A Temporary Shelter Proposal for Displaced People

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Abstract**—**Forced migration, whether caused by conflicts or other factors, frequently places individuals in vulnerable situations, necessitating immediate access to shelter. To promptly address the immediate needs of affected individuals, temporary shelters are often established. These shelters are characterized by their adaptable and functional nature, encompassing lightweight and sustainable structural systems, rapid assembly capabilities, modularity, and transportability. The shelter design is contingent upon demand, resulting in distinct phases for different structural forms. A multi-phased shelter approach covers emergency response, temporary shelter, and permanent reconstruction. Emergency shelters play a critical role in providing immediate life-saving aid. In contrast, temporary and transitional shelters, also called "T-shelters," offer longer-term living environments during the recovery and rebuilding. Among these, temporary shelters are more extensively covered in the literature due to their diverse inhabiting functions. The roles of emergency shelters and temporary shelters are inherently separate, addressing distinct aspects of sheltering processes. Given their prolonged usage, temporary shelters are built for greater durability compared to emergency shelters. Nonetheless, inadequacies in temporary shelters can lead to challenges in ensuring habitability. Issues like non-expandable structures unsuitable for accommodating large families, short-term shelters that worsen conditions, non-waterproof materials providing insufficient protection against bad weather conditions, and complex installation systems contribute to these problems. Given the aforementioned problems, there arises a need to develop adaptive shelters featuring lightweight components for ease of transport, possess the ability for rapid assembly, and utilize durable materials to withstand adverse weather conditions. In this study, first, the state-of-the-art on temporary shelters is presented. Then, a temporary shelter composed of foldable plates is proposed, which can easily be assembled and transportable. The proposed shelter is deliberated upon its movement capacity, transportability, and flexibility. This study makes a valuable contribution to the literature since it not only offers a systematic analysis of temporary shelters utilizing kinetic systems but also presents a practical solution that meets the necessary design requirements.

Keywords**—**Deployable structures, disasters, foldable plates, temporary shelters, transformable structures.

I. Introduction

MILLIONS of people are left homeless due to a variety of causes, including natural disasters such as climate change-included events and man-made disasters like conflicts. Displacement is on the rise, driven by events, such as flooding, earthquakes, and hurricanes. Moreover, socioeconomic challenges such as insufficient food supplies, insecurity, and limited job prospects further propel individuals and families to seek better opportunities elsewhere. This has resulted in approximately 6.6 million refugees, who have resorted to maintaining their daily lives in self-established camps [1]. Following various disasters, roughly 2 million makeshift shelters have been constructed by displaced people with their efforts using local materials [2]. However, these shelters fall short in meeting user needs, unable to adequately withstand harsh weather conditions or provide sufficient ventilation. In addition, they lack compliance with technical standards set forth by humanitarian organizations, such as resistance to direct sunlight, fire, water, and humidity issues [3]. This issue is not only for the makeshift shelter examples but also involves most existing temporary shelters. Furthermore, many of these shelters exhibit structural deficiencies resulting in complex assembly processes that require professional assistance, thus prolonging the setup time. More time-efficient structural solutions that are functional and sustainable must be developed to address this issue effectively.

Shelters used after natural or man-made disasters may vary significantly depending on their location and the overseeing organizations. Such shelters are provided in certain regions, especially in emergencies or densely populated refugees. However, the lack of adequate insulation, privacy, and sanitary facilities in these shelters poses substantial risks to the physical and emotional well-being of migrants [4]. To enhance the livability of shelters, it is essential to create private spaces for occupants. Moreover, the concepts of adaptability and flexibility need to be integrated into shelter design to meet changing circumstances and user needs.

Factors such as disaster type, duration of stay, and occupants' needs determine the shelter type to be used after natural or man-made disasters. For instance, emergency shelters are used in the aftermath of a disaster to offer immediate accommodations for people who lost their houses [2]. Such shelters can be used for a short period such as a week. On the other hand, temporary shelters are one type of alternative solution preferred to be used in transition periods until permanent dwellings are constructed for those people. These shelters may offer longer-term stays from weeks to several months. There are also other types of shelters like transitional shelters that aim to facilitate the transition from displacement to secure and sustainable housing for individuals or families. These shelters distinguish

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themselves through features, such as reusability, upgradability, recyclability, mobility, and resold, which enhances their versatility as a housing solution.

