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Research Paper

Proposing a Flexible Model for Temporary Housing using Digital Design Techniques †

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Abstract
Temporary accommodation is a necessary measure for various purposes that can be used by the homeless after events such as floods, earthquakes, and wars. Depending on the location of the disaster, temporary shelter users may have different groups of people with different attitudes and social, cultural, and climatic conditions. The incompatibility of the quantitative and qualitative characteristics of temporary housing with the conditions leads to the dissatisfaction of the users and increases the psychological consequences of the disaster for them. Hence, the concept of flexibility in such situations is proposed to solve current problems and increase the responsiveness and desirability of temporary housing. The main question of the article is how to design flexible temporary housing with the help of digital tools. This paper seeks to provide a flexible physical model for improving the quality of temporary accommodation and responding to the different needs of different residents through digital tools. To achieve the goal and solve major problems in the design of temporary housing, digital design techniques can be very useful because the subject of the design has many limitations and expectations.
This is a practical study and a review of the literature and its theoretical foundations have been prepared through library documents and research. According to the studies and components obtained from the literature review, a parametric and modular design approach to achieve a flexible physical model through a user-friendly method is proposed. From both design and evaluation perspectives, the Space Syntax Toolkit is used to obtain diagrams and basic information for designing responsive designs in terms of social and cultural components, and the Galapagos and Grasshopper plugins in the Rhinoceros environment for optimization. The minimum and standard dimensions of the Ladybug and Bee plugin are also used in the Grasshopper environment for climatic evaluation of the proposed physical models in the four cities of Tabriz, Tehran, Yazd, and Bandar Abbas.
The results of this article indicate that the rectangular modules with an area of 6 square meters have the maximum ability to provide different patterns for the temporary housing plan according to the needs and tastes of users. Expandable modules are also an effective solution for the optimal use of the minimum dimensions in the plan, which can meet the climate needs according to the climate data of the four cities.

Keywords: *Temporary housing, Flexibility, Algorithmic tools.*

1. INTRODUCTION

The rapid pace of climate change and global warming in recent years has led to widespread natural disasters such as fires, floods, hurricanes, and earthquakes. The intensity and frequency of natural hazards in the world are increasing which results in tens of thousands of lost lives and the displacement of

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millions of people (Farrokhsiar, Mirhosseini, & Saeedfar, 2020). In 2018, disasters led to the prolonged displacement of over 400,000 people globally (Perrucci & Baroud, 2020). In addition to natural disasters, wars have left many of the world's population homeless. Many countries around the world have experienced disasters and wars which have had plenty of material and moral disadvantages over those nations and their inhabitants. The destruction of the urban construction and built environment is one of the most dangerous physical outcomes of wars and disasters due to the serious impacts it creates on the lives of individuals and families, undermining different normalcy aspects of them related to the livelihood, security, privacy, and stability (from temporary to permanent). In Iran, the main natural disaster that has always led to countless financial and moral losses is an earthquake because Iran is one of the five earthquake-stricken countries in the world, being located on the Alpine-Himalayan orogenic belt. Engineering statistics and probabilities indicate that, on average, a severe earthquake occurs every four years in Iran. These earthquakes result in the destruction of 97% of rural housing in the earthquake-stricken areas (Asefi & Farrokhi, 2018a).

When a natural disaster occurs on a widespread and large scale, existing residential areas typically become unusable and survivors are forced to reside in places other than their own homes (Khodadadeh & Ziaei, 2008).

“Housing” is the basic place of human life. If there’s no complete living space and comfortable living conditions, residents will be affected by both physical and psychological factors for a long time (Yu & Bai, 2018). One of the most critical issues after a disaster is the gap between short-term needs (emergency or temporary shelter) and long-term needs (permanent housing). In most cases, the process of achieving permanent accommodation takes years for various reasons, such as the removal of rubble and finding suitable and safe space on which reconstruction can take place (Nocera, Castagneto, & Gagliano, 2020). As the reconstruction and repair of damaged and demolished houses is usually a long process and may take a considerable time for the properties and homes to become inhabitable once again. It is necessary to provide the disadvantaged groups with temporary accommodation to resume their households’ activities and normal life responsibilities during the gap time between the aftermath of a disaster or the end of a war, and the completion of the reconstruction process of the permanent houses (from temporary to permanent). In natural disasters, it is crucial to provide temporary housing and suitable conditions for the construction of permanent houses. Hence temporary housing is of great importance even in a temporary location and is considered an essential step in reconstruction plans to encourage the return to normal circumstances under chaotic and uncertain post-disaster conditions (Félix, Branco, & Feio, 2013).

