scissor mechanisms or bar structures, they do not require professional assistance to assemble the structures. The *Deployable Scissor Arch* can be assembled in 2 hours by three people.



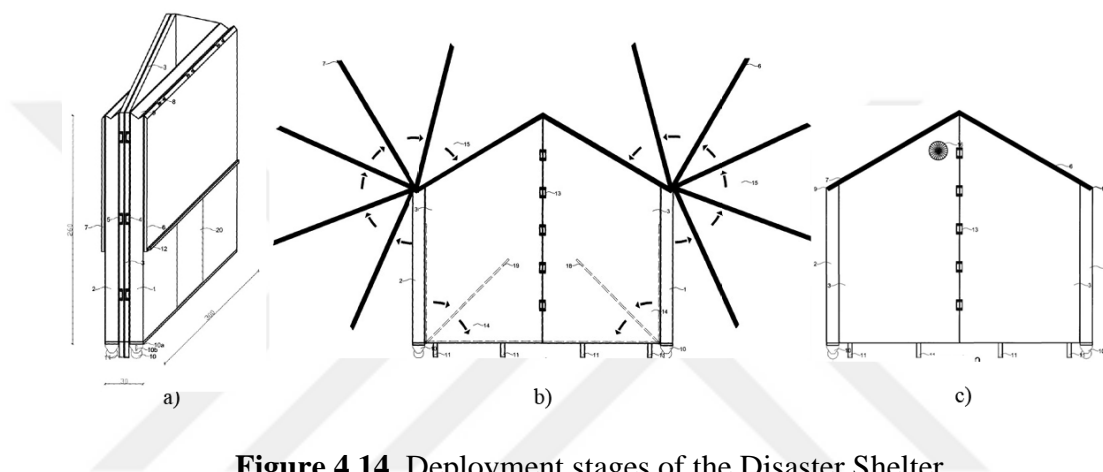
**Figure 4.13.** Deployment stages of the Deployable Yurt

Source: Pérez-Valcárcel, 2021

The *TF-64* is another deployable example composed of a steel structure and insulated foldable plates that are used for walls, roofs, and slabs. Its height can be changed thanks to its adjustable steel legs. The *TF-64* needs electrical power for deployment, which is provided by solar panels and batteries attached to the system. The deployment of the whole structure takes minutes. Covering an area of 68m<sup>2</sup>, this shelter provides living space for six people. It covers 10.4 m<sup>2</sup> in its compact state. Thanks to its expandable feature, the units can be combined for space additions to meet the spatial needs of shelter users.

The *Hush Shelter-2* and the *Disaster Shelter* have foldable wooden plates that are connected by rotating hinges. The *Hush Shelter-2* may require fieldwork and cannot be fully folded. It can be unfolded in 2 hours by one person if the foundation is ready for the shelter. Otherwise, it may take more than 2 hours. On the other hand, the *Disaster Shelter* does not require fieldwork thanks to its adjustable legs, which allow

the shelter to be used even on sloping terrain. Although the shelter is heavy, the adjustable legs make the shelter easy to move and relocate. Since the shelter has wheels, they can be locked when placed. The slab and roof of the *Disaster Shelter* are also foldable, which makes the shelter more compact (Figure 4.14). The shelter has L-shaped elements placed above the roof and wall intersection to prevent water leaks. Both examined foldable shelters are durable and easy to store and transport because they can remain in their compact foldable states while transporting. These shelters are spatially flexible, but they can be extended only if new units are added by removing the side panels from the shelter.



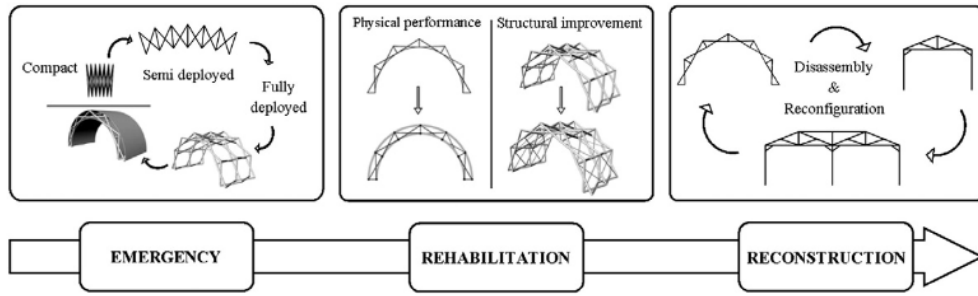
**Figure 4.14.** Deployment stages of the Disaster Shelter

Source: TMMOB Ankara, 2012

#### 4.4. Discussion

In the shelter duration, users face challenging and changing conditions. Therefore, designers should develop adaptive design solutions to meet user needs. The function of shelters, user types, weather conditions, and such parameters may change. There appears to be a need for several types of shelters during that time if shelters are not adaptive enough. Some of the selected temporary shelter designs consider this adaptiveness need.

The structure of the *Deployable Scissor Arch* is designed to be transformed and used in stages of sheltering by spatial transformation (Figure 4.15). On the other hand, *AbleNook* is designed as modular units to be used in diverse sheltering stages and functions (Figure 4.16). In this shelter design, open spaces are designed as well with potential use with stairs.



**Figure 4.15.** Using the same structural elements in diverse phases of relief and technical solutions for transitional sheltering

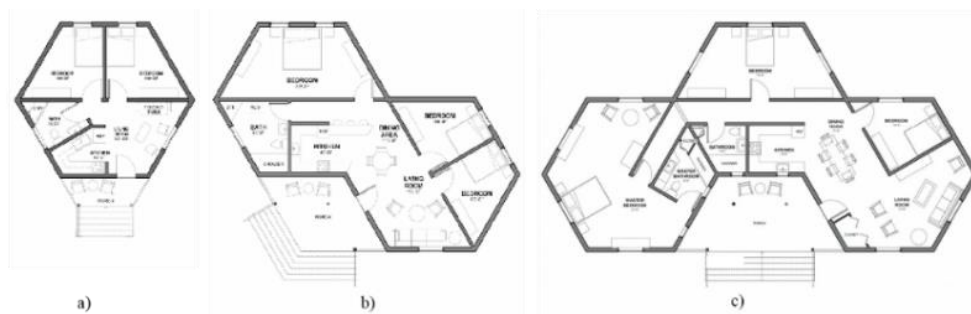
Source: Mira et al, 2014



**Figure 4.16.** Using the same module in diverse phases of relief for transitional sheltering

Source: AbleNook, 2011

Furthermore, the addition of building elements is required to transition from transitional sheltering to permanent housing. The *Hex House* is designed to combine such structural elements to give strength to the combined spaces (Figure 4.17).



**Figure 4.17.** Shelter unit combination from transitional sheltering to permanent housing

Source: Hex House, 2017

## **CHAPTER 5**

### **CASE STUDY DESIGN PROPOSAL**

In this chapter, a detailed case study is presented, covering the design process from initial ideas to the final concept. Its mechanism, folding stages, and module combination alternatives with corresponding plan layouts are presented.


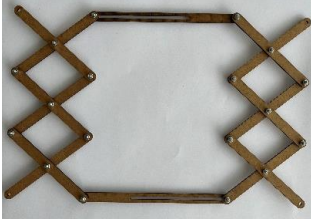

#### **5.1. Design Process**

In the design process, several scissor mechanisms have been examined and modeled both physically and digitally by using Solidworks® to assess their potential in temporary shelter designs. Adaptive and transformable structures offer significant advantages in terms of ease of transport, storage, and implementation. The combination of scissor mechanism and foldable plates is not commonly found in existing literature and fields. To fill this gap and explore the potential of novel structural solutions, temporary shelter modules that integrate scissor mechanisms with foldable plates are developed.