Temporary and transitional shelters, commonly called "T-shelters," share many similarities. One key feature that distinguishes transitional shelters is their utilization of renewable materials. Intended for 6 to 12 months or potentially longer, these shelters employ durable materials resistant to deformation, facilitating multiple reuses and relocations. Consequently, they are designed with storage and transportation ease in mind.

In the design of a shelter, it is crucial to meet the technical and design standards determined by humanitarian organizations. A minimum of 3.5 square meters of space within a temporary living unit should be allocated per individual, ensuring adequate living, sleeping, and storage areas. Families should benefit from a more spacious environment, typically around 14 square meters allowing for the maintenance of daily routines like work or school, and leisure activities [5]. Moreover, it is important to incorporate essential amenities such as sanitation facilities (including toilets and bathrooms), effective drainage systems, and provisions for hygiene (e.g. access to clean water and sinks for handwashing). Especially in emergency or humanitarian contexts, these provisions are essential to protect health and maintain hygiene standards. The aforementioned design considerations are significant to provide habitable and suitable living conditions for the people displaced from their homes.

Temporary shelters should be designed for easy transportability, facilitating relocation as needed. However, conventional temporary shelters often rely on prefabricated units which are typically heavy, limiting the number that can be transported at once and lacking adaptability to varying spatial requirements such as the integration of service units. Embracing adaptable designs for temporary shelters is essential for providing short-term accommodation that can adjust to changing circumstances. This adaptability can be achieved by integrating kinetic structural systems into shelter designs. Further research and implementation of kinetic systems have the potential to enhance the flexibility and effectiveness of temporary shelter solutions significantly, ultimately improving the overall response to emergencies.

This paper begins by exploring temporary shelters featuring kinetic systems to uncover their potential and identify design considerations for developing a new foldable system. Following this, a foldable shelter is proposed which offers adaptability, flexibility, and easy transportation.

II. Comparison of Selected Temporary Shelters

The literature has been thoroughly reviewed and various temporary shelters featuring different kinetic structural systems such as demountable, relocatable, and portable have been selected for analysis and comparison. The selected shelters have been analyzed based on system characteristics (i.e. shelter type, used materials, life span), functionality (i.e. provided area, usage purpose, flexibility), and design considerations (i.e. lightness, installation, reusability, compactness). In this context, 20 distinct temporary shelter examples have been examined, comprising four demountable, seven relocatable, and nine portable shelters.

A. Demountable Shelters

Demountable shelters are primarily assembled by combining multiple components on-site. Although these systems are prevalent in shelter construction, portable examples have been predominantly chosen in the sample selection due to their inherent advantages (Fig. 1).

The *Tentative* shelter stands for its durability, constructed from fiberglass panels designed to last over a year and withstand multiple uses. With a compact form compared to other demountable shelters, it occupies minimal space when packaged, measuring just 30 cm in height. Despite its small footprint, it offers an area of 8 m^2 which makes it suitable for accommodating up to 3 individuals.

SHELTERS			SYSTEM CHARACTERISTICS				FUNCTIONALITY			DESIGN CONSIDERATIONS			
#	NAME	3D VIEW	SYSTEM	SHELTER TYPE	USED MATERIALS	LIFE SPAN	PROVIDED AREA	USAGE PURPOSE	FLEXIBILITY	LIGHTNESS	INSTALLATION	REUSABILITY	COMPACTNESS
1	Tentative Shelter		Structural components are assembled at the site	DEMOUNTABLE	fiberglass panels	> 1 year	8 sqm	disaster shelter	NO	Lightweight	Not found	YES	One unit as kits of parts compact size = 30 cm
2	Shelter Pack		Structural components are assembled at the site	DEMOUNTABLE	plastic frame	> 6 month	12 sqm	disaster shelter	NO	Lightweight	3 hours by 2 people	YES	One unit as kits of parts compact
3	IKEA Better Shelter		Structural components are assembled at the site	DEMOUNTABLE	polyetilene fibres, polyefelin panels	> 1 year	17.5 sqm	refugee shelter	NO	Heavy	1 hour by 2 people	YES	One unit as kits of parts compact
4	Telescopic Tent		Structural components are assembled at the site	DEMOUNTABLE	elastic waterproof nylon material	> 6 month	16 sqm	disaster shelter	YES	Lightweight	4-5 minutes by 2 people	YES	One unit as kits of parts compact