Losing shelter causes a breakdown in the morale and dispersion of human beings. For this reason, after natural disasters, the first issue that creates some security and comfort for the injured is the provision of adequate shelter and family reunification (Khoram, Tirani Najaran, & Sadeghi Naeini, 2014). The injured who suffer from the loss of their families and devastation of their properties, homes, and assets encounter intense mental conditions and require a safe and peaceful shelter to recover their normal lives gradually. Relief seekers need good housing in terms of safety, culture, and climate, with simple maintenance (Reza Mojahedi, Vafamehr, & Ekhlassi, 2021) and the shelter must protect them from cold, heat, wind, rain, etc. and their properties from probable robberies and help to preserve their privacy and re-establish their family life.

According to the U.S. Department of Health and Human Services (2019), depending on the duration and living situation of the dwellers, temporary settlements can have many different forms and use cases (Farrokhsiar et al., 2020). Many studies have been conducted on the types of temporary housing that can be provided to victims of natural and unnatural disasters, and most often point out that the temporary housing provided has many drawbacks such as single space mode, chaotic function, low comfort, poor ecological efficiency, and so on (Yu & Bai, 2018).

When designing post-disaster relief houses, the aspects prioritized are the speed of mass production and the holistic aspect of reconstruction. As a consequence, each occupant's uniqueness and particular needs are often forgotten (Pramishinta, 2021). What provided today as temporary accommodation for the victims of natural disasters are poor dwellings in form of tents and containers which cannot satisfy dimensional, spatial, and climatic standards and do not meet the social and cultural needs of users. The different characteristics of users of temporary housing support the theory of the need for an accommodation adaptable to changing conditions. This is possible through flexibility. In fact, flexibility is an approach to respond to changes over time, but it may be useful for the customization of space by different users in different times and local conditions and geographies. This capability is what solves many problems of temporary housing.

Temporary housing is mass-produced and used in a variety of climatic, cultural, and social conditions. The design of flexible temporary houses can be so efficient to adapt temporary housing to changing environmental conditions and different needs of various users. Unique features, for example, light weight, transience, practicality, portability, prefabrication, dismantlability, adaptability, and small size of the structure, are continuously developed (Acharya, 2013). These features as well as the concept of flexibility help to design optimum temporary housing with maximum adaptability to the needs of injured users. However, the importance of designing temporary housing according to the needs of the user, in most articles, emphasizes the construction aspects of temporary housing and also increasing energy efficiency is a topic that has attracted more articles. The present article takes a parallel look at the issue of temporary housing and tries to provide flexible housing with optimal performance for residents, despite its limited dimensions. Also, the ability to use in different climates through light analysis is a topic that has been addressed.

The purpose of this article is to design a flexible temporary housing that has the maximum flexibility and variety to plan with appropriate dimensions for sparsely populated and large families, and despite the limited space, optimal spatial relationships, and sufficient light to enhance the comfort of residents. This can be achieved through new design techniques and digital tools. Today, design and digital tools are used in all architectural subjects, so in a subject such as temporary housing, where there are many limitations but many expectations, this possibility can be used.

Therefore, the article seeks the fundamental question:

How to design flexible temporary housing with the help of digital design techniques?

By answering this question, it is possible to design a flexible temporary accommodation that can adapt to different conditions of users around the world and, instead of being stored after use, be replaced in other places after critical situations and disasters with permanent functions. Save like an echo. Camp etc. to be used.

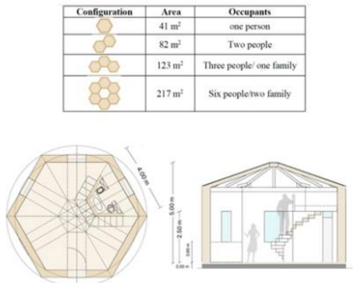
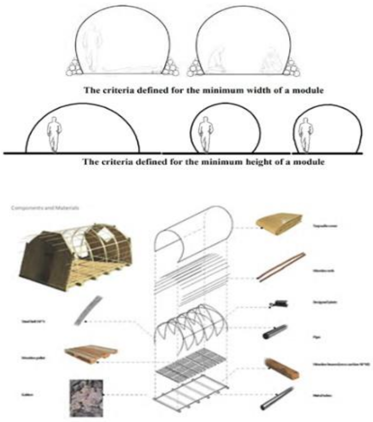
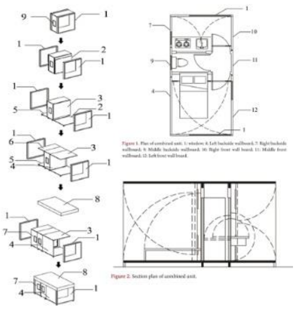
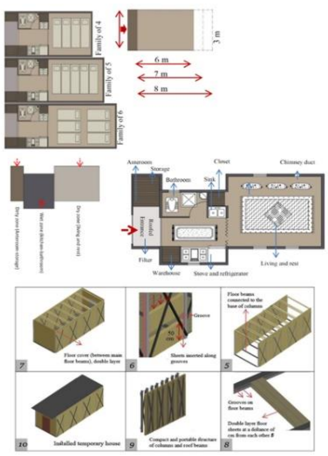
2. RESEARCH BACKGROUND

