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Exploring the Potential of Modular Design in Addressing Post-Disaster Temporary Housing Needs

Afet Sonrası Geçici Barınma İhtiyacının Karşılanmasında Modüler Tasarımın Potansiyelinin Araştırılması

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ABSTRACT

In February 2023, a devastating earthquake struck Southeastern Turkey resulting in numerous fatalities and displacements. The number of displaced people seems to increase worldwide. This paper examines current solutions for temporary housing needs and evaluates how modular structures can improve flexibility, customizability, and sustainability. This article discusses the need for adaptable temporary housing. For this purpose, examples produced in different geographies are examined and compared with each other in terms of their climate zone, construction technologies, construction period, floor areas, plan schemes, and number of users in the scope of this paper. Traditional shelters often lack customizability, leaving users feeling a lack of privacy. Modular designs, however, offer flexibility and adaptability, making them an effective solution for temporary housing needs. Despite their advantages, modular designs face challenges such as high costs, transportation logistics, and regulatory compliance. With careful planning, these challenges can be addressed.

Keywords: Modular Design, Displaced People, Post-Disaster Housing, Temporary Housing, Adaptability

ÖZ

Şubat 2023'te Türkiye'nin Güneydoğu Anadolu Bölgesi'nde meydana gelen yıkıcı deprem, sayısız can kaybına ve yerinden edilmeye sebep olmuştur. Bu makale, geçici barınma çözümlerini incelemekte ve modüler sistemlerin yapıların esnekliğini, kişiselleştirilebilirliğini ve sürdürülebilirliğini artırmadaki potansiyelini değerlendirmektedir. Makale, adapte edilebilir geçici konut ihtiyacını karşılamaya yönelik çözümleri tartışmaktadır. Bu amaçla farklı coğrafyalarda üretilmiş örnekler, bulundukları iklim kuşağı, yapım teknolojileri, yapım süreleri, taban alanları, plan şemaları ve kullanıcı sayıları üzerinden incelenerek birbirleriyle karşılaştırılmaktadır. Alışılagelmiş barınma birimleri genellikle kişiselleştirilebilir nitelikler taşımamakta, bu da kullanıcıların mahremiyet eksikliği hissetmesine neden olmaktadır. Modüler tasarımlar esneklik ve adaptasyon kapasitesi sunmakta, bu da onları geçici konut ihtiyaçları için etkili bir çözüm haline getirmektedir. Avantajlarına rağmen, modüler tasarımlar yüksek maliyetler, lojistik problemler ve mevzuata uygunluk gibi konularda zorluklara da sahiptirler. Ancak nitelikli bir planlama süreci ile bu zorluklar da rahatlıkla aşılabilir.

Anahtar Kelimeler: Modüler Tasarım, Yerlerinden Olmuş İnsanlar, Afet Sonrası Konut, Geçici Konut, Uyarlanabilirlik

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INTRODUCTION:

The increasing frequency, intensity of natural disasters and conflicts globally have led to a significant rise in the number of displaced people. According to the UNHCR, displaced people include "persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights, or natural or human-made disasters" (UNHCR, 2022). By the end of 2022, 108.4 million people were forcibly displaced worldwide due to persecution, conflict, violence, or human rights violations (UNHCR, 2022). Displaced individuals can be categorized as internal (within their own country) or external (across international borders), each group facing unique challenges and needs.

The urgency for effective temporary housing solutions is crucial, particularly in the immediate aftermath of such events. Modular housing has emerged as a promising solution due to its speed of construction, practicality, and economic advantages. Modular housing designs are pre-assembled in factories and then transported to the site for final assembly. This approach offers several benefits, including increased energy efficiency, sustainability, and better-quality control compared to traditional construction methods (Lawson et al., 2014; Bayliss & Bergin, 2020). The adaptability and customizability of modular housing make it an ideal option for addressing the varied needs of displaced populations in diverse geographical and climatic conditions.

This study draws inspiration from the Kahramanmaraş earthquake in February 2023, which highlighted the urgent need for efficient temporary housing solutions. Although the earthquake serves as a poignant example, this research is not limited to this specific event. Instead, it aims to explore the broader potential of modular design in meeting post-disaster temporary housing needs across different contexts.

By examining various case studies of temporary housing solutions produced following natural disasters, this paper assesses the advantages and challenges of modular designs compared to traditional shelters. Factors such as climate zone, construction technologies, construction period, floor areas, plan schemes, and number of users are analyzed to provide a comprehensive understanding of the effectiveness and practicality of each housing approach. The aim of the paper is to discuss the potential of modular design as temporary housing in post-disaster zones.

1. Materials And Methods

This study investigates the concept of displaced people and the role of modular design in addressing their temporary housing needs. The research begins with a literature review to explore these concepts and then moves on to analyze five case studies of temporary housing solutions following natural disasters with variable levels of modularity.