Fig. 1 Demountable shelters

Having a heavy structure, the *IKEA* Shelter covers 17.5 m^2 whereas the *Shelter Pack* and the *Telescopic Tent* examples are characterized by their lighter build, albeit with slightly reduced durability due to their plastic materials. Notably, the *Telescopic Tent* stands apart for its quick setup time of 4-5 minutes, requiring only two people for assembly. Each of the four demountable examples presented here meets all technical requirements. However, the *Telescopic Tent* differs in one aspect: it lacks fire resistance due to the materials used in its production.

B. Relocatable Shelters

Relocatable shelters are transported in sizable components, with assembly taking place on-site. Since relocatable systems are structurally less complex than portable systems, they are well-suited for meeting the need for short-term temporary shelters (Fig. 2).

During the assembly process of the *Emergency Shelter* example, foldable plates unfold, and door and opening parts are raised from the ground to form the side walls. The system's relocatability stems from its disassembled parts, allowing for swift assembly in 7-8 minutes by 2 people. With a spacious area of 15.7 square meters, it accommodates a minimum of 3 and a maximum of 5 people.

In certain systems, prefabricated components encompass not only plastic materials but also elements such as wood and its derivatives. For instance, wooden prefabricated elements are used in the *Extremis Technology Hush Shelter* [6] that is assembled on-site. One can install this shelter in two hours, and its durability exceeds a year. A larger area can be covered when multiple units are combined. On the other hand, the *Just a Minute Shelter* is made of bamboo-based material which makes the system lightweight and provides ease of transportation compared to the *Extremis Technology Hush Shelter*.

Lightweight systems not only provide significant advantages but also enhance flexibility in mechanisms. Composed of lightweight plastic material, the *SURI Shelters* and *Modular Flex Shelter* are flexible but have a shorter lifespan when compared to other examples. Featuring an accordion-like design, the *Suri Shelters* allow for ease of folding and unfolding. Having steel elements, the *Dingrong shelter* is heavier than others; however, it has an extended lifespan of around 20-30 years. Composed of 45 separate modules that can be transported on a single truck, the *TMMOB Disaster Shelter* [7] has multifunctionality. It is equipped with wheels at the bottom to offer ease of mobility.

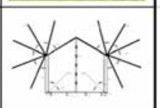
SHELTERS			SYSTEM CHARACTERISTICS				FUNCTIONALITY			DESIGN CONSIDERATIONS			
#	NAME	3D VIEW	SYSTEM	SHELTER TYPE	USED MATERIALS	LIFE SPAN	PROVIDED AREA	USAGE PURPOSE	FLEXIBILITY	LIGHTNESS	INSTALLATION	REUSABILITY	COMPACTNESS
5	Emergency Shelter		Foldable plates are opened, and door and opening parts are lifted from the ground to install side walls	RELOCATABLE	fire retardant materials	> 6 month	15.7 sqm	disaster shelter	NO	Lightweight	7-8 minutes by 2 people	YES	-
6	Just a Minute		Some components of the structure can be prefabricated off-site, with the system and finishing elements integrated on-site	RELOCATABLE	bamboo bars, tent	> 1 year	29 sqm	refugee shelter	YES	Lightweight	-	YES	-
7	SURI shelters		The accordion-like design allows for the folding and unfolding of the system	RELOCATABLE	biodegradable materials	< 1 year	expandable	refugee shelter	YES	Lightweight	-	YES	-
8	Modularflex Shelter		Structural components are assembled at the site	RELOCATABLE	plastic frame	> 6 month	expandable	disaster shelter	YES	Lightweight	-	YES	-
9	Dingrong		Foldable plates are opened, and door and opening parts are lifted from the ground to install side walls	RELOCATABLE	plastic frame	> 10 year	35 sqm	disaster shelter	NO	Heavy	-	YES	-
10	Extremis Technology Hush Shelter-2 2014		Foldable plates with hinges	RELOCATABLE	Wooden insulated walls	> 1 year	19 sqm	disaster shelter	YES: Units can be combined	Heavy	2 hours by one person	YES	Compact folded unit No size specified
11	TMMOB Disaster Shelter 2012		Foldable plates & panels with hinges	RELOCATABLE	MDF plates, panels & L-shaped water-protective components with white lacquer coating	> 1 year	9 sqm	disaster shelter	YES: Panels can be removed & another unit can be combined with hinges	Lightweight & has wheels to carry	< 1 hour by one person	YES	As one compact module = 30x300x260cm 45 modules can be carried in one truck