In all the articles related to temporary housing, it has been mentioned that temporary housing has many problems such as single space, dysfunction, low comfort, poor ecological efficiency, etc., but each of them has taken different approaches to solve the problems. Many famous designers and architects in recent decades have proposed a variety of shelters and models. Many ideas have been developed as prototypes, and despite the mass production of some products, their application to the homeless has often led to unspecified failures. Current experience shows that those temporary shelters used by homeless people have been surprisingly affected by changes, additions, or deletions of space, thus making these units more vulnerable and as a result, most of the proposals have failed (Asefi & Farrokhi, 2018a). Nevertheless, researchers are looking to address the issues and provide optimal suggestions. Most articles on temporary housing focus on areas such as rapid construction, installation and dismantling, low cost, and energy efficiency. The following are some examples of articles that have been published in recent years on these topics.

Park (2017) proposes a design based on recycled paper tubes with prefabricated fittings that introduces an easy approach to building a lightweight shelter for those affected by a disaster. The challenge of using this plan is immediate access to sufficient sources of material near the scene. In other proposals, ground-based deployable structures are used for temporary and emergency situations. Asefi and Sirus (2012) proposed a modular retractable tent that could be deployed at the site of a disaster. Henrottay et al. (2006) propose a model that consists of a small variety of composite structural elements that form different shapes and structures based on location and environment. Kwaglia et al. (2014) use origami-inspired design for deplorable shelters that can be quickly retracted and used for military purposes. Gunavardena et al. (2014) state that prefabricated modular construction can be used as an effective method for permanent housing after a disaster that reduces the time required for temporary housing. The temporary shelter was proposed by the 2020 Residential Building Design and Construction Conference. Abdulpour et al. (2017) propose a one-story building with a rectangular area that consists of floor, ceiling, and wall modules. The walls are made up of fiberglass and the joints are prefabricated and can be assembled on site. While these proposals offer various alternatives to temporary shelters after a disaster, there is a need to explore more cost-effective methods using materials available at the site of the disaster (Farrokhsiar et al., 2020).

In addition to articles on the structure of temporary housing, there are a limited number of articles focusing on the functional aspects of temporary housing. Among these articles, there is no article that directly addresses the issue of flexibility and temporary accommodation. However, a few articles written in the last four years that contain functional aspects and efforts to adapt temporary housing to the needs of the user are listed in Table 1. The sample is selected in such a way that each has a different approach to solve housing problems and has achieved different results. The similarity of the samples with each other and with the subject of the article is that all the samples try to be optimal in terms of size and area and prepare the design for different users to use through expandability and modular (Table 1).

Table 1. Types of Forms Proposed for Temporary Housing in the Last Four Years (Source: Authors)

article	Proposed form	Approach and solutions provided
Passive house as temporary housing after disasters (2020) (Nocera et al., 2020)		- Emphasis on energy consumption, thermal performance and net carbon emission - design for Mediterranean climate - modular design - use of hexagonal module based on bee cell ratio - Ability to accommodate families of 1 to 6 people - Minimum module area 41 square meters
Proposing A Deployable Post-disaster Modular Temporary Shelter Using Vernacular Materials (2020) (Farrokhsiar et al., 2020)		- Emphasis on low cost - Easy and fast assembly - Use of native and recyclable materials - Ability to customize based on the specific needs of families and the number of inhabitants - Use the shape of a circle and a cylinder - Minimize the space occupied on the ground - Define dimensions with Pay attention to the space required for the person lying on the floor and enough space for another person to pass - Define a height of 2.4 at the edges to avoid getting stuck while sitting
Research on Modularization and Sustainable Design of Temporary Housing (2018) (Yu & Bai, 2018)		- Modular design - Design of prefabricated modules with dimensions 1.35 * 2.7 * 2.7 - Module consisting of bedroom, kitchen and bathroom - Folding interior furniture - Use of plywood in the structure - Minimum module area 21.7 square meters
Proposing a Model for the Design of Post-Disaster Temporary Housing Based on the Needs of the Injured with Post-Implementation Evaluation Approach (2018) (Asefi & Farrokhi, 2018b)		- Paying attention to the dimensions and size of the space (3 * 4 for 4 people) - Simplicity of the design to induce a sense of security and visual comfort - Designing a three-part plan (entrance, living space, wet space) Installing heating devices - Changing the length of the model and adapting the space for use 4 to 6 people - Possibility of group arrangement for relatives and creating inner courtyards for periods and conversations - Use scissor likes structure to extend temporary housing - Minimum module area 18 square meters

