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Examination of Post-Disaster Temporary Housing Units in the Scope of Deployment Directions

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Abstract

Temporary houses are needed for the rehabilitation phase, which emerges a few weeks after the disaster and lasts until the finish of permanent houses. It is practically difficult to construct temporary houses in a short period. In particular, there are technical problems related to the logistics and installation speed. Therefore, the deployability feature, which can speed up the process, comes to the fore in this context. In this study, three examples with different deployment directions, which could be deployed in one, two and four directions, were examined regarding their capacity, storage and transportation, area per user and effective land utilization. Selected examples from the literature were compared according to the performances. As a result of this study, each example came to the fore in different performances. In this way, the advantages and disadvantages of each system were shown.

Keywords: *Disaster management, earthquake, deployable structures, rehabilitation.*

Afet Sonrası Geçici Konut Birimlerinin Konuşlanma Yönleri Açısından İncelenmesi

Öz

Afetten birkaç hafta sonra ortaya çıkan ve kalıcı konutların kullanımına kadar geçen rehabilitasyon aşaması için geçici konutlara ihtiyaç duyulmaktadır. Afet durumunun getirdiği zor koşullarda birkaç hafta gibi kısa bir zaman aralığında geçici konutların inşa edilmesi pratik anlamda zordur. Özellikle afet bölgelerine geçici konutların sevkiyatı ve kurulum hızı ile ilgili teknik problemler bulunmaktadır. Dolayısıyla süreci hızlandırabilecek olan konuşlanma özelliği bu bağlamda öne çıkmaktadır. Çalışma kapsamında bir, iki ve dört yöne doğru açılabilen farklı konuşlanma yönlerine sahip üç örnek barındırabileceği kişi sayısı, depolama ve sevkiyata uygunluğu, kişi başına düşen yaşam alanı ve araziyi verimli kullanma performansları açısından incelenmiştir. Konuşlanma yönleri incelenirken literatürden seçilmiş örnekler tanımlanan performanslara göre birbiri ile kıyaslanmıştır. Çalışma sonucunda her örnek farklı performanslarda öne çıkmıştır. Bu sayede her bir sistemin avantajlı ve dezavantajlı olduğu noktalar gösterilmiştir.

Anahtar kelimeler: *Afet yönetimi, deprem, konuşlandırılabilir yapılar, rehabilitasyon.*

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1. Introduction

Disasters, which may occur because of artificial or natural reasons, are kind of events that affect human life and cause economic, environmental and social problems (Ergünay, 2007). Due to the effects of global warming, the frequency of hurricanes, climate changes and other disasters is increasing. This is now considered a part of daily life on our planet (Pinkowski, 2008). Consequently, it has become a necessity to take precautions and be prepared for these disasters. Disaster and emergency management systems are prepared to minimize the effects of disasters (Moore, 2008). Emergency managers should be able to adapt and make decisions against unexpected situations, such as changing conditions and resource scarcity, especially in areas that are vulnerable to the devastating effects of disasters (Grover et al., 2022). Although the ability of emergency managers to adapt to changing conditions is important in carrying out the necessary tasks during disasters, disaster management system still maintains its importance, especially in regions where disasters occur frequently, as seen in the 6 February 2023 earthquake in Turkey (Asfuroğlu et al., 2023).

Disaster management, which includes pre-disaster preparedness and post-disaster logistics operation and coordination, is a multiphased and multidimensional process. According to disaster management, national and local governments and national or international non-governmental organizations make an effort to ensure that the victims return to their daily routines (United Nations Disaster Relief Coordinator [UNDRO], 1982). Disaster managements, especially temporary housing programmes are mostly carried out with tactical and short-term decisions in chaotic situations that occur after disasters instead of comprehensive strategic planning before the disasters. Moreover, this situation causes many issues about reconstruction (Johnson, 2007a). In the literature, the processes after the disaster, the sheltering conditions of the victims and the sheltering time intervals have been determined. Emergency shelters during the immediate relief period and temporary houses during the rehabilitation and reconstruction periods are utilized. When the reconstruction is completed, permanent houses are used. Temporary sheltering and temporary housing are also distinguished in the literature. Victims do not have to reestablish household routines according to temporary sheltering. Since, it is expected that they are displaced from their homes for a short period of time (e.g., residents in flooded area). However, the latter needs resumption of household activities and responsibilities in the new place (Quarantelli, 1995).