Fig. 2 Relocatable shelters

C. Portable Shelters

Portable shelters can be transported as a whole and do not need on-site construction; thus, they provide ideal design solutions for urgent situations like natural disasters or humanitarian crises (Fig. 3). Their rapid deployment capabilities enable prompt assistance and relief to those in need.

The *Folding Pod* and the *Accordion Shelter* employ hinges between folding plates to facilitate movement and expansion. Expanding longitudinally, the *Accordion Shelter* resembles the folding origami. In origami-like shelters, multiple plates fold to occupy minimal space. However, a membrane and bar system are used in the *Cmax* rather than rigid plates. Although this provides advantages in terms of portability and storage, it does not comprise long-term durability as the others.

Portable shelters composed of scissor mechanisms and foldable plates are promising since they allow large shape transformations. Uçar's *Portable Shelter* [8] and *Tenfold* shelters are examples of the integration of scissors and folding plates. Using a scissor system, expandable parts extend outward from the core area to create a voluminous structure. While

Tenfold shelters are robust and capable of reaching their largest form within minutes by a single person, they are relatively heavy due to the materials used. Despite this, they boast one of the longest durability periods among the selected examples.

In contrast, the *Yanko Design House*'s folding plates incorporate telescopic elements that allow the system to transform from a compact form to a deployed state. The *Awning* example, which is not intended for emergency use, showcases the potential of membrane and folding systems, albeit with a durability period of less than 6 months.

SHELTERS			SYSTEM CHARACTERISTICS				FUNCTIONALITY			DESIGN CONSIDERATIONS			
#	NAME	3D VIEW	SYSTEM	SHELTER TYPE	USED MATERIALS	LIFE SPAN	PROVIDED AREA	USAGE PURPOSE	FLEXIBILITY	LIGHTNESS	INSTALLATION	REUSABILITY	COMPACTNESS
12	Yanko Design House		The scissor mechanism facilitates the opening of the structure's walls, while the bottom part features folded plates that expand the floor area	PORTABLE	Steel scissor structure, panels	> 1 year	-	disaster shelter	NO	Heavy	-	YES	-
13	The Awning		Hand-operated movable panels are integrated, and designed to open alongside the tent walls they accompany	PORTABLE	movable panels, tent	> 6 month	-	versatile	NO	Heavy	-	YES	-
14	Drop Off Unit		The system of retractable and cantilevered elements emerges from the lateral sides, facilitating the expansion of the unit's main floor area with ease	PORTABLE	aluminum bars and foam materials	-	-	versatile	NO	Heavy	-	YES	20 shelters can be transported at once in one truck
15	Accordion Shelter		The shelter's base consists of folded plates, while the walls and roof unfold and extend longitudinally, expanding the structure	PORTABLE	movable panels, tent	> 6 months	-	disaster & refugee shelter	YES	Lightweight	-	YES	-
16	Cmax Units		Hand-operated movable panels slide open while the tent is manually pushed and secured into place using two bars	PORTABLE	movable panels, tent	< 6 months	9 sqm	versatile	YES	Lightweight	2 minutes by 2 people	YES	-
17	Fold-Out Rigid Temporary Shelter		The foldable roof, floor, and walls unfold from the core transforming the space	PORTABLE	alumunium structural frame with plates	> 6 months	280 sqm	versatile	NO	Heavy	2 minutes by 2 people	YES	-
18	Uçar - Portable Shelter Proposal 2015		Container-type structure with steel expansion solution	PORTABLE	Steel, PVC panels	Materials are durable but cannot be assured time	18 sqm	disaster shelter	YES: Expands by changing dimensions of scissors & panels	Heavy	2 minutes by 2 people	YES	One unit package = 120x650x270cm
19	TenFold Self Deploying Structures		The foldable roof, floor, and walls opened from the core transforming the space	PORTABLE	alumunium structural frame with plates	> 1 year	15.9 sqm	versatile	YES	Heavy	In minutes by one person	YES	-
20	Folding Pod		Foldable plates with hinges	PORTABLE	lightweight sustainable panels	> 6 months	128 sqm	versatile	NO	Lightweight	In minutes by one person	YES	16 feet long x 8 feet wide x 8 feet high