Examining the examples mentioned in Table 1, it can be seen that good efforts have been made to adapt housing for small and large families, and the lack of space is one of the main problems in temporary housing. But the problem is that the samples did not provide a precise solution to determine the dimensions of housing based on observations made to determine the dimensions required for temporary housing. Also, in relation to the variety of the plan and giving the user the right to choose to create the desired plan, it seems that there is no choice for the user, and the modules do not have enough flexibility to allow different layouts. Another issue that is observed is the issue of climate. The samples both focused on a specific climate and determined the dimensions based on it, or did not offer a proposal for different climates. Therefore, this article tries to reach the maximum flexibility in the plan and form presented regarding the climate issue.

3. REVIEW OF THE LITERATURE

3.1. Temporary Housing

Quarantelli classified post-disaster settlements into four categories: a) emergency shelter which may be in the form of tents, relatives' houses, or dwellings with basic appliances, b) temporary shelter which may be used for several weeks after the disaster and resemble a tent, c) temporary accommodation which prepares people to return to normal conditions and do their routine activities and may be in the form of prefabricated buildings or other options, and d) permanent accommodation (Quarantelli, 1995) (Chart 1).

In addition to the classification above, these three terms are also used in the literature of disasters:

a) Transitional housing: This term includes the process of residence from the emergency to the settlement time, for which the time factor is a top priority as the main indicator.

b) Intermediate housing: This term encompasses the meaning of the term (a) more or less and, consequently, it simultaneously includes the "time process" and "physical form" of temporary housing.

c) Temporary shelter: This term is more structural and physical in comparison with the other two terms and includes a broad range of structural forms and temporary accommodations, from emergency tents to prefabricated houses.

The concept of temporary accommodation is a combination of these three terms, which includes the physical and non-physical aspects of shelter and post-accident accommodation. The concept of temporary accommodation is a combination of these three terms, which includes the physical and non-physical aspects of shelter and post-accident accommodation. Therefore, temporary housing can be defined as follows:

- A physical structure inhabited by people after a catastrophe,
- A part of post-disaster accommodation process; a house not as a part of production but as a part of the process, as defined by Teroner,
- A place as a post-disaster shelter for people until provision of permanent housing (Johnson, 2007)

The duration of temporary accommodation, depending on the circumstances, type of crisis, and facilities, is estimated at 6 months to 2 years, which is considered by some researchers and rescue agencies as the core of permanent accommodation. The general meaning of shelter and temporary accommodation goes beyond living space and includes concepts such as peace, comfort, and tranquility. It should be noted that people become "homeless" after a catastrophe, not "just lose their buildings". Destruction and loss of the home is the major cause of stress among the injured after the death of their relatives (Carballo, Heal, & Horbaty, 2006). Loss of housing is a loss of value, dignity, identity, and privacy instead of physical deprivation. Therefore, shelters should be considered as a space for peace, security, tranquility, and mental rehabilitation of the injured. Providing housing is an essential step to create a sense of psychological balance and prevent further deaths and catastrophes in affected communities (Khorshidian, 2012). From the survivors' view, temporary housing should cover the following tasks and features: protection from heat, cold, wind, and rain; storage of intact furniture and assets; stabilization and maintenance of borders of the house; provision of initial conditions for next operations; provision of security, mental comfort, and privacy; determination of a specific address to receive services; settlement of people in a zone with access to work; provision of accommodation for families who have evacuated their homes for fear of post-disaster damages (Hajinejad, Bazrafshan, Vosoogi Hamzeh Khanloo, & Badri, 2016). Given the scale of the disaster and existing facilities, temporary houses are provided for victims in various ways. The recognition of the typology of temporary housing is a top priority to choose the best option among temporary houses in accordance with local conditions. Therefore, Chart 1 presents the physical types of temporary housing.