Five case studies were selected: two traditional and three modular shelters, chosen based on relevance to post-disaster scenarios, diversity in geographic locations, and representation of both traditional and modular housing solutions. The selected case studies span from 2000 to 2022, offering a view of recent developments in temporary housing. These case studies are examined based on topics such as climate zone, construction technologies, construction period, floor areas, plan schemes, and number of users. The comparison of these case studies aims to provide a thorough understanding of the effectiveness and practicality of each temporary housing approach.

Data were collected through literature reviews, archival research, and direct analysis of the case studies. The analysis focused on comparing the advantages and challenges of traditional and modular designs. Modular designs were evaluated for their flexibility, speed of construction, and cost-effectiveness, while traditional designs were assessed for their historical context and adaptability. The research questions explore how modular housing compares to traditional shelters in terms of flexibility and adaptability, the challenges and advantages of implementing modular designs, and the influence of different contexts on their effectiveness. The hypotheses propose that modular designs offer greater flexibility and adaptability, that challenges such as costs and logistics can be mitigated through planning, and that modular designs are more effective in diverse contexts due to their customizability.

A comparison chart summarizing the findings will be provided at the end of the section to visually present the results and facilitate a clearer understanding of the different temporary housing approaches analyzed.

2. Theoretical Framework

Displaced people, as defined by the UNHCR, are individuals forced to leave their homes due to conflicts, violence, human rights violations, or disasters. By the end of 2022, 108.4 million people were forcibly displaced worldwide. Displaced individuals can be internal (within their own country) or external (across international borders). Post-disaster housing needs are critical, involving stages from emergency to permanent housing. Effective housing recovery policies must address these needs to ensure the well-being of displaced populations.

Modular designs, pre-assembled in factories and organized on-site, offer flexibility, adaptability, and customizability, making them suitable for post-disaster housing. They are known for energy efficiency, sustainability, and quality control. This study examines temporary housing solutions through case studies, highlighting the potential of modular designs.

The research questions explore how modular housing compares to traditional shelters in flexibility and adaptability, the challenges and advantages of implementing modular designs, and the influence of different contexts on their effectiveness. The hypotheses propose that modular designs offer greater flexibility and adaptability, that challenges such as costs and logistics can be mitigated through planning, and that modular designs are more effective in diverse contexts due to their customizability.

2.1. Displaced People and Their Housing Needs

According to the UNHCR (United Nations High Commissioner for Refugees) displaced people are "persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights". They are fleeing natural or human-made disasters. By the end of 2022, 108.4 million people were forcibly displaced worldwide as a result of persecution, conflict, violence or human rights violations (UNHCR, 2022, p.2).

Displaced individuals are categorized as either internal or external, depending on whether they have crossed an internationally recognized border. Internally displaced people remain within their own country, while externally displaced people have crossed an international border (UNHCR, 2022).

Post-disaster housing needs are critical for displaced people, as they often face challenges in finding safe and adequate shelter. The transition from emergency sheltering to permanent housing involves multiple stages, including temporary sheltering, temporary housing, and permanent housing (Quarantelli, 1982). Effective post-disaster housing recovery policies must address these needs to ensure the well-being and stability of displaced populations (UN-Habitat, 2019)

The housing needs of displaced people depends based on when they were displaced from their home of origin. The order for the housing needs goes from a short term towards a medium-term need and long-term housing needs where they can fully resume their lives. In the immediate aftermath of a disaster or conflict, displaced communities often require basic shelter. However, from the very onset of their displacement, the recovery process for these communities begins. Consequently, the role of housing evolves beyond mere physical protection to encompass a multifaceted purpose. Housing serves as a space for personal activities, addresses the social and emotional needs of the community, facilitates economic conditions for the displaced, and fosters a sense of belongingness and social cohesion (Jayakody et al., 2022).

Emergency shelter is a structure that provides the basic need of sheltering humans from the elements in citations where they have been displaced from where they used to live by natural or man-made causes. These types of shelters need to be provided in a very short period of time. Emergency shelters need to be delivered to the affected people as soon as possible and this makes speed the most important factor. Due to the immediate need of these shelters, they are most of the time low quality and just provide enough to shelter the users from the elements.

Temporary housing is a type of shelter that is meant for short term to medium term use. This involves the reestablishment of household routines but with the understanding that more permanent quarters will be eventually obtained. The duration of stay in such temporary houses may be limited, and therefore prioritizing speed and limiting the costs should be taken into account when constructing this type of houses (Quarantelli, 1991).

2.2. Modular Housing Designs

Modular houses use prefabricated construction method, which involves designing and producing individual components in a factory or a controlled setting, after which those components are delivered to be assembled into a completed structure (Lawson and etc., 2014).

Using modular construction methods provides several advantages over traditional construction methods. Speed is one of the major advantages, as modular construction can reduce the construction time by up to 20-50% (Johnson, 2007). In addition, modular designs offer flexibility, allowing for customization to specific requirements and preferences of clients and end-users. Modular construction also uses less materials as using this method reduces waste. This makes modular structures more environmentally friendly and reduces labor on site (Bertram and etc., 2019).