Fig. 3 Portable shelters

Comparing Uçar's *Portable Shelter* with the *Fold-Out Rigid Temporary Shelter*, the latter replaces scissor elements with telescopic bars to lower the floor plate from the core area. One of the biggest contributions of the carrier elements supporting the ground allows for installation without requiring site work, offering flexibility in placement.

Two people can efficiently install the *Drop-Off Unit* within just 30 minutes. A single truck can transport 20 *Drop-Off Units* at once. These units, constructed from durable aluminum and foam materials, are equipped with both bathroom and kitchen facilities for added convenience.

III. Temporary Shelter Design Proposal

In times of emergency and situations demanding swift deployment of temporary shelters, kinetic structures can be used since they offer various advantages, including portability, space efficiency, rapid assembly, and adaptability. To address the aforementioned requirements, a foldable shelter system has been proposed which is composed of a total of 18 plates (Fig. 4).

All plates function within the foldable system, except two rectangular side plates. The system is activated by moving a 6-piece triangular foldable plate positioned along the short sides of the shelter. As the plates fold inward, the rectangular plates divided into two equal parts on the ceiling and floor also fold inward. Consequently, the mechanism divides the facade into two sections: 4 small triangles and 2 large triangles.

As depicted in Fig. 4, the objective is to facilitate movement bringing the large facades closer together by incorporating the floor and ceiling within the shelter. This configuration is achieved through the layout of foldable plates determined on the short facades of the system. When the system is folded, the plates move inward, maximizing space utilization within the shelter. Constructed from insulated materials, these plates are intended for repeated use across various climates and regions, ensuring versatility and durability.

A single shelter unit spans an area of 9.6 m², accommodating up to 2 or 3 occupants with a ceiling height of 2.6 meters.

Within this unit, there is a designated resting area covering 6.2 m² and a separate bathroom space measuring 3.4 m² (Fig. 5). Emphasizing practicality, the design maximizes storage capacity to accommodate the belongings of shelter users efficiently. Using foldable plates, the structure can be compacted into a small package facilitating easy packing, storage, and transportation. To optimize space utilization, sliding doors have been integrated into the design, ensuring a minimal footprint when the system is deployed.