By researching and following the latest designs and examinations, several mechanisms comprising one or two types of bars have been developed using simple scissor mechanisms. While some of these multiple primary derivations show potential, most were not suitable for constructing shelter units. However, some prove applicable, particularly in the structure of slabs and roofs. These derivations function in conjunction with foldable plates equipped with continuous hinges along their edges. To facilitate the design of a robust shelter unit, specialized scissor mechanisms have been developed. The degrees of mobility and folding capabilities of the studied models reveal that certain units offer enhanced flexibility in movement, whereas others exhibit restricted configurations due to their complexity.



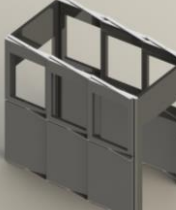
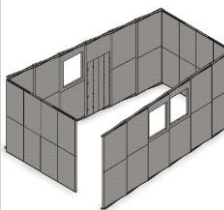
Deployable modules can be created using a combination of scissor mechanisms and foldable plates. At first, a simple scissor mechanism with a pin and a slot, referred to as Unit A, has been designed and positioned as the frame of the shelter layout. In Unit A, a scissor mechanism features two slots equipped with sliders (Figure 5.1). This

mechanism has been placed at both the bottom and top of the shelter to ensure stability and functionality.

UNIT NAME	PHYSICAL MODEL		
	COMPACT CONFIGURATION	SEMI-DEPLOYED	DEPLOYED CONFIGURATION
UNIT A SCISSOR MECHANISM			

**Figure 5.1.** Physical model of Unit A






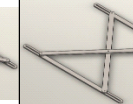
The plates have been strategically positioned to fold inwards, mimicking the compact movement of scissors. Additionally, the scissors have been positioned outwardly to avoid hindering the deployment or closure of Unit A. This unit can be folded from the long side of the shelter to the short sides, achieving a fully compact state. Although the potential use of this design has been investigated and presented with layouts as temporary shelters (Figure 5.5), it has not been developed further due to the disadvantages associated with its compactness.

UNIT NAME	PHYSICAL MODEL	SOLIDWORKS MODEL		
UNIT A				

**Figure 5.2.** Unit A and its 4-modules combination


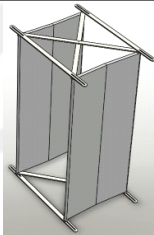
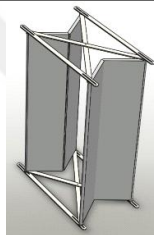
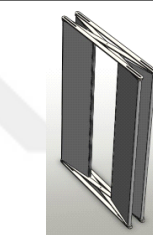
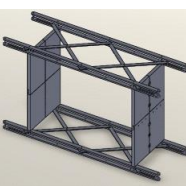
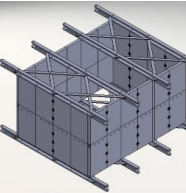
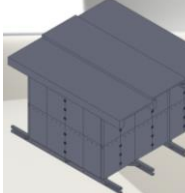

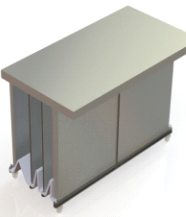

The design process continued with the creation of a single module called Unit 1x1. This initial module consists of 6 scissors and 2 bars with sliders (Figure 5.3). The unit features plates that pivot and rotate along designated slots, enhancing its compactness. Both ends of the slots are equipped with sliders, and the plates are divided into two parts with central mounting to optimize space. One of the upper plates has been customized to serve as a window, while two plates have been adapted to function as a door for the shelter unit. Covering an area of 3.6 square meters, this unit can accommodate two individuals, although it lacks provisions for a wet core. Subsequent

designs evolved from the initial concept, with units named according to the number of scissor mechanisms they incorporate.

UNIT NAME	PHYSICAL MODEL			SOLIDWORKS MODEL		
	COMPACT CONFIGURATION	SEMI-DEPLOYED	DEPLOYED CONFIGURATION	COMPACT CONFIGURATION	SEMI-DEPLOYED	DEPLOYED CONFIGURATION
UNIT 1X1 SCISSOR MECHANISM						

**Figure 5.3.** Deployment stages of Unit 1x1


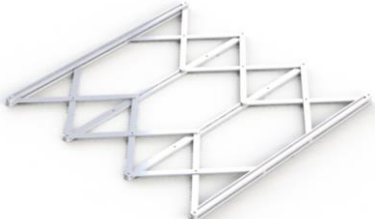
Unit 2x3 has been designed as an evolution of Unit 1x1. This new unit employs two scissor units, with modified scissor bars with sliders to create larger spaces as shown in Figure 5.4. The scissor bars are doubled and hinged at the corner of the shelter unit, enhancing its structural stability and expanding the usable area.

UNIT NAME	PHYSICAL MODEL	SOLIDWORKS MODEL		
UNIT 1X1				
UNIT 2X3				
UNIT 3X3				

**Figure 5.4.** Module combinations to create shelter units

By combining two modified units, Unit 2x3 can accommodate four people within a 24-square-meter area. The plates are designed as two upper and lower parts to reduce weight and facilitate easy installation in the demountable option. These plates are

designed to interlock and be screwed together, with folding hinges used for assembly. The initial folding systems have been meticulously designed in this unit and later developed into the *Shelter Module X* folding system. The foldable plates necessitate continuous hinges along their edges, which have been thoroughly studied and examined to achieve maximum rotation with minimal gap between the plates.

UNIT NAME	SOLIDWORKS MODEL	
	COMPACT CONFIGURATION	DEPLOYED CONFIGURATION
UNIT 3X3 SCISSOR MECHANISM		

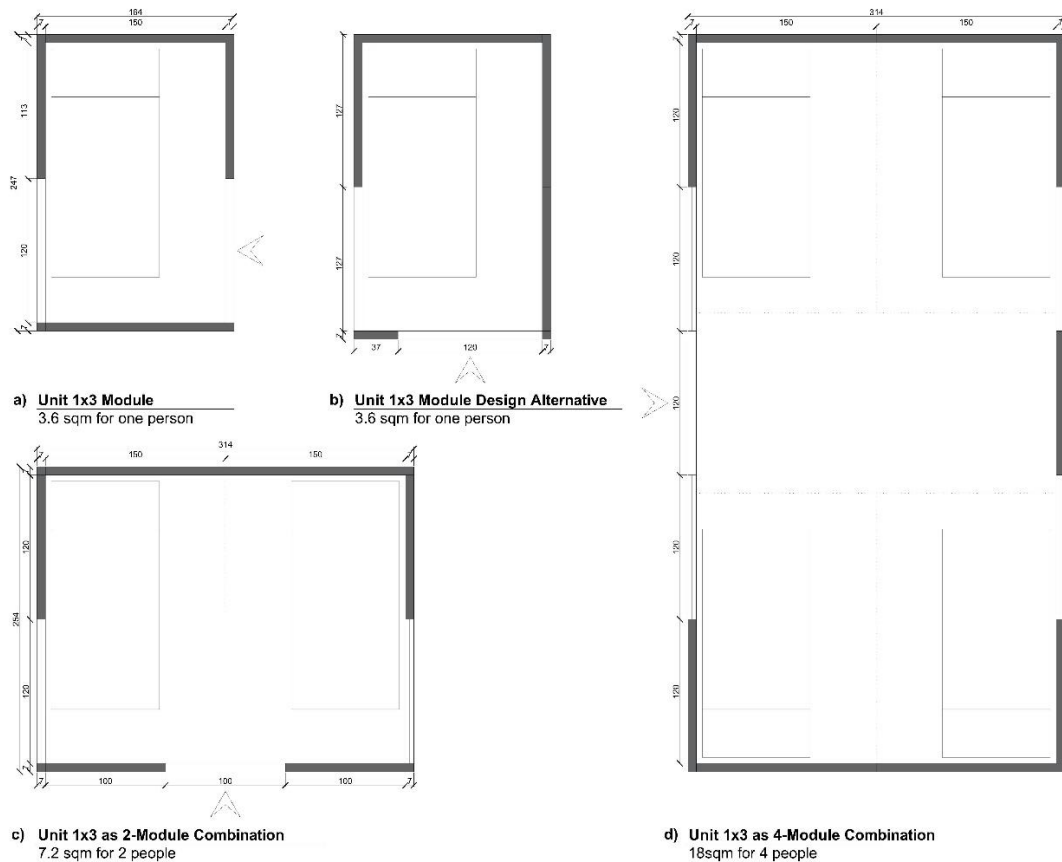
**Figure 5.5.** Modelling studies of the Unit 3x3