Modular housing possesses several advantages over traditional construction methods, first among which is it is faster to build. Since the modules are built in a factory or an enclosed workshop, most of the components arrive prebuilt on the building site. This can significantly reduce construction time, which is especially important in emergencies. Secondly, when the cost is considered, modular housing is more cost-effective when compared to the traditional construction methods. By prefabricated components, manufacturers' economies of scale can be archived which translates into lower construction costs (Bertram and etc., 2019).

Several challenges will be encountered while using modular structures, one major challenge is the expensive initial cost of designing and manufacturing. In addition, the transportation costs can be high especially when the delivery is to disaster areas which can be hard to access (O'Neill, 2021). Modular homes are typically transported by truck, meaning they must conform to transportation regulations limiting the size and design of the modules. Costs can increase when the distance of transportation is increased (YiWen and etc., 2019). Modular housing requires a different set of skills than traditional construction, and there may be a shortage of workers with the necessary expertise. Finally, modular housing may face challenges related to zoning and building codes. Since modular housing is a relatively new construction method, local building codes and zoning regulations may not be adapted to this type of housing. This can create challenges for builders and developers (YiWen and etc., 2019).

Modular housing designs offer several advantages over traditional construction methods for emergency housing needs. However, there are also potential challenges and limitations to be considered. With an exquisite evaluation of these factors and development of appropriate solutions, modular housing can be a highly effective solution for the urgent housing needs following natural disasters such as the earthquake took place in Turkey on February 6th, 2023. It is worth noting that while many of the advantages and challenges of modular construction are similar worldwide, there may be some variations in terms of local regulations, availability of skilled labor, and cultural factors that should be considered when implementing modular designs in different regions, including Turkey.

3. Case Study: Examples of Temporary Housing

The case studies selected for this paper focus on temporary housing structures designed to shelter displaced individuals in the aftermath of disasters. These case studies are analyzed based on several key aspects: their design and layout, the materials employed, and the successes and challenges encountered during their implementation. A comparative analysis of five temporary housing examples was conducted, chosen based on a range of criteria including cost, geographic diversity, and climatic variability. The selected cases encompass structures ranging from low-cost to higher-cost solutions, ensuring a comprehensive evaluation across a broad spectrum of applications. Among these, the first two case studies utilize traditional construction methods, while the last three adopt modular approaches. In addition to examining their plans, layouts, and materials, the analysis also considers critical factor of cost efficiency, user satisfaction, durability, and the time required for construction.

Particular attention is given to how these factors influence the overall effectiveness of the housing solutions in meeting the needs of displaced populations.

3.1. No-1: Dadaab Settlement

Figure 1: Dadaab shelters (UNHCR, 2021)

Dadaab is a refugee complex found in the horn of Africa in the Garissa County, Kenya. This area has a yearly temperature varying from 22 to 36 °C. The area is very hot and is classified as a desert however sometimes it is prone to flooding during the rainy season between October and May. The shelters built here are independent units, which are used as a sleeping and living quadrant while the bathroom and cooking facilities are shared between the units (Figure 1).

Each singular structure has an internal service area of 19.8 m2 [3.2 m x 6.2m]. The structures are not partitioned inside having an open single room (Figure 2). These structures are designed to accommodate a maximum of 6 people inside. The structure is designed with an ingress point front façade with no windows. The dimensions of the door are 100x195 cm. and for with the ventilation being provided by the opening under the eaves. This structure doesn't possess any wet service areas (kitchen and toilet). As a result, settlement was equipped with access to water sources and communal toilets and showers (UNHCR, 2021).

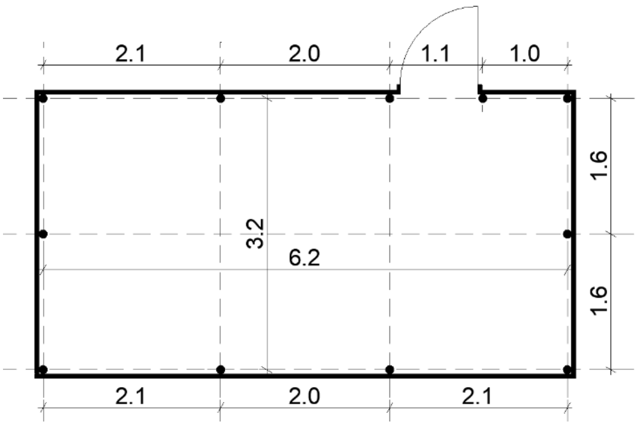


Figure 2: Daddab shelter floor plan (UNHCR, 2021)

The materials used for this project are a combination of local and imported materials. The timber frames that were used for the structure was imported from neighboring countries. Other materials like plastic-based items, steel and iron products were generally imported from China (UNHCR, 2021).

The Dadaab shelters demonstrate modularity through their use of standardized, prefabricated components, enabling quick assembly and consistent replication across the settlement. This design ensures efficiency and adaptability in layout planning. However, the current modular approach lacks features like internal partitions or integrated wet service areas, limiting its ability to address privacy and functional needs.