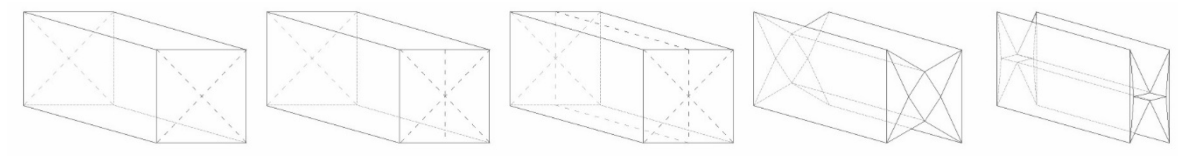


Fig. 4 Folding diagram of the proposed shelter

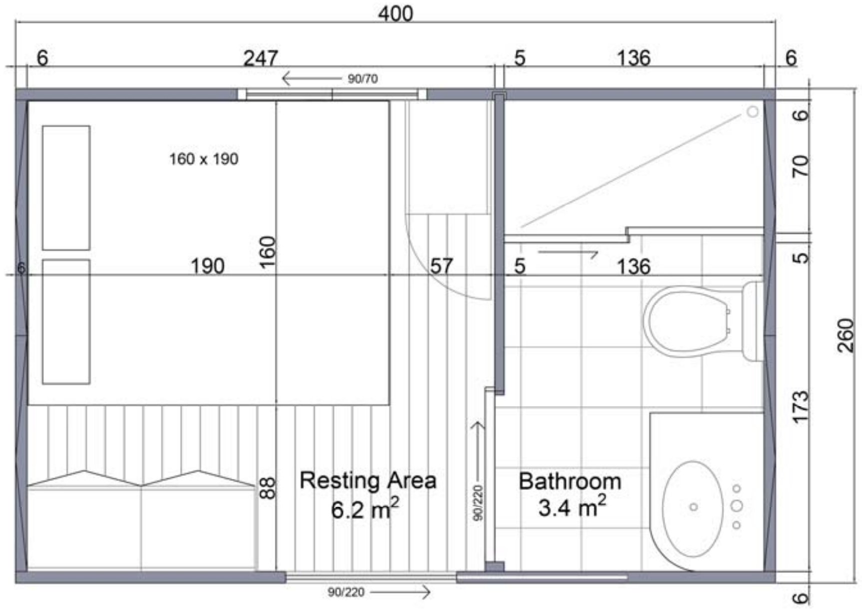


Fig. 5 Plan layout for a single shelter unit

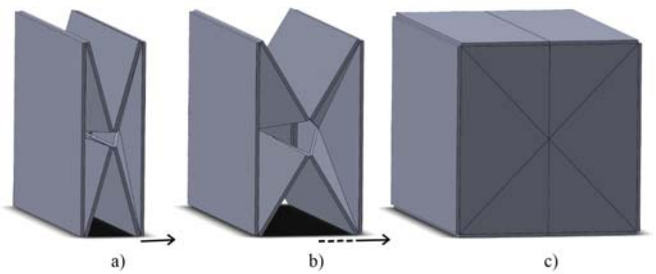


Fig. 6 Proposed foldable shelter: (a) compact state, (b) semi-deployed state, (c) deployed state

Even though the overall system may be heavy due to its large pieces of plates which necessitate 3-4 people for transportation, only a pulling force from one side is required during the installation phase (Fig. 6). The installation of the shelter can be efficiently carried out by just 1-2 people by deploying the plates from one side. In its compact state, a single shelter unit measures 90 cm x 400 cm x 260 cm (Fig. 7), allowing 6 units to be vertically stacked and transported by truck simultaneously.

Two separate modules can be combined from their short sides as shown in Fig. 8, forming a versatile space ideal for families with more than 2 people. The newly expanded space is divided by partition walls to create resting and living areas. The partition walls are designed to slide along the ceiling and floor, ensuring flexibility and ease of movement.

Unlike typical temporary shelters designed for short-term use lasting no longer than 6 months under normal conditions, the proposed shelter boasts an extended lifespan owing to its durable materials. Incorporating a folding plate system not only within the shelter's structural framework but also in its furniture enhances functionality. Using folding furniture creates additional areas for activities such as working, playing, or cooking within the shelter units, effectively expanding usable space for diverse needs.

Invisible cross hinges have been used to connect foldable plates, ensuring smooth and unobstructed folding. Positioned within gaps located at the edges of the plates, these hinges follow an arc-shaped path that facilitates the folding process (Fig. 9). This placement prevents the plates from colliding with each other during folding as depicted in Fig. 10. Careful consideration has been given to the spacing between the hinges to ensure that it does not impede the rotation of the shaft along its path. This guarantees optimal functionality and reliability of the hinge mechanism.