Unit 3x3 represents an evolved design based on the refined mechanisms and details from Shelter Module X. The primitive design, presented as the *Shelter Module X* proposal, was published in a journal (Tosun & Maden, 2023). In Unit 3x3, the slots are doubled at the corners, with two used in the middle as part of the mechanism. The sliders are positioned in the middle of the slot, defining the path of the scissor mechanism movements. Similar to Unit 2x3, scissor mechanisms are placed at the bottom and top of the shelter, with the plates folding inwards.

The short side plates are designed to fold inward for compact storage when the shelter is folded. The long side of the shelter features a double-folding wall, and the shelter can be dismantled when used as a detachable unit. As the shelter deploys, the floor plates also deploy, causing the short side plates to split to avoid obstruction. However, to divide the plates, continuous hinge-type rods need to be detached. These rods are heavy and hard to remove, leading to the evolution of outward-folding plates in the subsequent design, *Shelter Module X*.

The roof structure is designed to fold and slide simultaneously, enhancing compactness. All shelter components, including side walls, scissor mechanisms at the top and bottom, slab parts, roof parts, and adjustable legs, can be stored in larger sections. This design allows the shelter to be transported and implemented as a

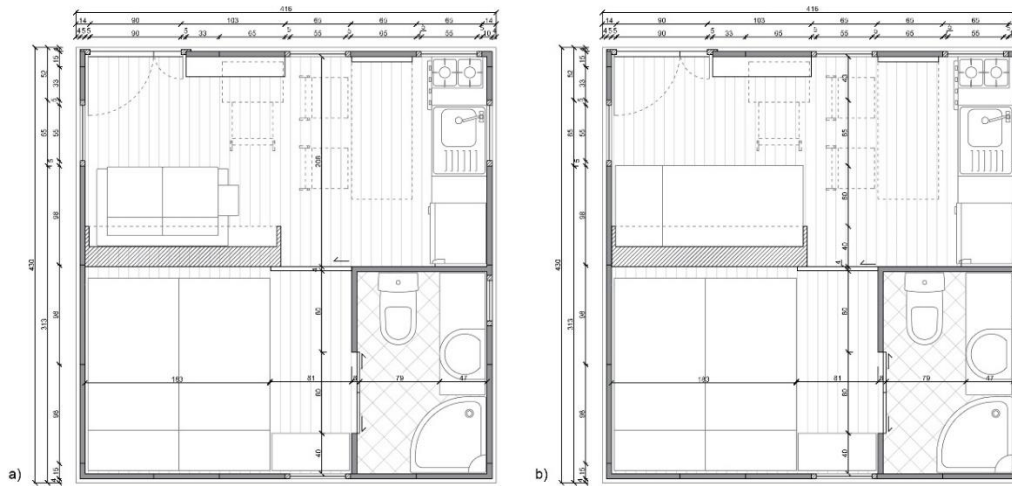
demountable shelter. The larger parts make this option advantageous due to the reduced number of components for assembly.



**Figure 5.6.** Plan layout of Unit A with module combination alternatives  
a) one module design with the long-sided entrance facing window opening,  
b) one module design with a short-sided entrance, c) 2-module combinations,  
d) 4-module combinations

In this part, the studied plan layouts of the units are presented. When two units of Unit 1x1 are combined and additional plates are added to the sidewalls, the area expands to 12 square meters. This design accommodates a bedroom for two, with various options for openings and the entrance to the shelter (Figure 5.6a and 5.6b). The plates can be modified to function as windows, doors, or structural elements framing the shelter. Curtains can provide privacy during the early stages of the relief period.

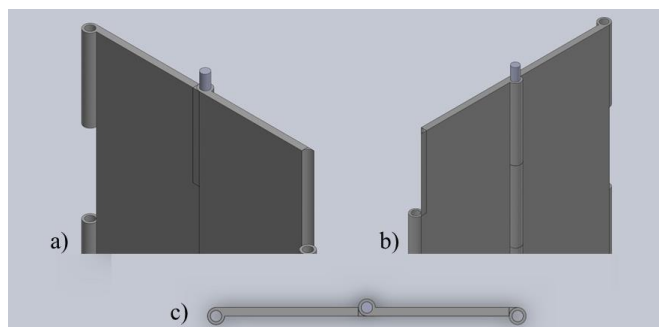
Similar to the single-module opening design, windows are positioned on both sides of the bed in both 2-module and 4-module combinations, allowing occupants to access fresh air whenever needed. Moreover, units can be equipped with fixtures to serve as multipurpose living and working areas, as well as a sanitary facility.



**Figure 5.7.** Plan layout of Unit 3x3 with foldable furniture a) living room with sofa, b) living room with folding bed open

As shown in the plan layout of the Unit 3x3 design, special multifunctional foldable furniture has been incorporated (Figure 5.7). Foldable tables and chairs are placed within the shelter, designed for easy storage by folding or hanging on walls. The partition wall between the living room and bedroom features furniture that serves as both a bed and a library, also doubling as a sofa. This setup is specifically intended for accommodating a third person or child who must live with the shelter occupants.

After completing the initial designs, the study shifted its focus to refining crucial details necessary for the complete folding of the plate elements. This iterative process involved deriving various details, modeling them, and subsequently producing prototypes. The rods have been designed as hinges to support and fold insulated plates. Between these rods, a specially shaped rubber-like material has been designed and integrated into the hinges (Figure 5.8). This material covers the entire hinge space, ensuring smooth folding without hindrance.

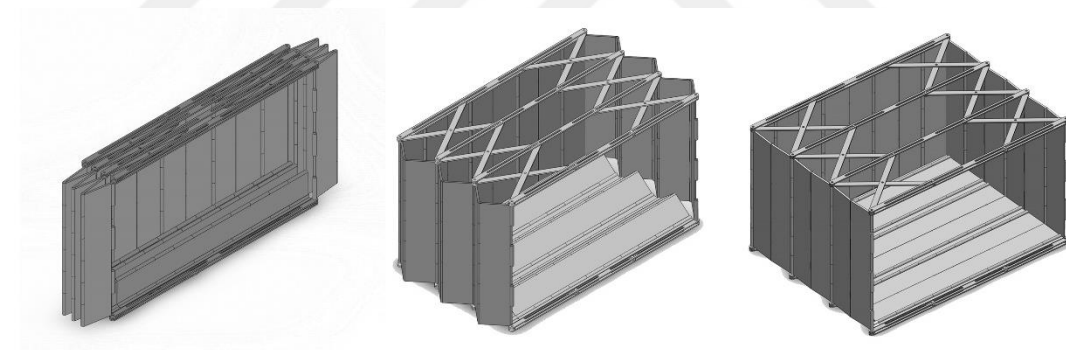


**Figure 5.8.** Foldable plate hinge detail a) outside view, b) inside view, c) top view

Lastly, in the next section, *Shelter Module X* is introduced, designed as a 3x4 modular unit to provide adequate sheltering for two people over a year. Each module combination offers flexible plan layout changes to meet diverse user needs with additional features. For example, a 1x1 module can be configured to serve as a sanitary zone, while a 3x3 shelter can function as an office space without dedicated sanitary facilities. The furniture used in *Shelter Module X* has also been designed to be foldable and multifunctional, maximizing space efficiency and usability.