These houses are very cheap and fast to make with an estimated minimum price of 463 USD to manufacture a single unit which is estimated to last two years. The shelters were designed to be useful for two years but these shelters have been used for a longer span. These houses are designated for single-use, implying that they were not designed to be reused. The biggest downside of these structures is that they were not designed to counteract the effects of the heat during peak summer as the corrugated iron sheets that were used as the roofing material can create a greenhouse effect inside. The room was designed to shelter 5 people with the kitchen and the toilet being communal. Making the toilets and the kitchen communal contributed in making the shelters cheaper but took away from the privacy aspect of things. The singular spatial configuration of these shelters engenders a notable drawback: a deficiency in privacy. This deficiency manifests on two fronts: firstly, in the context of the shared accommodation, where a single room accommodates five individuals without any partitioning, and secondly, in the communal bathing facilities.

3.2. No-2: Kutapalong Settlement

Kutapalong is a settlement constructed for the displaced Rohingya people and is located in Ukhia, Bangladesh. The site is located in the hilly landscape area which is located in a highly cyclone-prone area. The site planning, infrastructure and facilities was handled by the UNHCR (The United Nations High Commission for refugees). The people that were hosted on the site were assisted with either finalized shelters or shelter kits (Figure 3).

Figure 3: Kutaplalong shelters (UNHCR, 2021)

Each singular structure has an internal service area of 17.5 m2 (5 m x 3.5 m). The structures are not partitioned inside having an open single room (Figure 4). The structure is designed with a single door on the front façade and three windows. The dimensions of the door are 90 x 200 cm. and for the windows 60 x 100 cm. This structure doesn't possess any wet service areas (kitchen and toilet). As a result, settlement was equipped with access to water sources and communal toilets and showers. The temporary shelters were designed to have a bamboo structure which is elevated to mitigate the frequent flooding that regularly happens in that area. The structures also have a concrete pad foundation to counteract against landslide.

The structure of the shelters is made from locally sourced treated bamboo frame with the walls being lined up from one of two materials. The walls were lined up with either woven bamboo mats or by

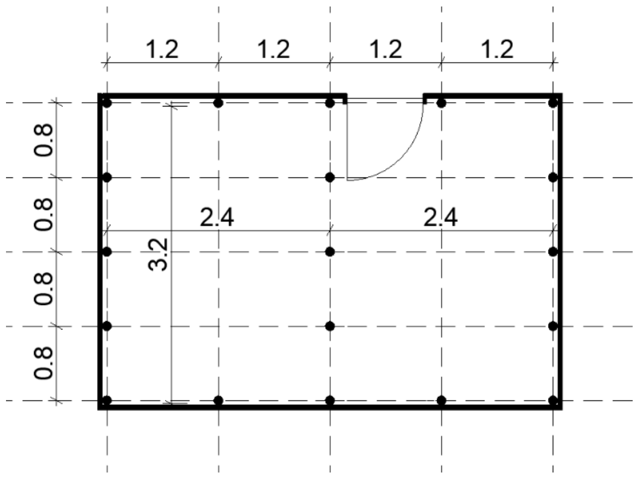


Figure 4: Kutaplalong shelters floor plan (UNHCR, 2021)

plastic tarpaulins. For the roofs also there were two types of materials used with one of them being the plastic tarpaulins and the other being corrugated iron sheets. The foundation for the shelter were precast reinforced concrete posts. The floors were made up of woven bamboo mats that rest on bamboo poles (UNHCR, 2021,). The water, bricks, sand, aggregates, cement, timber and bamboo were sourced locally while the plastic-based items and some steel and iron products are generally imported (UNHCR, 2021). The cost of the shelters was estimated in 2021 to be a minimum of 739 USD per shelter according to the UNHCR.

The Kutapalong shelters showcase flexibility through the use of bamboo structures and prefabricated concrete posts, enabling quick construction and adaptability to challenging terrain. While cost-effective and flexible, the same as the Dadaab Settlement the absence of internal partitions and integrated wet areas limits functionality and privacy. This project was able to provide the displaced people with a shelter that was not that expensive to build, maintain and modify. The shelters were designed to have a life span of 2 years but they have been utilized for longer that the design intended. These shelters were designed with the environmental hazards in mind as they try to mitigate them. These shelters were bare bones and basic as in their stock format they provide a single 17.5m2 room. The room was designed to shelter 5 people with the kitchen and the toilet being communal. Making the toilets and the kitchen communal contributed in making the shelters cheaper. As these shelters have a single room one of their disadvantages are the lack of privacy. The lack of privacy can be felt in both the shelters having a single room to be shared by five people and also the bathrooms being communal.

3.3. No-3: Temporary Prefabricated Settlements, Kocaeli

Kocaeli is a city located in the northwestern part of Türkiye located approximately 110 kilometers east of Istanbul. On August 17th, 1999, a 7.4 Richter scale earthquake struck the province of Kocaeli (Toksoz et al., 1999, p.670). The earthquake resulted in the loss of more than 17,000 lives and leaving 400,000 to 600,000 people homeless (Scawthorn and Johnson, 2000, p.744). This earthquake was the most destructive and deadly earthquake in Türkiye until 2023.