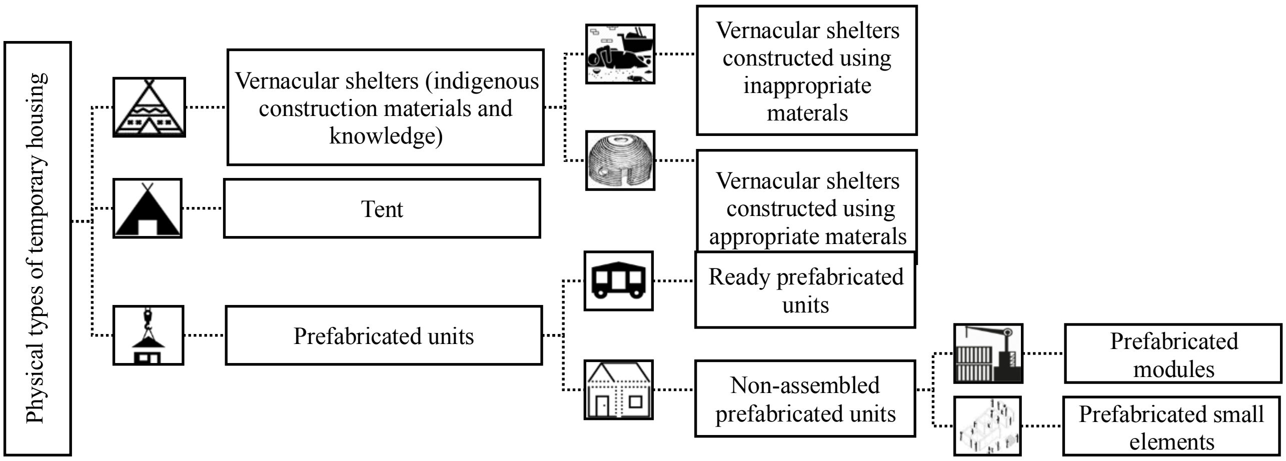


Chart 1. Physical Types of Temporary Housing (Source: Authors)

Features such as high speed of construction and assembly, low cost of construction, and ease of transportation to the site are the priorities for choosing the type of temporary accommodation. For this reason, the tent is always considered as the first option for temporary accommodation of natural disaster victims. According to studies, in most cases, temporary housing includes tents, assembly plate houses, and container houses. The tent has the advantages of low storage volume, easier placement, quick installation, low cost, reuse, and so on. However, it has disadvantages such as the poor ability to withstand bad weather, monotonous atmosphere, inadequate housing and poor hygiene that are not suitable for long-term use. Assembly plate houses can quickly install the assembled function and have a relatively complete performance space. But the cost of materials is high, and the construction process requires a professional construction team. Once recycled, the use value is not high enough for reuse. It also needs a lot of money to support. Container homes as new sustainable housing in recent years can quickly solve the housing problem. The integrity of container houses is good, it also has strong seismic resistance and deformation. At the same time, it can be easily disassembled and assembled, and it has a good sealing performance. It can also be placed directly on the terrace with better drainage conditions (Yu & Bai, 2018). But the main problem of container houses is not adapting to the needs of different users and the problem of space. Therefore, considering the types of temporary housing that exist, it is an optimal example that has a small volume of tents for transport and the capacity of the container for housing. Also, the cost is low and the erection speed is high.

Today temporary houses provided for the injured are not often welcomed by users in spite of high construction and assembling speed and ease of transport; hence the recognition of problems of existing temporary housing is effective for better design and elimination of their inadequacies.

Given the studies and experiences of previous catastrophes in Iran and abroad, natural disasters have physical and psychological consequences. The psychological consequences of disasters are intensive so that it is impossible to predict and control many issues. According to a study conducted by Watson et al. in 2002, only 10% of victims of natural disasters can be safe from stress and mental pressure in the short term. Thus, 50% of people need more time to calm down and 40% are affected severely and require much more time to return to normal circumstances (Norris, Friedman, & Watson, 2002). After natural disasters, the level of calm and mental health of people highly depends on their accommodation type (Caia, Ventimiglia, & Maass, 2010). Temporary houses provided for victims of natural disasters have problems that can be briefly classified as unsustainability and inconsistency. Temporary housing leads to economic and environmental unsustainability and their inconsistency is associated with cultural, social, and physical issues. The problems of temporary housing are listed in Table 2 for better understanding.