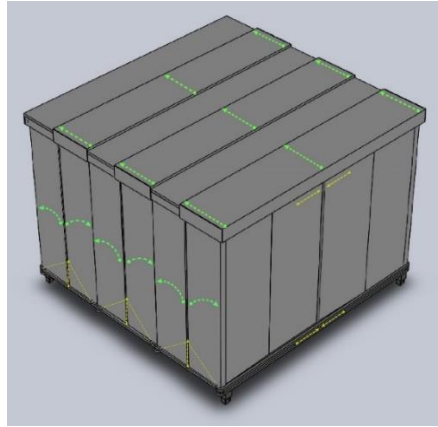
## 5.2. Design Proposal: *Shelter Module X*

*Shelter Module X* has been designed to provide lightness, protection from changing environmental conditions, ease of transport and storage, and quick installation by users. The shelter has a deployable system consisting of scissor linkages and insulated foldable plates. When unfolded, it measures 3m x 4.25m x 2.7m, covering an area of 12.75 m<sup>2</sup> (Figure 5.5). In its compact form, the module measures 0.7m x 5.3m x 2.7m. The sliding roof and adjustable legs can be dismantled, reducing the height of the shelter to 2.6m (Figure 5.5a).



**Figure 5.5.** Deployment stages of the *Shelter Module X* a) compact state; b) half deployed state; c) expanded form

The *Shelter Module X* is composed of twelve translational scissor units connected by revolute joints, with six units positioned at the bottom and the remaining six at the top (Figure 5.5c). These scissor elements play a crucial role in controlling the movement of the plates, as they are connected to all side plates. By sliding the scissor-like elements along the slots on the side plates, the deployable system initiates its movement and expansion (Figure 5.6).



**Figure 5.6.** Deployed configuration of the fully implemented shelter with indicated folding directions

The *Shelter Module X* deploys simultaneously on the sides, top and bottom, excluding the longer sides aligned with the y-direction (the longer sides of the unit) (Figure 5.7). The plates on the long sides are temporarily fixed to the scissor elements during transportation but are designed to be bifold for storage or as demountable design alternatives. The side plates aligned with the x-direction fold outward, optimizing space utilization and compactness. Both x- and y-direction side plates are connected at the corners by horizontal rods designed as hinges, enabling a 180° rotation without obstruction (Figure 5.7).



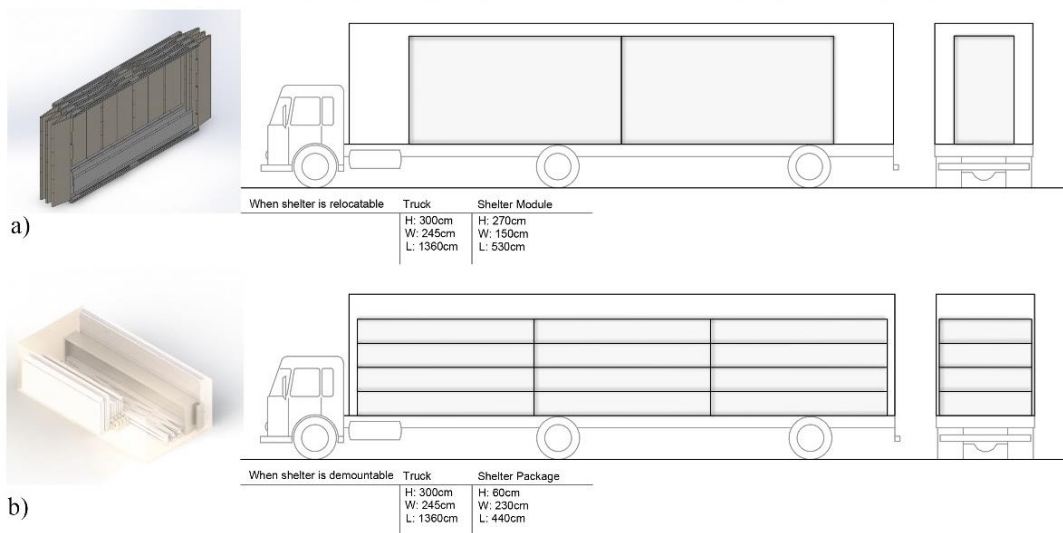
**Figure 5.7** The physical model of proposal shelter perspective view

The slab folds vertically within the shelter and is supported by horizontal rods. These rods are placed with small plates onto horizontal scissor bars that engage with stationary plates between the scissor elements. The roof encloses the shelter structure with eaves in front of the scissors and features a sliding mechanism that reduces its width to 70cm (Figure 5.8).



**Figure 5.8.** Perspective and front view of *Shelter Module X* physical model in deployed configuration

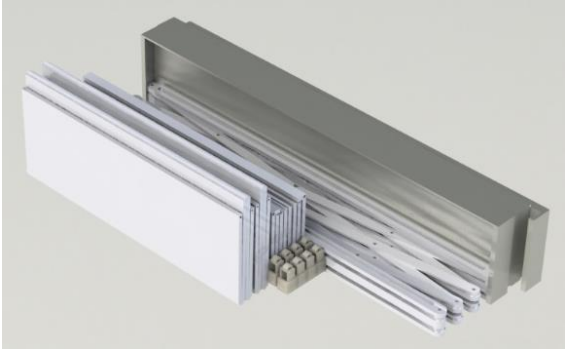
The system's deployability allows the *Shelter Module X* to be folded into a compact bundle, facilitating ease of transport and storage. It can be transported on a truck either in a half-folded state as a portable option measuring 1.5m x 5.3m x 2.7m, or by detaching the roof plates and wheels for an even more compact, relocatable option. Two shelter modules can be transported as portable units, while three shelters can be carried on a truck in their fully compact configurations, as shown in Figure 5.9. The size of each shelter is reduced by one-third, occupying an area of 3.71 m<sup>2</sup> (0.7m x 5.3m).



**Figure 5.9.** Transportation of the *Shelter Module X* a) half deployed state; b) demounted state by shelter package

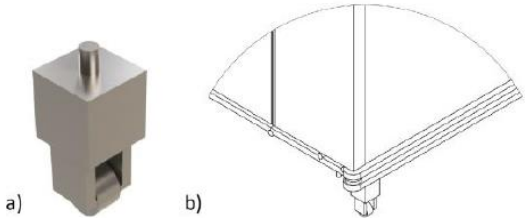
Each component of the shelter can be packed with its corresponding carrier rods for easy storage. Dismantling all the components offers a demountable option, enabling the transportation of up to 12 shelters on a single truck (Figure 5.9b). When fully

dismantled, the shelter package measures 2.3m x 4.4m x 0.6m, making it a compact solution for temporary shelter needs (Figure 5.10).