After the disaster the people who survived were housed in emergency shelters which mostly consisted of tents. Those tents were winterized as at that time the fall season was starting. After staying in these tents, the survivors started moving into temporary houses in a period of 6 months to a year. After the disaster around a total of 44000 diverse types of temporary housing solutions were used, with the majority of them being state owned (Figure 5) (Baş, 2011, p.38). The Minister in charge of the project stated after using the temporary houses they will be dismantled and reused in Southeast Anatolia. The temporary houses were 30m2 blocks consisting of two units. The site plan included administrative units, agricultural areas, commercial areas, educational areas, healthcare facilities, mosques, public toilets, showers and laundry units, security, socio-cultural areas, water storage, carparks, and green areas being arranged in a linear form.

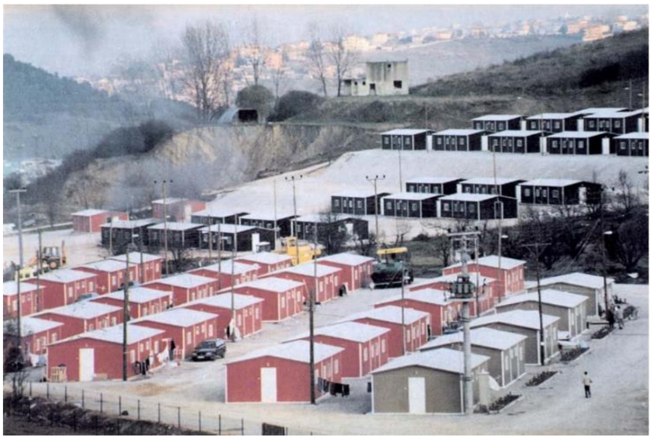


Figure 5: Temporary housing settlement İzmit (Baş, 2011)

The proposed solution was prefabricated houses with containing two mirrored units (Figure 6). The prefabricated houses contain two individual houses on the same unit. Each unit had its own studio living space which has the kitchen included. There is also a bathroom and a bedroom included in each house. The houses were designed to be occupied by a maximum of four people. All temporary settlements were established using a grid outline with twin house blocks arranged in a row housing order. The twin house blocks have either 12.5m x 6.5m or 11m x 5.5m as an internal dimension (Figure 6). The concrete bases ranged from 0.5m to 0.32m. The houses suffered from inadequate ventilation due to back-to-back construction. Unlike squatter houses they are not allowing for cross ventilation. The lackluster interior partitions did not give the adequate privacy for the residents resulting in the residents installing their own. The units each were supplied with two bunk beds and a pull-out couch.

The materials used for this project are different and diverse. The base (foundation) of the houses was made of concrete. This gave the house a platform and raised it from the ground. The frame of the houses was wooden with the walls being made out of gypsum and wooden sandwich panels. The roof was lined with corrugated iron sheets which were not the ideal materials especially when it comes to warm days.

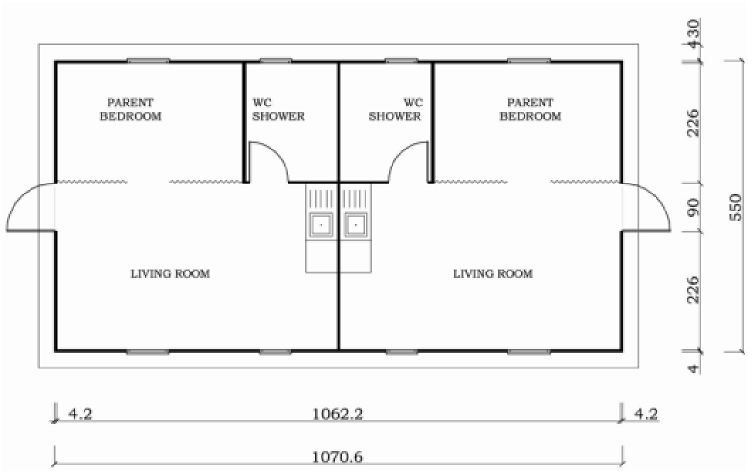


Figure 6: Floor plan of the temporary settlements 1999(Baş, 2011)

This project showed that prefabricated structures can be used as temporary houses after a disaster in Turkey. The project was able to provide housing for more than 100,000 people until their primary residences were constructed. The project was partially able to prove that after using these houses they can be disassembled and used in other areas and also can be kept in case of an emergency. This project was designed in a short amount of time and because of that it didn't properly take into consideration what the need of the final users in the medium term. In addition, considering everything including the infrastructure the cost of these units was 150 USD per square meter. The primary problem for the residents was the perceived lack of privacy. The use of thin gypsum board walls between two units proved insufficient, as it allowed for clear auditory transmission between the residences. Having a material with a better acoustic property in between the two units would have fixed that problem. Internally in each unit there was a lack of partition as there was only one bedroom and the bed was combined with the couch. This resulted in the lack of privacy for the kids that were sleeping in the living room. This resulted in the people modifying these spaces and placing their own partitions to make the spaces fit their own lives and activities.