Between thousands or millions of emergency shelters should be sent to the affected region rapidly after a disaster (Tafahomi & Egyedi, 2008). Furthermore, it is critical for victims who have lost their homes to settle in temporary houses as soon as possible to be able to return to daily life for more positive social, physical and psychological conditions (Arslan & Coşgun, 2008). Temporary housings prevent the spread of diseases and protect people from external factors, such as weather (Félix et al., 2013). Also, earthquake disaster on 6 February 2023 in Turkey, it is demonstrated once again that basic and critical supplies such as temporary housing must be provided (Mavrouli et al., 2023). However, in a post-disaster situation, it is foreseen that the supply and shipment of materials for temporary houses may take time (Barakat, 2003). Assembling the parts of a complex system, such as a house that reaches the site, also requires time and labor. Therefore, this situation creates a problem that needs to be solved from a technical and practical point of view. Apart from this issue, the active and efficient use of national resources in temporary housing plays a crucial role in the future development of the affected area (Arslan, 2007). Thus, these problems related to temporary housing have been evaluated in this study.

In the context of the problem, temporary housings are examined through their deployability feature, which can speed up the shipment and installation process. Deployable structures are systems that can be contracted in size for shipping and storage and can be rapidly expanded in a predetermined manner (Del Grosso & Basso, 2012). Thanks to these features, deployable structures can be used in different locations in a post-disaster scenario. They can be dispatched to the disaster area and allocated to the victims as houses. Therefore, dealing with construction work in a chaotic post-disaster environment is not required. In this way, limited resources can be used to improve the lives of victims. In this study, examples of deployable structures that can be used for various functions have been selected. These examples, which can be utilized as a house and have different numbers of deployment directions as one, two or four, are examined with the performance criteria defined in the study.

The purpose is to determine the effects of the deployment directions on the defined performance criteria and to examine the relationship with other design variables. Alternative scenarios of deployability features for the second life of temporary houses are also discussed. Besides, the criteria related to spatial organization, aesthetic and social objectives, which cannot be evaluated quantitatively, unlike the determined criteria, are also interpreted in the discussion section. There are research studies in the literature that examine demountable structures as temporary housing (Garofalo & Hill, 2008; Avlar et al., 2023).

2. Material and Method

2.1. Post-Disaster Temporary Housing

Temporary houses are utilized in rehabilitation and reconstruction periods that start a few weeks after the disaster and last until the construction of permanent houses (Limoncu & Bayülgen, 2005). Temporary houses, which can be considered a type of temporary accommodation, can be produced using different techniques. In terms of disaster management, it is a part of the transition process from emergency shelter to permanent housing (Johnson, 2002). In this process, it should be determined where the temporary housing will be established before the disaster. It is known from past experiences that temporary houses were built in forest, coastal and agricultural zones due to a lack of planning and preparation (Savaşır, 2008).

It is possible to improve the lives of victims and return their daily routines that cannot be applied in emergency shelters with temporary housing (Hadafi & Fallahi, 2010). One of the major problems with temporary housing is that it must be completed within a few weeks. Thus, the necessary materials and components for the housing should be produced and stored in certain regions before the disaster. Otherwise, stocks can be insufficient and the time required to complete temporary houses may increase to three and a half months as in the 1999 Marmara Earthquakes (Turkey) (Savaşır, 2008).

In temporary housing designs, several objectives have been developed by Şener & Altun (2009) according to past experiences, research studies on existing temporary housing systems, and user requirements. These have been defined as follows:

- objectives related to technology, construction and material,
- objectives related to ecology,
- objectives related to cost,
- objectives related to building physics,
- objectives related to spatial organisations,
- objectives related to sociology,
- objectives related to esthetic,

It is foreseen that the necessity of intervention or addition to housing units can be minimized by taking these design objectives into consideration during the planning phase. For example, additional parts were built beside the temporary houses with an area of approximately 30 m^2, which were used in Yalova after the Marmara Earthquakes. Thus, prefabricated houses are modified according to the number of family members and the user’s lifestyle. Interventions in the prefabricated houses by the users harm the physical integrity of the buildings (Enginöz, 2005). Therefore, it is important to provide diversity in design and offer different options for families.

Depending on the country or the context, such as rural or urban, temporary houses, can be in many different forms, such as prefabricated housing, mobile trailer, shipping container, rental flats or user-built cottages. It is understood that some of the temporary housing approaches require new constructions (such as prefabricated housing) and some of them (such as rental flats) utilize existing structures (Johnson, 2010). Deployable structures bear traces of both approaches. Since they are brought to areas after a disaster and utilized in different locations before the disaster.

Temporary housing projects are often criticized for being economically, socially and environmentally unsustainable. However, though temporary houses require disaster management planning and impose severe burdens on the economy, it is also a fact that their construction requires urgency and necessity. At this point, one of the biggest problems with temporary housing is that they are costly compared to relatively short lifespan (Johnson, 2010; UNDRO, 1982). Therefore, this situation needs to be solved practically and rationally. Second-life scenarios can be considered, such as transforming them into public buildings or core housing that are incrementally built up by victims to turn into permanent houses (Johnson, 2008). For example, after the Marmara Earthquakes, a building consisting of eight units and an area of 200 m^2 could be transformed into a sports center in a different location (Johnson, 2007b). In this context, deployable structures can be considered an alternative for the second life of temporary housing.