To solve or minimize temporary housing problems associated with unsustainability and inconsistency issues, temporary housing should be designed to meet the needs of different users and adapt to a variety of cultural, social, and physical conditions. Flexibility as a strategic concept can be effective in this regard and enable temporary housing to respond to different conditions of users. Numerous problems of temporary housing, associated with economic and environmental unsustainability, are also eliminated using flexibility and energy-efficient and sustainable measures.

Table 2. Problems of Temporary Housing (Source: Authors)

Problems of temporary housing	Unsustainability	Economic	- The construction and transfer of temporary housing units to the site sometimes cost as three times as a permanent housing unit (Hadafi & Fallahi, 2010). - The cost of infrastructure necessary for installation of temporary housing units, e.g. road, water supply, electricity, sewerage, etc. (al-Ulumi & Avaj, 2015). - Costly process of implementation and removal (al-Ulumi & Avaj, 2015). - Incompatibility between features of temporary housing and users' needs and inappropriate changes in or abandonment of temporary housing by users, which poses costs and expenses to rescue institutes
		Environmental	- Inability to collect all infrastructure, foundations, and the remaining temporary housing units after use - Inability to re-use temporary housing units by changes in its use (al-Ulumi & Avaj, 2015). - Inability of temporary housing to meet basic needs of users, improper supply of fuel and food using environmental resources and damage to the environment (Thadaniti & Chantavanich, 2013).
	Inconsistency	Cultural	- Use of technology and standardization and ignorance of cultural and vernacular issues (El-Masri & Kellett, 2001) - Inattention to climatic differences, the form of houses, size and number of households and variable needs of users (al-Ulumi & Avaj, 2015).
		Social	- Humiliation or passivity of service recipients
		Physical	- Inattention to form and materials of temporary housing for good mental effect on users and acceptance of this structure as their home (Caia et al., 2010). - Physical inconsistency between temporary housing and users' mental image of home (Boen & Jigyasu, 2005). - Lack of sufficient space in temporary housing for large families.

3.2. Flexibility

Flexibility is defined in general terms as bendability, variability, capacity to adapt to different purposes or conditions, and freedom from stiffness or stiffness (Rasouli Sani Abadi, Farhady, & Ghaffari 2020). The flexible architecture has been interested around the world and used for centuries. Flexible architecture includes a wide range from the tents of nomads and the Mongolians to the portable houses attached to cars and has been the source of inspiration for architects. The term "flexibility" was first introduced as an architectural term in the early 1950s and Walter Gropius was one of the first flexibility theorists in 1954 (Khorshidian, 2012). Regardingthe flexibility, Gropius argued that architects should not consider the building as a monument, but it should be considered as a basis and place for living to provide adequate flexibility for future needs and modern human life. In 1958, Robenk, Shephard, and Ton defined flexibility as a capability that gives users the right to choose and allows for customization. In 2011, Kronenbourg offered a comprehensive definition of flexibility that embraced all architectural forms. He believed that flexible architecture is a floating architecture complemented through its users' habitation and exploitation. In fact, this concept is extremely related and limited to the reality of our lives (i.e. both the spirit and the material). The most important effects of flexibility in architecture are related to the effect by which the building is flexible in adapting to changes in human life and, as a result, extends its lifespan (Ghafourian, 2018). Also, adaptation of housing to the needs of the user also promotes public satisfaction with housing (Asefi & Farrokhi, 2018b).

The definitions of flexible architecture indicate that the solution for temporary housing lies in flexibility and there is maximum consistency between flexibility concepts and necessary characteristics of temporary housing. Temporary housing is faced by a variety of users with different social, cultural, and climatic characteristics, and flexibility can enable temporary housing to meet the diverse needs of various users.

There are a variety of methods to apply flexibility in temporary housing, described as the types of flexibility. Adaptability, diversity, changeability, interaction, and mobility are the five main types defined for flexibility by various theorists (Asefi & Ahmadnejad Karimi, 2016). Among the types above, adaptability, diversity, and changeability are the most compatible with temporary housing issues, and their components are given in Table 3.

Among the types of flexibility, considering that in temporary housing there is a need to expand the volume to adapt to large families and also to change the interior space to use the space according to the user's needs, two types of adaptability and changeability are the most adaptable with the subject of temporary housing. However, components of diversity such as mobile furniture and the installation of potential spaces for use in accordance with the user's needs can be used in the design of flexible temporary housing.

The proper use of a variety of flexibility is a basic condition for the design of temporary housing to meet all the needs of affected users. Therefore, in the following, flexibility solutions of all three types that can solve the problems expressed for temporary housing in Table 2 are listed in chart 2. The contents of chart 2 present the components that should be considered in the design of flexible temporary housing.