3.4. No-4: Container Temporary Housing, Onagawa

Figure 7: Viviendas temporales Container (URL 1)

The initiative entailed the conceptualization, design, and erection of multi-level provisional residences in response to the 2011 Tohoku earthquake and tsunami. The goal was to promptly furnish affordable and cozy temporary homes for the individuals impacted by the colossal catastrophe (Hikone and Tokubuchi, 2011, p.3).

Built with shipping containers, this community was created to address the shortage of housing after the earthquake of 2011 in Onagawa, in Miyagi Prefecture. Unlike the usual emergency units, which need a lot of flat land for construction, this project increases the building density by stacking multi-story containers, a solution that also reduces construction time (Figure 7).

The site that was selected was not vast enough to accommodate all of the housing unit needs in a typical single unit temporary housing. To counteract that, the designers decided to stack up the units to create three distinctive floors in three individual buildings. Stacking the housing units into three-stories allowed to spare a central space to have communal spaces such as a market, a workshop, and a community center.

Each unit in these complexes was made up of two types of containers, the standard ISO one and plus box containers. The standard ISO containers were robust and easy to manufacture but they had some limitations concerning the size of the openings. On the other hand, the plus box had the same dimensions as the standard ISO container but without the restrictions attached to it. The plus box had open sides with only the corner frames to carry the structure (Figure 8). The designer cleverly combined the two types to create one unit with the ISO standard container being the bedroom and the bathroom section while the plus box was used as a living space (Hikone & Tokubuchi, 2011, p.4). There were two layout types provided, the 2DK with a single bedroom and the 3DK having two bedrooms. Both of these units had their own kitchen and bathroom, offering the users more privacy and independence. The 2DK is made up of 2 containers while the 3DK unit used three containers. The units could be accessed by an open corridor which was connected by an external staircase.

Figure 8: Left: Plus Box Frames Right: ISO converted frame, (Hikone & , Tokubuchi, 2011)

The materials used for this project were extensive, starting from the shipping containers which were made of Corten steel. The material plus the special high load bearing twist locks that were used to connect containers together, so that structural stability was achieved. The foundation used was a steel plate one which supported the weight of the containers on a compacted gravel layer. The floors of the units were lined up with laminated timber flooring.

The project was the first of its kind in Japan as these houses were the first temporary shelter that was built in a multistory fashion. Stacking the units on top of each other helped to increase the density of people living there. The use of the ISO container and the plus box helped in designing units that can be constructed in the shop and be ready made before shipping them to the site. In addition, the standard sizing was very helpful in terms of logistics. Most importantly, as far as these units were constructed as modules, they can potentially be transported and be used in different locations. The disadvantage of these units was their high cost and the time it took to design, manufacture and assemble on the site. Excluding the cost of the labor, the cost of the units per square meters is a minimum of 290 USD. The whole process from the design phase to the time the residents moving in took more than 7 months.

3.5. No-5: Close To Home: An Urban Model For Disaster Housing By NYC Emergency Management

Figure 9 Disaster housing by NYC emergency management prototype (URL 2)

Close to home is a prototype created for the general New York area to be used as an emergency house (Figure 9). New York is a state located in the northeast United States being the fourth most populous state having approximately 20 million people. This post-disaster housing prototype is planned to allow residents to stay in their neighborhood while their houses are repaired after a major disaster. The project is unique as it explores the idea of having a high density of temporary houses. Normally in cities there is no space to have temporary houses that have lower density as cities have a limited amount of space. This project was designed to overcome this characteristic of cities by hiving modular homes that are capable of high density. The prototype was designed and manufactured by Garrisons Architects and with input from the New York City's Office of Emergency Management, the Department of Design, construction, FEMA and the Army Corps of Engineer (Ford & Ahn, 2014, p.85). The design can be stacked one on top of the other enabling for a higher density. It can be transported by a truck, rail, or cargo ship to be deployed in affected areas. After extended use, it can be disassembled, stored off-site, and reassembled for future reuse.

There are two types of floor configurations with a one bedroom and three-bedroom configuration. The two configurations are based on the same overall footprint. These modular houses are fully fabricated and furnished in the factory which after are transported into the site for assembly. The one-bedroom layout can accommodate 2-4 people while the three bedrooms can handle 4-6 people. The prototype comes with a one bed and two bed configurations providing the residents with a living area, kitchen, store, bathroom. It also includes ventilation systems that are extremely energy efficient (Figure 10).

In the design phase all the stakeholders and professional were invited. Focus groups were established to work out what is the upmost priority for the residents of New York for a temporary house. Professionals including planners were involved from the planning stage to work out how the units should work individually and how those units will interact with each other on an urban scheme.