The method to be followed in the study to evaluate deployable temporary housing options is determined as follows. Selecting the examples, determining the evaluation criteria and evaluating the samples in the context of the criteria. In the findings and discussion, performances of selected examples are evaluated. It was taken into account that the examples to be selected had the same characteristics except for their deployment directions. For this reason, examples that can deploy one, two and four directions were chosen. Four performance criteria were determined to evaluate the selected examples. Three criteria were related to temporary housing units, and the fourth criterion was related to settlement planning. The examples were evaluated with novel temporary housing plan schemes that authors suggest since they were currently used with different functions and spatial organizations in the literature. Also, the suggested site plans were utilized for the evaluation of the fourth criterion.

2.2. Deployable Structures

According to Kronenburg (1995), it is possible for a structure to change its location if it is portable, relocatable or demountable. Besides, the deployability feature can be added to this classification. Unlike the others, the deployability feature includes mechanisms. According to De Temmerman et al. (2012), transformable structures are systems that can adapt their shape or function to rapidly changing conditions. These structures can be transformed using mechanisms/ hinges or disassembled components like demountable structures.

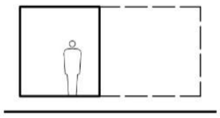
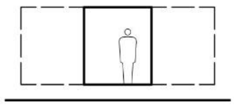
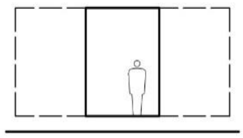
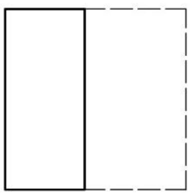
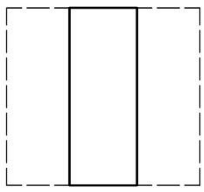
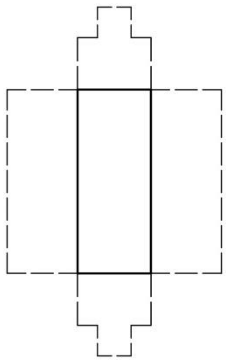
In the definition of deployability used within the scope of this study, the systems that perform their transformation through mechanisms/ hinges are examined. Deployable structures are often used in everyday objects. The most common and oldest known example is the umbrella mechanism (Pellegrino, 2001). Types of deployable structures used in architecture; foldable systems, which are constituted from struts or surfaces. Pneumatic membrane structures, and systems that can maintain their integrity with cable tensions, are defined as tensegrity. Each of them has different morphological and kinematic features (Hanaor & Levy, 2001). Therefore, the deployment method that can meet the required functions most appropriately during the design phase is selected by considering the pros and cons of the existing techniques. Also, it can be stated that the deployability feature will positively affect the objectives related to technology, construction, material and cost proposed by Şener & Altun (2009) because of rapid installation and repetitive use.

2.3. Selection and Presentation of Examples

Foldable systems that are constituted from rigid surfaces were examined in this paper. They are also referred to in the literature as origami-based designs. Origami is a combination of the Japanese words 'oru' (fold) and 'kami' (paper). In architecture, origami-based designs are examined through patterns, such as Miura, Resch or egg-box (Lebée, 2015). Practical and theoretical studies are carried out on these crease patterns (Osório et al., 2014; Beatini & Korkmaz, 2013). Apart from these studies, there are also research studies on the mathematics and kinematics of origami (Bern & Hayes, 1996; Dureisseix, 2012). However, the examples in this paper were more understandable compared to the complex folding systems in the literature. Thus, it was foreseen that mechanical malfunctions might be prevented in a post-disaster scenario thanks to the simplicity of systems.

The selected examples were rectangular prisms with similar width, length and height in a folded configuration that were approximately the size of 20 Feet Standard Dry ISO Container. At this point, it is important that any dimension of the folded configuration is not too large to be transported by road (Van Gassel & Roders, 2006). However, the difference was the number of deployment directions, which were one, two or four. Three applied examples with different numbers of deployment directions, which contained sanitary and fixed furnishings like a toilet bowl and a sink in the folded configuration, were selected according to the defined characteristics. The fixed part of the structure could be considered a core that does not change during the deployment. Also, the number of actuators was not considered. The selected examples from the literature: Boxabl, container house and EBS block. The examples are schematically represented in Table 1.