There are many components that need to be considered in the design of flexible temporary housing. Many components of flexibility need to be considered in the plan, so it is important to design a flexible plan that can be changed to suit the user's needs. Digital tools have the ability to apply various components to the design and provide optimal and scientific results. Therefore, instead of using the previous methods of designing the plan, digital tools are used.

Table 3. Flexibility Types of Temporary Housing (Source: Authors)

Flexibility types	Components	
Adaptability	Ability to make changes by users Segregation of interior space by users according to their demands	The open plan of temporary housing
		Geometric structure of the plan
		Provision of adequate space for new equipment due to changes in use
Diversity	Ability to change interior space of temporary housing without changes in total area	Provision of potential spaces in the plan of temporary housing
		Ability to use interior sliding partitions, etc. for integration and segregation of interior spaces
		Use of mobile furniture
Changeability	Ability to increase and decrease the volume of the building	Increasing and decreasing the volume by horizontal and vertical connection of modules
		Increasing and decreasing the volume by exterior sliding partitions

	Problems	Solutions	Design
Unsustainability	**Economic** Transport and construction cost Essential infrastructure cost Implementation and removal process Abandonment of temporary housing or making changes in it	• Modular mass production and possibility of mass transport • Energy sustainability, ability to produce energy and energy-sufficiency • Modular design and construction and ease of assembling and dismantling with no need for skilled labor • Flexible design able to create predicted changes	• Modular design of plan and unassembled prefabricated units • PV panels, wind turbines and rainwater storage systems • Modular design and unassembled prefabricated units for implementation and removal by user • Application of types of changeability and diversity in temporary housing
Unsustainability	**Environmental** Inability to collect all infrastructure and residue of temporary housing Inability to re-use temporary housing by changes in its use Supply of fuel and food using natural resources	• Modular design and assembling without skilled labor • Changeability of temporary housing and usability in other places • Prediction of necessary spaces for comfortable living in temporary houses (e.g. kitchen, bathroom, etc.)	• Modular design of plan and unassembled prefabricated units • Flexible design and application of types of adaptability and diversity in temporary housing • Appropriate physical planning in accordance with standard dimensions for plan of temporary housing
Inconsistency	**Cultural** Inattention to cultural, vernacular and climatic issues Inattention to differences of families and variable needs of users	• Changeability and adaptability of design to vernacular and cultural conditions and responsiveness in terms of energy and climate • Changeability of plan dimensions according to needs of users and family size	• Ready prefabricated units and application of flexibility • Plan and volume analysis of temporary housing in terms of energy conservation and supply • Modular design of plan and volume of building, flexible design by applying types of changeability and diversity
Inconsistency	**Social** Humiliation or passivity of service recipients	• Participation of users in installation of temporary housing and their right to select favorable spatial layout	• Unassembled prefabricated units which can be installed and assembled by user • Modular design of plan and volume to generate a variety of layouts and volumes
Inconsistency	**Physical** Inattention to form and materials of temporary housing Physical inconsistency of temporary housing with users' mental image of home & lake of space	• Adaptability of temporary housing design to vernacular forms and use of local materials • Changeability and adaptability of temporary housing design to mental image of users	• Flexible design of temporary housing using types of adaptability, changeability and diversity

Chart 2. Temporary Housing Problems and Design Solutions and Components regarding Described Problems (Source: Authors)

3.3. Digital Design Techniques

In the Change or Destroy report, 2005 Pritzker Prize winner Tommy Maine argued that if you want to live in the 21st century, you have to adapt your thinking to this age or you will end up disappearing. Today is the age of digital architecture. At this age, the goal is to increase the speed and quality of the design. Temporary housing is also precisely aimed at improving quality along with increasing the speed of construction and assembly. To improve the quality of temporary housing and its flexible design, many features must be considered in its design.

Architecture has evolved a new style of architecture with the help of digital tools. A type of computer-aided design (CAD) technology that acts as a tool for designing specific projects and helps designers optimize and improve their projects. In this method, the computer solves very complex design problems with the help of algorithms. Advanced algorithms and computational methods in this style are used not only for design but also to create impossible possibilities. One of the most powerful tools that has made it easy for architects to use algorithms to solve problems is the Grasshopper plugin, which is installed on Rhino software. Grasshopper has several plugins that can be useful with the help of algorithms in discussing the types of structures, energy, plan, form, optimization, etc. The plugins used in the design of temporary housing in this article have been due to the importance of different parts of the design. Given that temporary housing requires an optimal plan in terms of dimensions and maximum efficiency and flexibility, the Space Syntax plugin, which directly addresses the plan, can be very useful. To optimize the dimensions of the plan, the Galapagos tools have been used, and to adapt to climate diversity, Honeybee and Ladybug extensions have been used.