**Figure 5.10.** Shelter package detail

To facilitate relocation and adaptability to uneven terrain, the shelter is equipped with wheels and adjustable legs (Figure 5.11). These wheels can be attached before moving the shelter or during its placement on the ground. With a height adjustment range between 24cm and 32cm, it is preferable to select relatively smooth terrain, though the wheels can accommodate variations in ground elevation. Moreover, the wheels can be locked to securely position the shelter and provide protection against flooding.



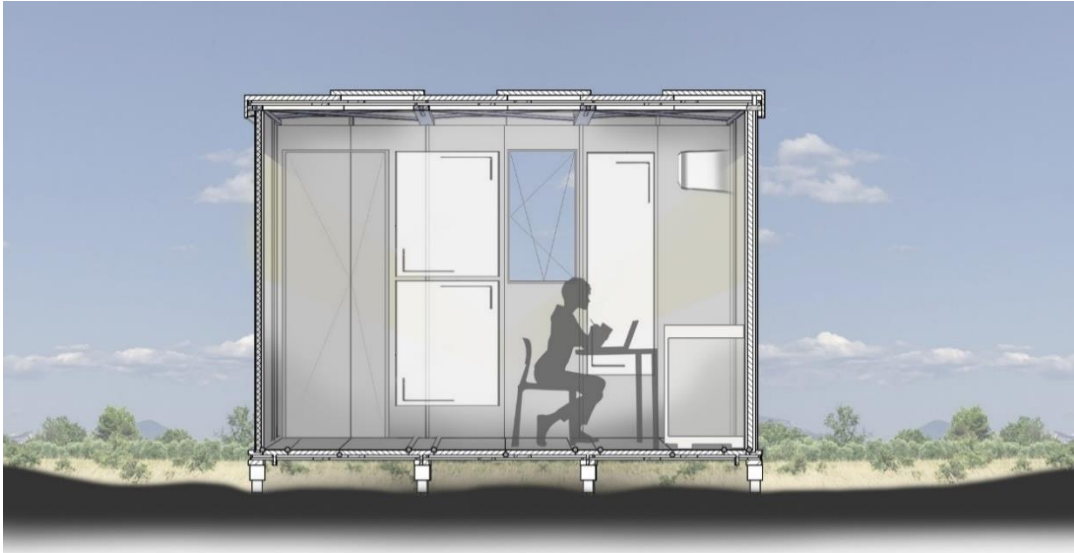
**Figure 5.11.** Adjustable legs and wheels connection detail

Crane-like machines are needed to unload shelter from the truck. Due to the weight of the plates, a machine or a muscle power of four people is required to open the shelter. Thanks to these wheels, users can quickly open the shelter and begin usage. Without the assistance of wheels, the process may take longer due to the physical effort and weight of the components.

If shelter packages are chosen, the assembly steps are as follows: first, connect the scissors and short side plates with adjustable legs; second, place the bifold long side plates; lastly, install the sliding roof mechanism into the top side scissors to complete



Covering an area of 12.75 m<sup>2</sup>, the proposed shelter can meet users' basic needs for longer use and accommodate up to three individuals when the living room is used as a sleeping area. The *Shelter Module X* has slim windows that provide cross ventilation, privacy, and natural light (Figure 5.13). The design of the shelter considers changing conditions to ensure habitable and sustainable spaces.



**Figure 5.13.** The sectional perspective of shelter represents shelter life

To provide user comfort and adaptability within these compact environments, foldable furniture is used. Lightweight folding partition walls are designed and placed around the bathroom. It is acceptable to deliver bathroom and kitchen fixtures with these walls within one week after the disaster.

To enhance the lightweight, cost-effective and easy of folding, the *Shelter Module X* utilizes aluminium scissors and plates (Figure 14). The plates are constructed to be 30mm thin with an insulation layer sandwiched between two layers of aluminium plates. Vertical rod hinges are integrated with circular insulation material to ensure long-term durability, preventing friction and minimizing impact between components. This design feature allows the shelters to be used repeatedly without sustaining damage to their parts (Figure 15).



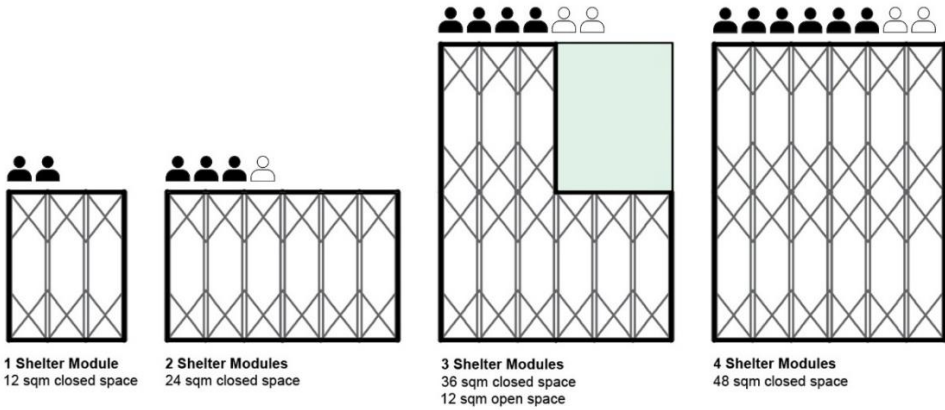
**Figure 5.14.** The physical model of proposal shelter in deployed configuration



**Figure 5.15.** The physical model of proposal shelter without roof

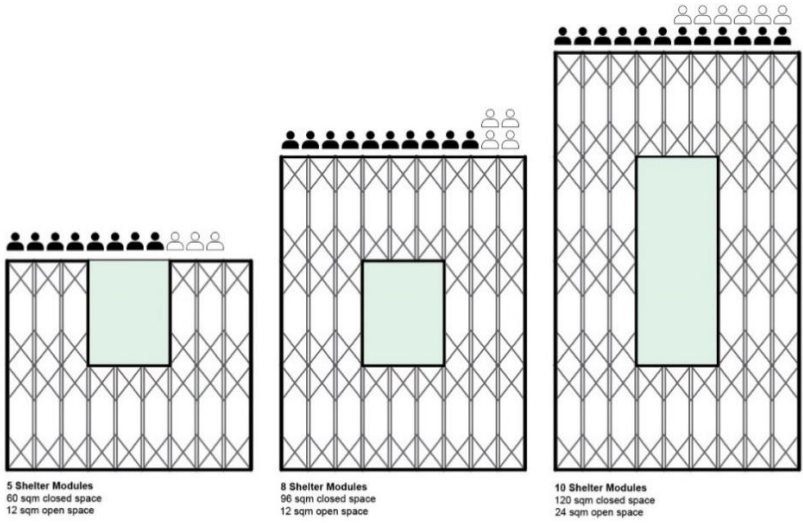
The proposed *Shelter Module X* is designed to function not only as a temporary shelter suitable for long-term use, featuring a kitchen and bathroom area but also as an emergency shelter when the service unit (kitchen and bathroom) is excluded. The system is adaptive, allowing for adjustment in the number of scissor linkages. Rather than using three scissor units in each row (i.e., a 3x2 module), two scissor units can be used to create a smaller module (a 2x2 module) covering an area of 8.5m<sup>2</sup>. this configuration can comfortably accommodate two people during emergency periods, albeit without bathroom or kitchen facilities.

The proposed *Shelter Module X* is highly adaptive, offering module combinations to cater to larger families (Figure 5.16) or diverse functions (Figure 5.17). These solutions incorporate the creation of common open areas to enhance the overall habitability of the shelter. These open spaces are designed to foster interaction among shelter users and connect individuals within the sheltering zone.