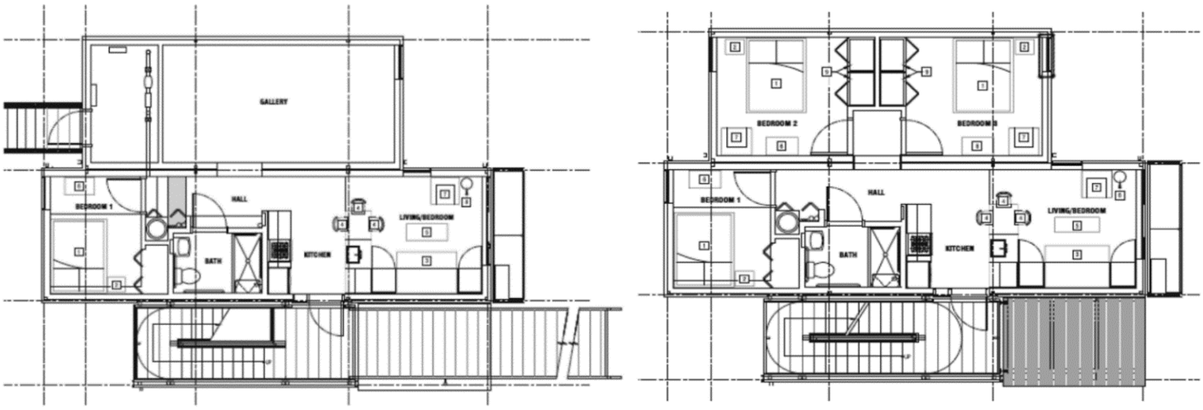


Figure 10 Right side One bedroom module, On the left the two bedroom module, NYC emergency management 2017

The frame of the structure is made of steel. The type of steel used is in the form of channel frames. The columns are also made of steel with a circular cross section. The floor is made of cork with a resin substrate which is tilled over. The exterior walls are made of gypsum wall boards which have a light steel gage framing. On the inside of the walls there is an insulation made up of mineral wool. The doors and the windows are made of fiber glass. The roof is a suspended gypsum board on a light gauge steel joist. The components of this modular house fit to the exact dimensions a commercial container so they can be transported by the use of common trucks. The buildings are planned to be placed on a concrete cast-in-place footings and piers. These components can be easily excavated when it is time to remove the building. After the completion of the foundation work the building can be constructed in a matter of two to three days.

This prototype shows how to design and build a temporary house which is suitable for cities as it allows for a higher density. The study revealed that the temporary disaster modular housing should possess a flexible building configuration and unit layout to cater to various configurations and form larger family dwelling units as needed.

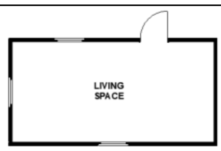
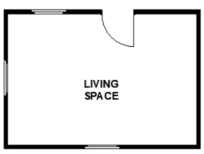
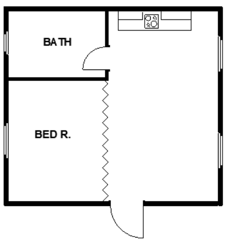
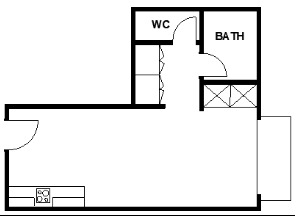
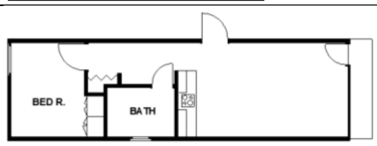
Furthermore, the modular housing for disaster areas must adhere to all zoning, code requirements, and regulations in a modern city, while each module being simple to transport and assemble. This design can be reused again and again in various environments as it doesn't need a large amount of space. The design also fulfils all the strict code requirements of New York city.

The challenges of this project are that the modules can be expensive as it consists of a lot of materials. The cost of these units is a minimum of 617 dollars per meter square. (NYC Emergency Management, 2017) Producing the modules at a higher scale would be expensive. Another way can be using these units can be as a semi-permanent residence as they are made in a high-quality manner compare to other temporary housing units.

4. Findings And Evaluation

A comparative analysis of five case studies of temporary houses after a disaster was conducted. These houses were selected based on their cost, geographic and also climatic variability. The five cases that were examined range from a low cost to higher cost ones. These structures were evaluated generally on their plans, layout and also materials. Inside these categories the cost, user satisfaction, the amount of time it took to build these structures is also examined (Table-1).

Table 1 Case study comparison

NO	NAME	LOCATION	CLIMATE	PLAN SCHEMA	BUILDING SYSTEMS	INHABITANTS PER UNIT	COST M²
1	Dadaab Settlement	Garissa County, Kenya	22 to 36 °C		TRADITIONAL	5	24.4 USD
2	Kutapalong settlement	Ukhia, Bangladesh	17 to 33 °C		TRADITIONAL	5	42.5 USD
3	The temporary prefabricated settlements in Kocaeli	Kocaeli, Turkey	5 to 29 °C		MODULAR	4-5	150 USD
4	Container temporary housing, Onagawa	Onagawa, Japan	4 to 30 °C		MODULAR	3-5	290 USD
5	Close to Home, NYC emergency management	NYC, USA	-5 to 30 °C		MODULAR	4-6	617 USD

Case No 1-Dadaab Settlement: The advantage of these shelter design is its Cost-Effectiveness. The houses are economical, with a minimum total cost of approximately $463 per unit. These structures are designed to last two years, although they have been used for longer periods. The main drawback is the inability of this structure to withstand high temperatures due to the corrugated iron roofing, which can cause a greenhouse effect inside during peak summer. Each shelter accommodates five people in a basic one plan layout arrangement and also features communal kitchens and toilets. The single-room design and communal facilities significantly reduce privacy for the inhabitants. The design in this case doesn't encourage the users to customize the spaces they are living in in addition to its being extremely hot during the summer season.