Table 1. Schematic representations of the units that have different deployment directions

	Boxabl	Container house	EBS block
Number of deployment direction	One direction	Two directions	Four directions
Section			
Plan			
	*The dashed line represents deployed configuration, and the solid line represents folded configuration		

The examples were evaluated with novel plan schemes and functions the authors suggest since they were currently used with different functions and spatial organizations in the literature. Novel plan schemes were designed according to information obtained from the examples, which are the number and orientation of deployment directions, the outline contour and the location of cores within the structures. In the paper, examples were introduced according to the number of their deployment directions.

Boxabl is a company in the USA that produces foldable housing units. Each unit can be brought to the site in one piece and installed in a few hours with the help of a crane. It has a height of 2.90 m, a length of 5.90 m, and a width of 2.60 m in folded and 5.90 m in the deployed configurations (Figure 1). The unit has a 34.80 m^2 area when it is deployed. Window and door frames are inserted into perforated wall panels. Units that can be positioned on top of each other can also be combined together in the horizontal plane and different plannings can be generated (Boxabl, n.d.).

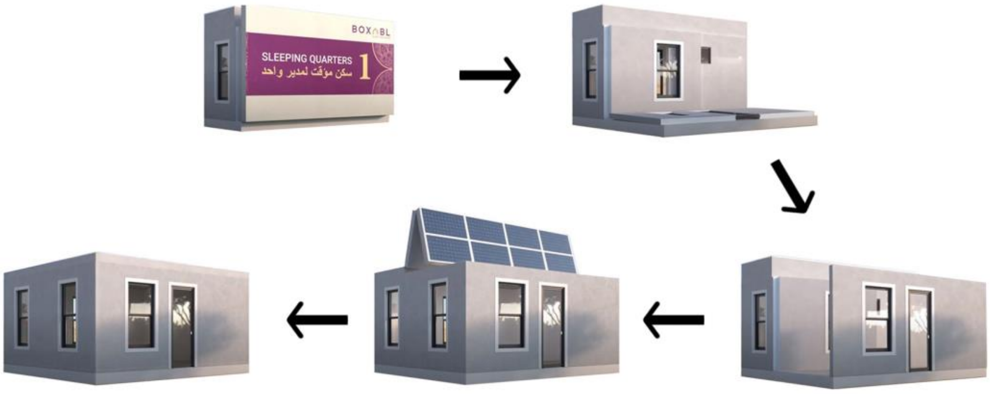


Figure 1. The deployment stages of the Boxabl housing unit (Boxabl, 2020; Süalp, 2021)

Container house can be deployed with a team of at least five people and no crane is needed. However, a crane is required during transportation. Since it is transported in one piece, it has a height of 2.50 m, a length of 5.80 m, and a width of 2.20 m in folded and 6.30 m in the deployed configurations (Figure 2). The unit has a 36.50 m^2 area when it is deployed. Also, 15 mm fiber-reinforced concrete panels are used for floor construction (Moneybox Modular Housing, n.d.; Alibaba, n.d.).

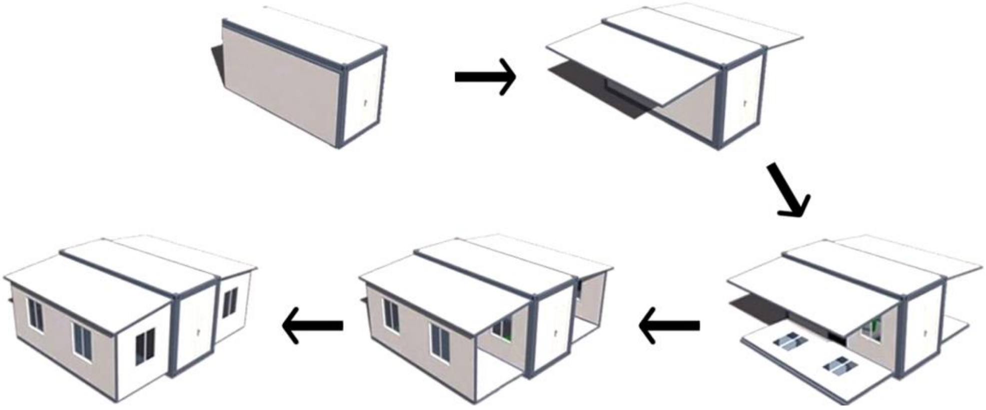


Figure 2. The deployment stages of container housing unit (Alibaba, n.d.; Süalp, 2021)

EBS block is a company in Australia that produces foldable housing units. As it is understood that it is not active at present. However, the deployment feature of the product is suitable for the examination. It has a height of 3.50 m, a length of 6.00 m in folded and 11.40 m in the deployed configurations, and a width of 2.40 m in folded and 7.00 m in the deployed configurations (Figure 3). The unit has a cross shape and a 55.00 m^2 area when deployed. The kitchen and bathroom are located at both ends of the unit that deploy telescopically (Potter, 2021; Off-Grid World, 2016).