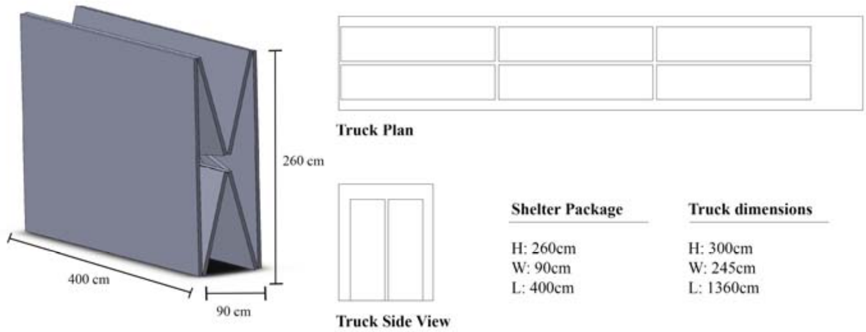


Fig. 7 Transportation packaging diagram

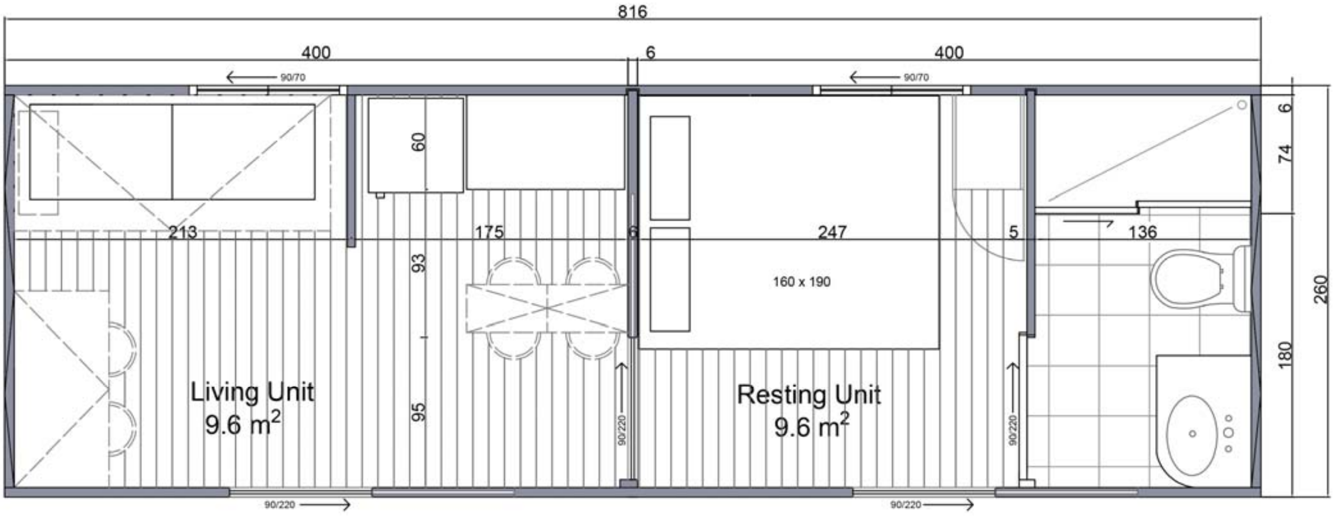


Fig. 8 Plan layout of two shelter unit combination

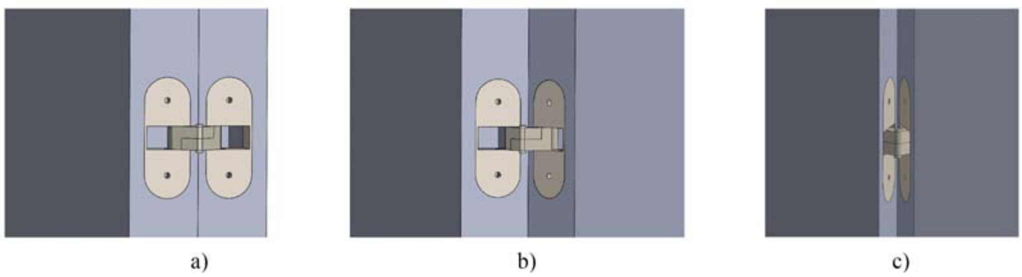


Fig. 9 Invisible hinge placed between plates

IV. Conclusion

The rise in displacement can be attributed to the frequent occurrence of both natural catastrophes and man-made disasters in recent years. As a result, the demand for shelter in the aftermath of these events increases but conventional types of temporary shelters cannot fully meet people's needs. This has spurred the emergence of innovative design solutions for temporary shelters, among which kinetic solutions have gained prominence for their adaptability to changing post-disaster conditions.

In this paper, first, different types of temporary shelters having kinetic systems have been reviewed. Based on the examined examples, it can be said that portable shelters have emerged as a particularly viable option due to their ease of implementation, transport, and storage. Despite their potential heaviness, many portable and foldable temporary shelters can be transported in bulk, offering a significant logistical advantage over prefabricated or container-based alternatives commonly deployed in the field. In contrast to portable shelters, demountable and relocatable shelters occupy minimal space as they can be easily disassembled. This feature offers the added benefit of transporting multiple units at once.