Case No 2- Kutapalong Camp: This initiative successfully delivered cost-effective shelters to those displaced, ensuring affordability in construction. Originally intended for a two-year use as in the first case study, these shelters have surpassed expectations in longevity. Constructed with environmental challenges in mind, they aim to reduce such risks. The shelters offer a minimalist design, providing a single 17.5m² space intended to accommodate five individuals. Communal kitchens and toilets are a strategic choice, contributing to the shelters' cost-efficiency. However, the same as the first case study the drawback of this design is the limited privacy. This is evident in the shared living space for five occupants and the communal nature of the bathroom facilities. The same as the first case study this design doesn't encourage the users to customize the spaces to create a more private space for themselves.

Case No 3- The temporary prefabricated settlements, Kocaeli: The temporary prefabricated settlements, Kocaeli: The project demonstrated the viability of prefabricated structures for temporary housing in Turkey following a disaster. It successfully housed over 100,000 people until their permanent homes were rebuilt. Each unit has their rooms which were the living which contained the kitchen, a bedroom and a bathroom. The structures were designed to be disassembled and reused or stored for future emergencies but due to poor planning most of the materials ended up being destroyed during the disassembly process. However, the project faced challenges due to the rapid design process, which overlooked end-user needs. The main issue was the lack of privacy due to thin gypsum board walls that failed to provide sound insulation between units. Additionally, the internal layout of each unit, with only one bedroom and a bed-couch combination, offered a better amenity when compared to the 1st and 2nd case studies but it did not offer sufficient privacy, leading residents to modify the spaces with their own partitions.

Case No 4- Container temporary housing, Onagawa: This project in Japan was groundbreaking as it introduced the first multistory temporary shelters, enhancing the density of occupants. Utilizing ISO containers and the Plus Box frames allowed for pre-construction in workshops, facilitating ready-made units upon delivery. The standardized sizing proved advantageous for shipping and vehicle transport. Compared to the first three case studies this temporary housing units provide creature comforts that are closer to a permanent house rather than a temporary one. The units are meticulously planned to provide the users a comfortable and enjoyable state. The modular nature of the units also means they can be relocated and reused elsewhere. However, the project faced challenges with high costs and lengthy timelines as the design of the units happened after the disaster had already happened. As a result, the entire process, from design to occupancy, spanned over seven months.

Case No 5- Close to home, this prototype for temporary modular housing is designed for urban environments, emphasizing high density and flexibility. The housing units can be configured to accommodate larger families and must comply with city zoning and building codes. They are easy to transport and assemble, reusable in different settings, and meet New York City's stringent regulations. However, the project faces challenges due to the high cost of materials and production at scale, suggesting an alternative use as semi-permanent residences due to their quality. Compared to the four pervious case studies Close to Home is a prefabricated design that can be stored and implemented when there is a need for it in the city of New York. After a disaster this structure can be up and functional within a matter of a week if a suitable location is found.

CONCLUSION:

Temporary housing serves as a critical solution to short- to medium-term accommodation needs. Such shelters, as demonstrated in cases 1 and 2, may be utilized for periods extending beyond two years, underscoring their significance and the necessity for these spaces to be flexible enough to adapt to the evolving lifestyles of their occupants. However, the research reveals a significant shortfall in the customizability of these temporary dwellings. The inability of these structures to adapt to the changing requirements of their users often leads to a perceived lack of privacy. Furthermore, the design of these shelters as single-use structures poses additional challenges regarding sustainability and resource efficiency. This situation highlights the need for innovative approaches in the design and implementation of temporary housing that not only meet immediate shelter needs but also address privacy concerns and environmental impact.

Modular designs inherently offer several benefits, such as expedited construction timelines, enhanced flexibility, increased control over the quality of construction materials, and notably, adaptability. When appropriately conceived, modular designs can seamlessly adjust to both the occupants' requirements and the surrounding environment. These attributes position modular housing as a highly effective and efficient solution for addressing temporary housing needs. Case studies 3, 4 and 5 offer valuable insights into the practical application of modular designs, illustrating their successful utilization in providing temporary housing for displaced individuals and communities. However, a crucial aspect for the efficacy of modularly designed temporary dwellings is proactive design and construction, ensuring that these structures are readily available when needed.

While modular housing designs offer numerous advantages, they also come with certain challenges and limitations. Factors such as the high upfront costs associated with design and manufacturing, logistical complexities in transportation, shortages of skilled labor, and the need to comply with local building codes and zoning regulations present potential obstacles. However, through early and meticulous planning, it is possible to effectively address these challenges.

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