**Figure 5.16.** Alternative module combination diagrams

To mitigate secondary disasters such as fire risks and the spread of infectious diseases within shelter settlements, it is imperative to maintain space breaks of 1m to 1.5m between shelters. These breaks not only aid in noise control but also facilitate service access to the shelters. Service units should be strategically located in accessible areas within the sheltering zone, while service vehicles and supplies should be kept separate to isolate and protect shelter users from external hazards.



**Figure 5.17.** Alternative module combination schemes for greater multifunctional use

Once the immediate risks have passed and shelter settlements are organized, these temporary setups can be transitioned into permanent living zones. Additional shelter modules can be combined and reinforced for long-term use, serving as transitional shelters for 2-3 years before further adaptation into permanent housing.

To adapt the sheltering zone to changing needs, the design allows the combined larger modules to serve as service units, training areas, and office spaces when used temporarily (Figure 5.17). The created open spaces should be designed as leisure areas to motivate people to maintain their daily routines.

### **5.3. Design Limitations**

Although *Shelter Module X* offers advantages over conventional prefabricated shelters in its demountable option, only two can be transported simultaneously in the relocatable option. Deploying these relocatable shelters requires a simple crane mechanism.

In the demountable option, up to 12 shelters can be transported at once, but the shelter parts are larger and heavier, requiring the assistance of machines and professionals for assembly. Cranes are essential for lifting and deploying these parts to construct the entire shelter module. With the support of two cranes and four people, all 12 shelters can be assembled in a day.

This design proves sustainable for large deployments due to its durability and functionality. Each shelter can be used for up to a year, making it a viable long-term solution when hundreds of shelters are needed.

The *Shelter Module X* can be easily mounted within a day and offers flexibility through its modular design, allowing for adjustments by adding or removing shelter parts. Utilizing the same foldable plates with vertical hinges and scissor mechanisms across all variations, this shelter is adaptable to diverse post-disaster conditions, locations, climates and spatial needs.

The shelter parts are designed for durability, reusability, adaptability, and functionality. However, their performance in extremely hot and cold climates has not been tested. Enhancements are needed to ensure water and fire resistance, particularly for the sliding mechanism on the roof. The overall cost of the shelter has not been calculated, but repeated use over time is expected to lower the cost significantly.

## 5.4. Discussion

The disaster relief shelters examined in this study feature various structural systems that offer significant advantages in adapting to spatial, functional, and environmental changes. The analysis shows that the selected temporary shelters with variable mobility provide substantial benefits, as they can be relocated when needed. This mobility enables shelters to be moved within the settlement or to safer, permanent zones during the sheltering period. Using relocatable and portable shelters offers multiple advantages, including cost reduction, ease of transportation and storage, and the elimination of the need for extensive workforce or fieldwork during implementation.

The examples given in Table 3 are highly adaptive and flexible, capable of meeting the changing needs of users. Moreover, these shelters demonstrate durability in withstanding changing weather conditions and can be implemented easily, typically in less than one hour with the assistance of one or two people. Furthermore, they occupy less space compared to conventional shelters when in their compact configurations.

On the other hand, temporary shelters with variable geometry offer greater flexibility in shape control and can be compacted for easy relocation. This capability allows more shelters to be transported on a single truck. Compact shelters can be rapidly expanded by users in minutes, without the need for professional assistance or extensive fieldwork. Their structural systems, including adjustable legs, enable placement on various terrains and slopes without requiring significant land improvement. Among the examples of temporary shelters, shelters composed of scissors and foldable plates are promising due to their numerous advantages.

It is crucial to prioritize simplicity in the mechanisms used in such shelters, while also ensuring lightweight components for ease of transportation. Nevertheless, durable materials should be chosen to support extended usage beyond the initial timeframe. The majority of the temporary shelters given in Table 4 are lightweight and can be rapidly erected or dismantled within minutes when required, unlike the relocatable shelters in Table 3, which may require more assembly time. However, their compact design allows multiple units to be transported on a truck, maximizing efficiency in large-scale implementations. This advantage enables the rapid deployment of

thousands of shelters within a short timeframe, effectively addressing the urgent shelter needs of disaster-affected populations.

The lightweight and compact nature of temporary shelters necessitates careful integration of insulation solutions with structural systems, avoiding significant increases in weight or implementation time. Deployable temporary shelters composed of scissor-like and bar elements require using flexible or rigid covering materials to create enclosed living spaces. While designers typically prioritize mechanism design over covering materials, it's crucial to integrate these materials effectively.

Insulation can pose a challenge in these shelters when covering materials are not adequately addressed. On the other hand, foldable structures offer advantages as insulated panels can be seamlessly integrated into the foldable system. This integration ensures effective insulation without compromising functionality or adding excessive weight to the shelter.

The proposed *Shelter Module X* incorporates several carefully considered features. The scissor linkages and insulated folding panels are designed to operate smoothly without obstructing each other during the opening and closing processes. This consideration ensures smooth operation while maintaining insulation properties. Furthermore, there is a focus on minimizing additional weight, ensuring the shelter remains lightweight and portable without compromising its insulation capabilities.

## **CHAPTER 6**

### **CONCLUSIONS AND FUTURE WORK**

In conclusion, the global need for temporary shelters persists due to ongoing displacements worldwide. Novel structural solutions must address evolving spatial requirements and the changing temporality of sheltering, enabling disaster-affected people to swiftly return to their daily routines with secure sheltering solutions. It is essential to design these shelters as permanent products to avoid wasting resources and time.

The rapid onset of large-scale shelter needs necessitates adaptive designs that can endure for extended periods and respond effectively to diverse post-disaster scenarios. A multi-phased sheltering approach – encompassing emergency shelters, transitional shelters, and permanent reconstruction – requires the deployment of various shelter types until permanent dwellings are built. Tents serve primarily during the immediate relief period, while container-type shelters are used in the rehabilitation period.

Despite their cost-effectiveness, container-type shelters exhibit significant drawbacks such as poor thermal insulation, limited privacy, inflexibility, and instability, rendering them unsuitable for long-term use. Although these shelters are durable, they are insufficient in terms of transportation – only one can typically fit on a truck due to their size – and lack adaptability to meet changing user needs and environmental conditions.

On the other hand, temporary shelters having mobility and movement provide many advantages compared to those conventional types, encompassing not only adaptability to changing circumstances but also reduced implementation time and overall cost. Using multiple shelter types in the periods of immediate relief and rehabilitation such as tents and containers increases the overall cost spent for sheltering. However, with the development of efficient design solutions, kinetic disaster relief shelters have the potential to fulfill the criteria, standards, and requirements of both periods. They can even serve as permanent shelters due to their inherent ability to be relocated, upgraded, and reused. At this point, a question arises: can temporary kinetic disaster shelters

evolve into long-lasting solutions? The answer lies in their inherent flexibility and adaptability.

Because the energy crisis and limited resources led designers to develop sustainable and energy-efficient design solutions, more adaptive and flexible alternatives have been proposed in recent years not only in building and façade designs but also in the realm of temporary shelters. Kinetic disaster relief shelters can offer many benefits, from ease of storage, transportation, and implementation to spatial flexibility and adaptability. One notable benefit of kinetic shelters is their potential for multiple uses in various disaster scenarios, mitigating the need for continuous shelter production. Kinetic shelters might be more economical than three-stage sheltering which requires using different types of shelters. In addition, they can yield time and energy savings since their ease of assembly, disassembly, and transportation significantly reduces the time and effort required for implementation. Another advantage lies in the potential transformation of kinetic disaster shelters into permanent dwellings. By repurposing these shelters as long-term housing solutions, they can help prevent land waste and urban sprawl, while also reducing construction costs.