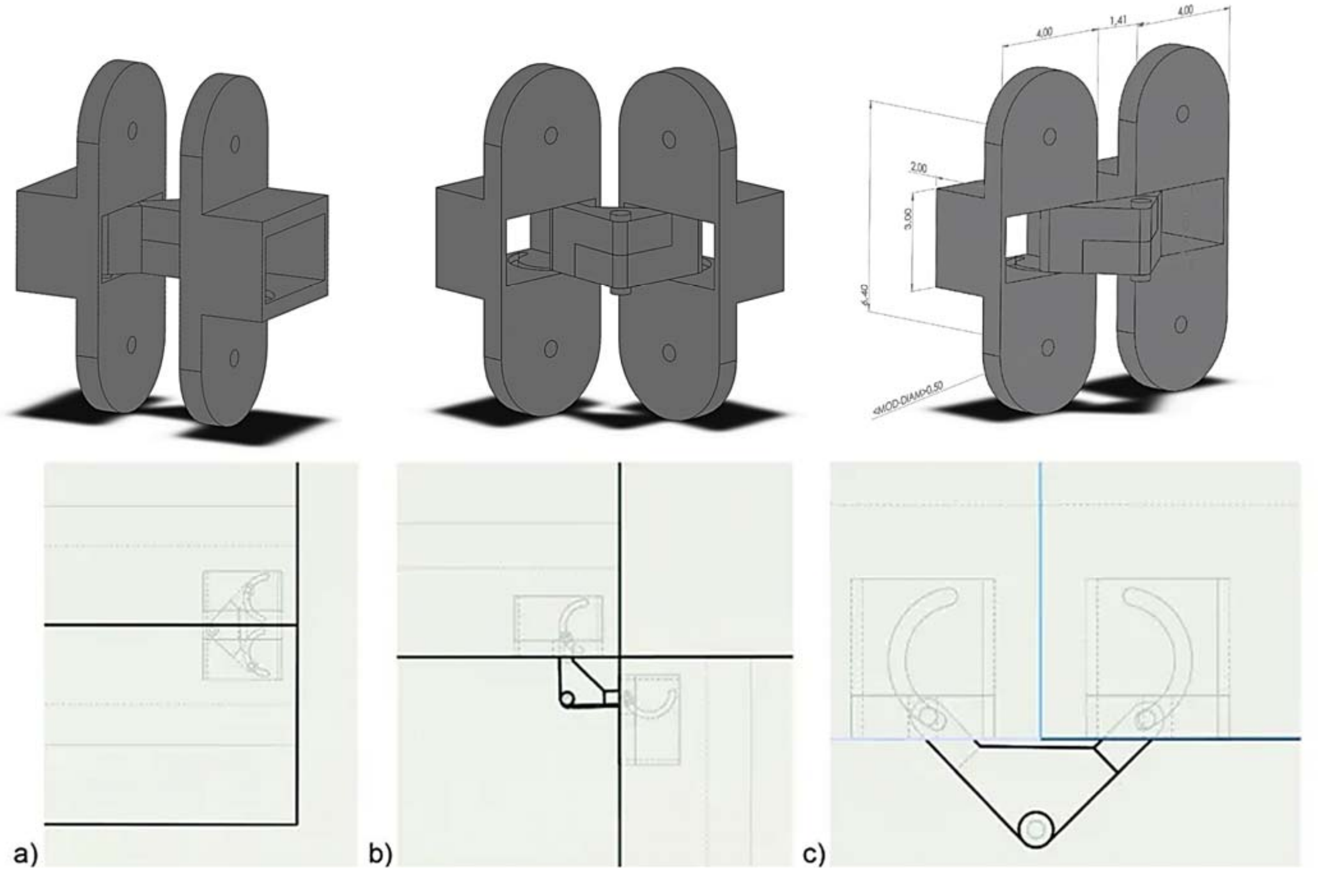


Fig. 10 Hinge detail: (a) fully closed state, (b) 90-degree opened state, (c) 180-degree opened state

Compared to the existing complex shelters, it can be claimed that the proposed foldable shelter offers a viable solution since it has a simple mechanism. Because it has a modular system composed of only foldable plates, various unit combinations can also be created to meet the changing needs and conditions.

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