Figure 3. The deployment stages of container housing unit (Potter, 2021; Süalp, 2021)

All of the examples are prefabricated units that have structural steel frames. The gaps in the frame are filled with sandwich panels that have thermal insulation. The units are transported to the site with their subsystems, such as heating, ventilation, plumbing and electricity, ready to use. They are connected to the infrastructure at their corners. Infrastructure should be prepared according to the site planning strategy. In regions without infrastructure, units can be used off-grid. They can be connected to support units, such as solar panels or water tanks in these regions (Boxabl, n.d.). Therefore, a certain number of units can be used off-grid according to the planning. Also, appropriate foundation design and application are recommended for the installation of units (Potter, 2021). These prefabricated and foldable structures are lighter than other structures that are produced with traditional construction techniques. Thus, they need relatively smaller-sized foundations that should hold the structures in place in adverse weather conditions, such as strong winds or hurricanes because of their lightweight construction.

2.4. Determination of Criteria

In this section, four performance criteria were determined to evaluate temporary housing units quantitatively. Social and physical sustainability, distances between houses and efficient use of resources were considered in the selection of criteria (Arslan, 2007). Thus, the criteria should not be determined to evaluate only the housing units. At this point, the criteria were required to evaluate both the housing unit scale and site plan scale (Süalp & Yapıcı, 2022). Therefore, three selected criteria were related to temporary housing units, and the fourth criterion was related to settlement planning. Material information and construction technologies were not included in the evaluation criteria since all the examples had steel frame construction and were made of similar materials.

At first, the number of family members (capacity) that could accommodate a unit, was determined in the context of unit scale criteria. The plans suggested by the authors were used to determine the capacities. The second criterion was the ratio of expansion. This ratio was important in terms of storage compactness and the efficiency of transportation (Zirbel et al., 2013). This criterion was calculated by the division of deployed area into the folded area. The third criterion was the area per user in a unit, which could be considered one of the comfort level indicators. It was determined by the division of deployed area to capacity.

After a disaster, hundreds of temporary housing units are brought together and settlements are formed. The area occupied by a unit on the land determines the parcel size of the unit. The parcel areas also determine the total settlement area. Therefore, this situation is also the determinant of infrastructure planning. Considering that the temporary housing units examined in the paper were single-storey, it was understood that vast land was required for the settlements. The costs of necessary infrastructure (road, water, electricity) services for large areas (e.g., 80 trillion Turkish Liras in the Marmara Earthquake) were more than the temporary housing costs (47 trillion TL) (Savaşır, 2008). Therefore, the population density of settlement was crucial for the efficient use of resources. To determine this efficiency, site plans for the different units were suggested by the authors. At first, the area that was occupied by 24 temporary housing units, pavements and the two roads between them was determined for each of the examples. Then the number of person who lived in the area was divided by the area to calculate the number of person per square meter. Then the value was multiplied by 10000 to determine the person per hectare (person/ ha) for each settlement.

As a result, temporary housing units;

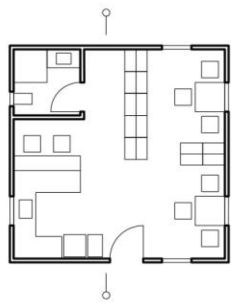
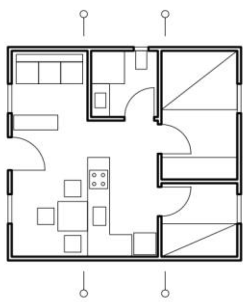
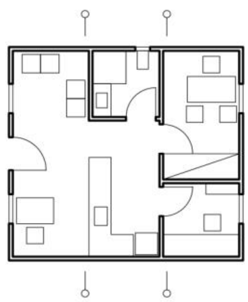
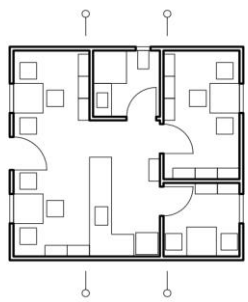
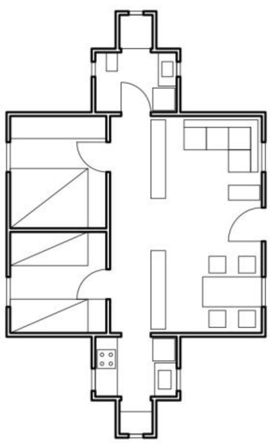
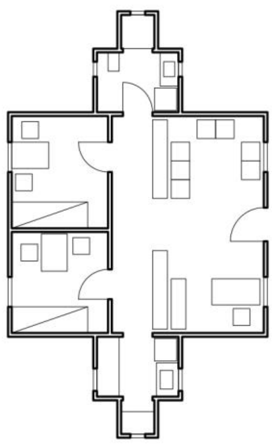
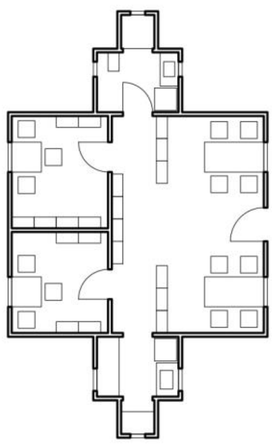
- capacity (number of people that can live in the unit)
- ratio of expansion (deployed area/ folded area)
- area per user in a unit (deployed area/ capacity)
- population density of settlement (the area that is occupied by 24 units)