Considering the aforementioned factors, the development of a modular shelter presents a viable solution for disaster relief shelters. The *Shelter Module X* is designed to be easily transportable and expandable, offering adaptability to varying shelter durations and changing conditions. Implementing the *Shelter Module X* does not require extensive fieldwork or professional assistance initially. However, in configurations involving diverse modules, professionals may assemble them on-site or beforehand to streamline deployment at shelter settlements.

For long-term use, the proposed design can be converted into a permanent dwelling by enclosing the entire structure, reinforcing insulated panels, and securely attaching them to the scissor elements. This transformation involves establishing a foundation by improving land quality, elevating the structure, and removing wheels. By following these steps and making the appropriate modifications, *Shelter Module X* can transition from a temporary shelter to a durable and functional permanent dwelling. This adaptation allows for the longevity of the shelter, ensuring its suitability for long-term usage and providing a sustainable solution for displaced individuals or communities. In this way, the life of the product can be extended.

*Shelter Module X* is designed with these considerations in mind, capable for lasting years with structural strengthening and module additions. In the emergency relief period, up to 2 relocatable shelters or 12 demounted shelter packages can be transported at once on a truck, offering advantages over conventional shelters like container-type and prefabricated ones. Its foldable structural mechanism allows for rapid implementation of numerous shelters in a single day.

This versatile design can accommodate large families and provides sufficient space for small schools and office setups, with open areas designed as leisure spaces for users. Future developments could be explored the shelter's adaptation to changing settlements conditions and its interaction with livelihoods over extended periods.



## REFERENCES

- Aburamadan, R., Trillo, C., & Makore, B. C. N. (2020). Designing refugees' camps: temporary emergency solutions, or contemporary paradigms of incomplete urban citizenship? Insights from Al Za'atari. *City, Territory and Architecture*, 7, 1-12.
- AFAD (Afet ve Acil Durum Yönetimi Başkanlığı). (2011). *İlk 72 Saat*. Access Address (05.06.2022): <https://www.afad.gov.tr/kitaplar>
- AFAD (Afet ve Acil Durum Yönetimi Başkanlığı). (2015). *Afet ve Acil Durum Yaşam Tesisi (Disaster and Emergency Living Facility)*. TUBITAK Patented Project. Türk Patent ve Marka Koruma Kurumu, Project No: 2015-09034. Project Date: 21.07.2015. Access Address (12.04.2022): <https://www.turkpatent.gov.tr/arastirma-yap?form=patent>
- AFAD (Afet ve Acil Durum Yönetimi Başkanlığı). (2015). *Geçici barınma merkezlerinin kurulması, yönetimi ve işletilmesi hakkında yönerge*. Access Address (15.01.2023): <https://www.afad.gov.tr/yonerge>
- AFAD (2018). Disaster management and natural disaster statistics in Turkey. Access Date: 05 June 2022. Available: <https://www.afad.gov.tr/kitaplar>
- Alharthi, O. (2020). Structures as emergency shelters. (Master's thesis). Universitat Politècnica de Catalunya, Spain. doi: 10.13140/RG.2.2.10665.01124
- Arslan, H. (2007). Re-design, re-use and re-cycle of temporary houses. *Building and Environment*, 42(1), 400-406.
- Arslan, A., Uçar, Z. & Aldemir, O. (2021). Deployable structure systems and application to temporary disaster shelters. *14th International Congress on Advances in Civil Engineering, ACE2020-21*.
- Asefi, M. & Sirius, F. A. (2012). Transformable shelter: Evaluation and new architectural design proposals. *Procedia-Social and Behavioral Sciences*, 51, 961-966.
- Askar, R., Rodrigues, A. L., Bragança, L. & Pinheiro, D. (2019). From temporary to permanent; a circular approach for post-disaster housing reconstruction. *IOP Conference Series: Earth and Environmental Science*, 225 (1), 12-32.
- Bayram, Y., Parlak, M., Çıkman, A., & Aypak, C. (2014). Van depreminin su-kaynaklı bazı bulaşıcı hastalıklar üzerine etkisi. *Dicle Tıp Dergisi*, 41(2), 313-318.

- Beyatlı, C. (2010). Acil durum barınakları ve bir barınak olarak acil durum konteynır öneri modeli. (Master's thesis). Trakya University, Türkiye. Access Address (07.01.2023):[https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=ynCHfLUmu-gav5AxTjEK\\_A&no=TG1-F0\\_p0AD4hy\\_q3X2OuQ](https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=ynCHfLUmu-gav5AxTjEK_A&no=TG1-F0_p0AD4hy_q3X2OuQ)
- Cerrahoğlu, M., & Maden, F. (2020). A review on portable structures. Proceedings of ATI Conference. İzmir, Turkey, 154-159.
- Choi, Y. R., Kim, E. J. & Kim, M. K. (2020). A planning guide for temporary disaster shelters focusing on habitability. *Indoor and Built Environment*, 29(10), 1412-1424.
- Corsellis, T. & Vitale, A. (2005). *Transitional settlement displaced population. Part A: Process, Chapter 2: Strategy*. Oxfam GB, University of Cambridge. ISBN: 978-0-85598-534-9. Access Address (07.01.2023): <https://policy-practice.oxfam.org/resources/transitional-settlement-displaced-populations-115526/>
- Dialameh, M. (2017). Portable post-disaster home. (Master's thesis). University of Waterloo, UWSpace, Canada. Access Address (12.04.2023): <http://hdl.handle.net/10012/11239>
- Diñçer, O. B., Federici, V., Ferris, E., Karaca, S., Kirişçi, K., & Çarmıklı, E. Ö. (2013). *Suriyeli mülteciler ve Türkiye: Sonu gelmeyen misafirlik*. International Strategic Research Organization (USAK).
- Extremis Technology. (2014). Hush Shelter-2 project. Access Address (10.07.2022): <https://www.hhftd.net/extremis>
- Félix, D., Monteiro, D., Branco, J. M., Bologna, R., & Feio, A. (2015). The role of temporary accommodation buildings for post-disaster housing reconstruction. *Journal of Housing and the Built Environment*, 30(4), 683-699.
- FEMA. (2005). Planning for post disaster recovery and reconstruction. Washington D.C., FEMA.
- George, J. W., Guthrie, P., & Orr, J. J. (2022). Re-defining shelter: Humanitarian sheltering. *Disasters*.
- Gomez-Jauregui, V., Quilligan, M., Manchado, C. & Otero, C. (2018). Design, fabrication and construction of a deployable double-layer tensegrity grid. *Structural Engineering International*, 28(1), 13-20.
- Hurkmans, B. (2018). Measuring the Adequacy of Shelter: Definitions, Criteria and Methodologies. *The State of Humanitarian Shelter and Settlements*, 174–76. Geneva: IFRC.