performances are analyzed.

2.5. Quantitative Evaluation of Selected Examples

The three examples introduced in the previous section were planned by the authors according to three different scenarios to examine both post-disaster and second-life scenarios. It was considered that a unit was utilized as temporary housing in post-disaster situations and a polyclinic or mobile library for its second life (Table 2). In the planning, the kitchen and bathroom were placed by paying attention to the fixed and movable parts of the building. In different scenarios, such as walls, windows, doors and fixed furnishings, were unchanged; only movable furnitures were changed according to the needs. Therefore, it is possible to switch between different scenarios with little intervention by the users. Thanks to the novel plans, the number of people that could be accommodated in the examples (capacity) was determined. The heights of the ceilings were excluded from this study.

Table 2. Plans of selected examples that are suggested and drawn by authors according to different scenarios (Pins out of the plans indicate the boundaries of the core)

	Temporary housing unit	Polyclinic	Mobile library
Boxabl, 34.80 m^2 (5.90 m * 5.90 m)			
Container house, 36.50 m^2 (6.30 m * 5.80 m)			
EBS block, 55.00 m^2 (7.00 m * 11.40 m)			

For the calculation of capacities, both size of the unit and interior planning were considered. As shown in Table 2, it can be predicted that two adults can be accommodated in the Boxabl considering the interior design since there was only one double-sized bed. It was thought that two adults and a child could be accommodated in the container house, which is 1.70 m^2 larger than Boxabl. It was foreseen that two adults and two children could be accommodated in the EBS block, which had the biggest area.

When the expansion ratios were examined, Boxabl covered an area of 34.80 m^2 in the deployed configuration and 15.30 m^2 in the folded configuration. The ratio of expansion was 2.27 (34.80/ 15.30). Therefore, its volume increased by 127% (100* (ratio of expansion- 1)). Similarly, the expansion ratios of the container house and EBS block were 2.85 and 3.82. Their volumes increased by 185% and 282%. The area per user in the units was 17.40 m^2/ person (34.80/ 2) for Boxabl, 12.20 m^2/ person for container house and 13.80 m^2/ person for EBS block.

The population densities of settlements were evaluated through the suggested site plans (Figure 4). The design approach utilized by Avlar et al. (2023) was used for the planning. Unlike their design, here social and technical areas were not added. Also, the instructions of Disaster and Emergency Management Presidency (AFAD, 2015) and Sphere Association (2018) were utilized. Only the issue of parcellation was focused.

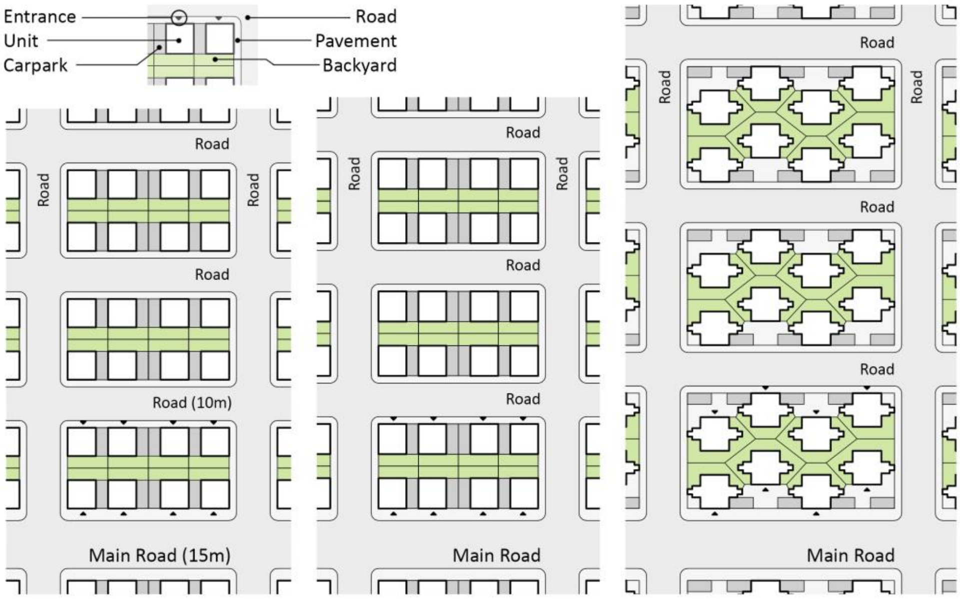


Figure 4. Site plans of temporary housing settlements, which are constituted of Boxabl (left), container house (middle) and EBS block (right) units (drawn by Authors)

According to Figure 4, each unit has its own parcel, backyard and carpark. The entrances of the units were on the roadside and the sleeping areas faced to their backyards for security and privacy. The width of the carpark and backyard was 2.50 m. The areas that were occupied by 24 parcels, pavements and two roads between them were 2723.04 m^2 for Boxabl, 2780.16 m^2 for container house and 4418.88 m^2 for Ebs block temporary housing settlements. Unlike the rectangular parcels of other site plans, Ebs blocks were positioned diagonally because of their cross-shaped unit plan. Diagonal positioning was a more efficient method than the side-by-side order for this case. If it is planned aforementioned regular order, the area becomes 4746.60 m^2 (58.60* 81.00).

The numbers of people that could accommodate the defined areas were 48 (24* 2) for Boxabl, 72 for container house and 96 for Ebs block. Therefore, the population densities of settlements were 176.27 person/ ha ((48/ 2723.04)* 10000) for Boxabl, 258.98 person/ ha for container houses and 217.25 person/ ha for Ebs block. The evaluation results are written in Table 3.

Table 3. Evaluation results of the units that have different deployment directions

	Boxabl	Container house	EBS block
Capacity (family members in the unit)	2 adults	2 adults and 1 child	2 adults and 2 children
Height	2.90 m	2.50 m	3.50 m
Area of the deployed unit	34.80 m^2 (5.90 m* 5.90 m)	36.50 m^2 (6.30 m* 5.80 m)	55.00 m^2 (7.00 m* 11.40 m)
Area of the folded unit	15.30 m^2 (2.60 m* 5.90 m)	12.80 m^2 (2.20 m* 5.80 m)	14.40 m^2 (2.40 m* 6.00 m)
The ratio of expansion (deployed area/ folded area)	2.27 (127 %) (34.80 m^2/ 15.30 m^2)	2.85 (185 %) (36.50 m^2/ 12.80 m^2)	3.82 (282 %) (55.00 m^2/ 14.40 m^2)
Area per user in the unit (deployed area/ capacity)	17.40 m^2/ person (34.80 m^2/ 2 persons)	12.20 m^2/ person (36.50 m^2/ 3 persons)	13.80 m^2/ person (55.00 m^2/ 4 persons)
The area of 24 parcels, pavements and two roads	2723.04 m^2 (36.60 m* 74.40 m)	2780.16 m^2 (36.20 m* 76.80 m)	4418.88 m^2 (46.03 m* 96.00 m)
Population density of the settlement	176.27 person/ ha (48 persons/ 2723.04 m^2)* 10000	258.98 person/ ha (72 persons/ 2780.16 m^2)* 10000	217.25 person/ ha (96 persons/ 4418.88 m^2)* 10000

3. Findings and Discussion

3.1. Performances of Selected Examples

In this section, ratios of compactness, area per user in units, population densities of settlements, which were considered performances, were analyzed. Thus, the data obtained in the previous section were evaluated as performance indicators. It was observed that three examples with different capacities and number of deployment directions perform at different levels. When the data in Table 3 were examined, it was understood that the expansion ratios increased as the number of deployment directions increased. There was an incrementation of 45.67 % (185/ 127) and 52.43 % (282/ 185) in the expansion ratios between the deployment directions.

The container house had the lowest area per user which is 12.20 m^2/ person. However, the site plan constituted of container houses performs the highest population density at 258.98 person/ ha since the system, which deployed in two directions, had the lowest and highest performances according to area per user and population density.

The examples were listed as follows according to their area per user in the units and the population densities of settlements:

- Boxabl (17.40 m^2/ person) > EBS block (13.80) > Container house (12.20)
- Container house (258.98 person/ ha) > EBS block (217.25) > Boxabl (176.27)

If the values were normalized as follows:

- Boxabl (100.00) (100* 17.40/ 17.40) > EBS block (79.31) (100* 13.80/ 17.40) > Container house (70.11) (100* 12.20/ 17.40)
- Container house (100.00) (100* 258.98/ 258.98) > EBS block (83.89) (100* 217.25/ 258.98) > Boxabl (68.06) (100* 176.27/ 258.98)

Then the summation of the normalized points, which can be considered the indicator of the performance summation of area per user and population densities, are written below:

- Container house (170.11) > Boxabl (168.06) > EBS block (163.20)

The reasons why the EBS block has the worst performance are discussed in the next section.