- IFRC (International Federation of Red Cross and Red Crescent Societies). (2013). *Post-disaster shelters: Ten designs*. Geneva: International Federation of Red Cross and Red Crescent Societies (IFRC) Publishing. Access Address (05.04.2023):<https://www.shelterprojects.org/tshelter8designs/10designs2013/2013-10-28-Post-disaster-shelter-ten-designs-IFRC-lores.pdf>
- Internal Displacement Monitoring Centre. (2024). *Global report on internal displacement 2024*. <https://www.internal-displacement.org/global-report/grid2024/>
- Janmyr, M. (2018). UNHCR and the Syrian refugee response: negotiating status and registration in Lebanon. *The International Journal of Human Rights*, 22(3), 393-419.
- Johnson, C. (2002). What's the big deal about temporary housing? Planning considerations for temporary accommodation after disasters: Example of the 1999 Turkish earthquakes. *2002 TIEMS Disaster Management Conference, Waterloo*.
- Kalkan, N., & Bozulmaz, T. (2019). Katlanabilir altıgen formda geçici afet konutu tasarımı üzerine bir inceleme. *The Journal of Academic Social Science*, 76(76), 332-343.
- Karaoglan Cemre, F., & Alaçam, S. (2018). Design of a post-disaster temporary living space through the use of shape evolution. *Proceedings of the 22nd Conference of the Iberoamerican Society of Digital Graphics*, Brazil, São Carlos, 191-198.
- Kawuwa, S. A. (2017). A proposed method of exploring the use of kinetic architecture for housing the migrant fulbe in Nigeria. *Journal of Applied Sciences & Environmental Sustainability*, 3(8): 72-83, 2360-8013.
- Kim, M., Kim, K., & Kim, E. (2021). Problems and Implications of Shelter Planning Focusing on Habitability: A Case Study of a Temporary Disaster Shelter after the Pohang Earthquake in South Korea. *International Journal of Environmental Research and Public Health*, 18(6), 28-68.
- Kronenburg, R. (2003). *Portable architecture*. Routledge.
- Larsen, O. P., Brancart, S., De Temmerman, N., De Laet, L. & Petrova, V. (2018). ReciPlyDome and ReciPlySkin bending-active transformable lightweight shelters. *International Association for Shell and Spatial Structures (IASS) Annual Symposia Proceedings*, 2018(14), 1-8.
- Lee, D. S., Larsen, O. P. & Kim, S. D. (2013). Study of the connection joint for scissor-type deployable structure for the possible application in emergency evacuation shelter. *The First Conference Transformables 2013 Proceedings*, 1-5.

- Lee, Y. L., Yeow, C. Y., Lim, M. H., Woon, K. S. & Woon, Y. B. (2022). Preliminary study on the rapid assembly emergency shelter. *E3S Web of Conferences*, 347, 05002.
- Maden, F. (2019). The architecture of movement: transformable structures and spaces. *The 6th International Congress on Livable Environments & Architecture Proceedings*, 551-567.
- Mira, L. A., Thrall, A. P. & De Temmerman, N. (2014). Deployable scissor arch for transitional shelters. *Automation in Construction*, 43, 123-131.
- Pérez-Valcárcel, J., López-César, I., Muñoz-Vidal, M., Suárez-Riestra, F. & Freire-Tellado, M. J. (2021). A new type of reciprocal structures: Deployable yurts for emergency situations. *Advances in Architecture and Civil Engineering*, 2, 1-15. doi: 10.31579/jaace.2021/002.
- Pérez-Valcárcel, J., Muñoz-Vidal, M., Suárez-Riestra, F., López-César, I. R. & Freire-Tellado, M. J. (2021). Deployable cylindrical vaults with reciprocal linkages for emergency buildings. *Structures*, 33, 4461-4474. Elsevier. doi: 10.1016/j.istruc.2021.06.094.
- Ramazani, R., Ostadtaghizadeh, A., Yari, A., Hanafi-Bojd, A. A., Soltani, A., Rostami, S. B., & Heydari, A. (2022). Criteria for Locating Temporary Shelters for Refugees of Conflicts: A Systematic Review. *Iranian Journal of Public Health*, 51(4), 758.
- Rohwerder, B. (2016). Transitional shelter in post-disaster contexts. *Birmingham, UK: GSDRC, University of Birmingham*.
- Quaglia, C. P., Dascanio, A. J. & Thrall, A. P. (2014). Bascule shelters: a novel erection strategy for origami-inspired deployable structures. *Engineering Structures*, 75, 276-287.
- Quarantelli, E. L. (1995). Patterns of sheltering and housing in US disasters. *Disaster prevention and management: an international journal*.
- S., Sanderson, D., Loosemore, M., & Mojtahedi, M. (2020). Fit for purpose? Lessons from transitional shelter provision for internally displaced persons in urban informal settlements in Brazil. *Disaster Prevention and Management: An International Journal*.
- Sarısayın, N. H., Akgün, Y., Maden, F. & Kilit, Ö. (2022). Geometric design of planar scissor linkages with hybrid loop assemblies. *Journal of Architectural Engineering*, 28(2), 04022012.
- Seikaly, A. (2015). *Weaving a Home Shelter project*. Access Address (28.07.2022): <https://archello.com/project/weaving-a-home>

- Sey, Y. & Tapan, M. (1987). Afet sonrasında barınma ve geçici konut sorunu raporu. (Unpublished academic source). İstanbul Technical University, Türkiye.
- Shelter Centre. (2012). Transitional shelter guidelines. Access Date: 20 June 2022. Available: <http://www.sheltercentre.org/library>
- Sphere Association. (2018). The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response. 4th edition, Geneva, Switzerland. [Online]. Access Date: 20 June 2022. Available: <https://www.spherestandards.org/handbook/>
- TenFold Engineering. (2017). TF-64 sheltering project. Access Address (10.07.2022): <https://engineerde.com/tenfold-house/>
- Thrall, A. P. & Quaglia, C. P. (2014). Accordion shelters: a historical review of origami-like deployable shelters developed by the US military. *Engineering structures*, 59, 686-692.
- TMMOB (Türkiye Mimar ve Mühendisler Odası Birliği) Ankara Şubesi. (2012). *Afet Barınağı (Disaster Shelter)*. TUBITAK Patented Project. Türk Patent ve Marka Koruma Kurumu, No: 2012-03019. Date: 13.07.2012. Access Address (10.01.2023): <https://www.turkpatent.gov.tr/arastirma-yap?form=patent>
- Tosun, S., & Maden F. (2022). Habitability in Temporary Disaster Shelters. *Barınma Kültürü, NEU Yayınevi*, 1(25), 535-556.
- Uçar, Z. T. (2015). Hareketli yapı sistemleri ve geçici afet korunaklarına uygulanması. (Master's thesis). Gazi University, Türkiye. Access Address (07.03.2023): [https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=7GYNTz91RqaE1XyxTjH8w&no=If0rGZQUHUHu3X\\_mVnIGQQ](https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=7GYNTz91RqaE1XyxTjH8w&no=If0rGZQUHUHu3X_mVnIGQQ)
- UN General Assembly. (1996). Chapter IV: B. Adequate Shelter for All. The Habitat Agenda. United Nations.
- UNHCR. (2001). Practising and Promoting Sound Environmental Management in Refugee/Returnee Operations. International Workshop, 22–25 October 2001, UNHCR, Geneva.
- UNHCR (United Nations High Commissioner for Refugees). (2021). *Shelter and Sustainability: a technical and environmental comparative overview of common shelter typologies found in settlements across UNHCR operations*. Shelter Cluster. Access Address (15.03.2023): <https://sheltercluster.org/resources/documents/unhcr-shelter-and-sustainability>
- Vaccari, M. S., Sanderson, D., Loosemore, M., & Mojtahedi, M. (2020). Fit for purpose? Lessons from transitional shelter provision for internally displaced persons in urban informal settlements in Brazil. *Disaster Prevention and Management: An International Journal*.

- Verzoni, A. & Rais-Rohani, M. (2022). Transition analysis of flat-foldable origami-inspired deployable shelter concepts. *Engineering Structures*, 273, 115074.
- Wagemann, E. & Moris, R. (2018). Transitional habitability: solutions for post-catastrophe in Chile. *International Journal of Disaster Risk Reduction*, 31, 514-525.
- Zuk, W. & Clark, R. H. (1970). *Kinetic Architecture*. New York: Litton Educational Publishing.