3.2. Evaluation

According to TTB (2001), after the 1999 Marmara Earthquakes, temporary houses were used by families with different numbers of members. Therefore, it should be considered that there are various-sized families in a temporary housing settlement. For the accommodation of these families, it is necessary to use the required number of units that have different capacities. Each example has different capacities ranging from two to four people. Thus, a temporary housing settlement can be constituted from these units to serve different-sized families. Besides, all the units can be dispatched to the area in a similar manner since units have approximately the same size when folded. The values of area per user in units depend simply on both the area and the number of users. Thus, any increment in the number of users can change the results significantly and affects negatively the users' comfort. Also, according to the interior planning of the house, any areas that are without function, which waste the area, should not be designed. In the example of the EBS block that deploys to four directions, the presence of the kitchen and bath at both ends ensures that the large rectangular area remains completely empty. Thus, the middle of the building has an open plan. This is a positive feature for functions that require an open plan, such as traveling exhibitions. However, the entrance of the kitchen and especially the bath should be covered in the house planning. This approach creates a corridor-like space that wastes the building's usable area. Apart from this, the system that deploys in two directions leaves the core in the center. In this way, the two sides of the building are divided automatically into two different functions. On the other hand, the one-sided example has less complex planning issues than the others. As a result, it can be stated that each example has pros and cons in terms of planning.

The population density of settlements is determined by person per hectare. If the units are positioned on top of each other, the density can be multiplied within almost the same area. However, the distances between the units must be reconsidered because of the sunlight. Besides, unlike Figure 4, the units can be combined as different typologies like twin or row houses. In these cases, the density and relationship between units will change significantly. In this paper, it was considered that all units were arranged separately and they were considered a single storey. As mentioned that container house has the lowest area per user and the highest population density. This feature can be perceived as a positive to constitute dense settlements and lower investment costs; it can also cause worsening living conditions. Also, the units that have one and two deployment directions can use their parcels with utmost efficiency. Since the deployed configurations of the units have rectangular plans. Unlike the EBS block, which has a cross-shaped plan that complicates the site planning. Thus, the EBS block has the lowest summation. When the relations between indoor and outdoor are examined, it is observed that all examples have windows at a certain height from the ground to be considered suitable for a temporary house. The limited size and number of openings are considered positive to mitigate the visual connection in terms of privacy and to contribute to the thermal performance. However, in different functions, such as mobile libraries that require more illuminance than housing, attention should be paid to the locations and directions of furnishings for energy saving. Apart from these objectives, different functions require different mechanical, plumbing and electrical projects. Utilizing a building, which is designed as a temporary house with different functions requires precautions and considerations for the other functions.

4. Conclusion and Suggestions

In the paper, temporary housing examples, which can be deployed in one, two and four directions with similar dimensions and geometries in folded configuration, were selected. The examples were redesigned with the functions suggested by the authors to evaluate the capacity, ratio of expansion, area per user and population density of settlements. Spatial organization, aesthetic and social objectives, which cannot be evaluated quantitatively, were also interpreted. Therefore, the pros and cons of deployable structures as temporary housing were examined in this study.

In each of the three performances examined, a different example came to the fore. Therefore, it can not be stated within the scope of this study that there is an example that is superior in every aspect. For example, Boxabl is the best choice according to area per user performance. On the contrary, it has the lowest population density in site planning. For the container house, the situation is exactly the opposite. Moreover, the EBS block has complex site planning and dysfunctional areas in the interior. The findings suggest that this situation makes the system with four deployment directions not a good option for temporary houses. It is predicted naturally that replacing the examples with different buildings with the same number of deployment directions will create deviations in performance values. However, it is thought that there will be similar results in terms of ranking in performances where the difference is high. It can be considered that there are various-sized families in a temporary housing settlement. Also, each example has different capacities ranging from two to four people. Thus, all of them may be needed in terms of its capacities.

Deployable structures can be utilized for urgent needs, such as post-disaster conditions. The examples have advantages in terms of allowing rapid installation. On the other hand, their transportation in one piece and the need for a crane during installation may pose some operational problems. Also, infrastructure must be ready before the installation. Additionally, cost analysis of settlements should be calculated in the planning phase. Apart from these, it is thought that having second life opportunities will be beneficial in overcoming the economic problems of temporary housing. As a result, a multi-dimensional post-disaster management system should be planned by considering these features.

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