Space syntax presents a computational toolkit developed for configurative architectural design, that is, a computational design process, equipped with real-time space syntax analyses in a parametric CAD environment, which begins with defining the desired spatial configuration in the form of a bubble diagram. The syntactic design methodology put forward by this toolkit aimed at bridging the gap between space syntax as an analytic theory of architecture and architectural design practice. The toolkit has been made in an attempt to investigate the possibility of deriving at the plan layout patterns through sketching spatial configuration using an 'interactive bubble diagram' that represents a spatial connectivity graph. Beginning the design process with a graph allows for real-time feedback of Space Syntax measures such as integration, choice, and difference factor. Besides, by choosing every space as a 'root', designers can immediately view their configurative ideas, literally from different points of views in automatically drawn justified graphs (Nourian, Rezvani, & Sariyildiz, 2013).

The Galapagos is a tool in the Grasshopper plugin that helps optimize problem-solving through the objective function using a genetic algorithm. In flexible temporary housing, this tool is used to optimize the dimensions of the plan, and how to define the objective function will be explained below.

Ladybug plugin by connecting Grace Hopper and Rhino environment to climate data provided by Power Energy Plus engine to analyze the initial design process including analysis of weather information, shading, solar energy, comfort parameters, thermal, psychometric, and bioclimatic diagrams and generalities can help you in the initial design process from large-scale and urban to the building. Honeybee plugin provides a powerful space for the user and the designer by connecting the user interface to Energy Plus, Radiance, D-SIM, Term, and Open Studio. The honeybee is a plugin for light and daylight analysis, modeling to optimize energy consumption, thermal simulation and building loads, cost estimation, wall execution details, mechanical system type, schedule, activity type, and all details for simulating and optimizing building energy consumption are included. In the design of temporary housing in this article, Ladybug and Honeybee plugins have been used to analyze the brightness of the interior of the housing.

4. DISCUSSION

The mentioned problems for temporary housing can be solved by providing an optimal physical plan for different families, designing a modular plan to provide the possibility of different layouts, designing in the form of prefabricated modules to reduce the volume to transfer and increase the cooperation of victims. In assembly and increasing the sense of belonging, the application of flexibility components such as external scalability, integration of indoor spaces, moving furniture, etc., as well as considering the amount of light radiation and adequate use of daylight in different climates, are eliminated. Figure 3 shows which of the introduced digital tools such as Space Syntax, Galapagos, Ladybug, and Honeybee can be used to solve the problem.

As shown in Chart 3, the first step in designing flexible temporary housing is to design a flexible plan that requires a basic physical plan. The physical program should consider sparsely populated and densely populated families. In most of the reviewed articles, temporary housing is designed for a minimum of 1 and a maximum of 6 people. Therefore, in this article, this range is considered in terms of the number of people.

For the plan of temporary housing, the proposed alternatives must satisfy the minimum dimensions and standard physical planning so that all spaces required by the user can be embedded in the plan (e.g. storage space and workplace). The modularity of the plan is also an essential condition to serve families of different sizes and it would be possible to integrate or combine different spaces in the plan to achieve flexibility and various uses. The Space Syntax plugin is a digital toolkit that can apply current requirements to the plan scientifically. The inputs of the Space Syntax plugin are the title of spaces in the plan, dimensions of spaces, geographic location of spaces, the relationship between various spaces, and the total area of the plan. Accordingly, the first step is to achieve an optimal plan is physical planning. The spaces intended for temporary housing are primarily the entrance space (lobby) because they help maintain health and create security inside the housing. Wc and kitchen space are important parts of the plan that are considered inside the housing. Living and sleeping areas are also among the main spaces that can be converted to each other through sliding walls due to the flexibility of the plan. For larger families, there is a potential space plan so that if there is a need for workspace, storage, or any other function intended by the user. The dimensions listed in Table 4 are derived from Neufert's Architects' Data as standard dimensions for different spaces.

The information listed in Table 4 is given to the Space Syntax algorithm as inputs and a schematic plan is extracted from the algorithm according to the analyses conducted by the plugin, for example, centralization, control, spatial mixing, and entropy analyses (Fig. 1). In the next step, the schematic plan is investigated by the architect for the modular design and the optimum modules are presented for temporary housing design (Table 5).

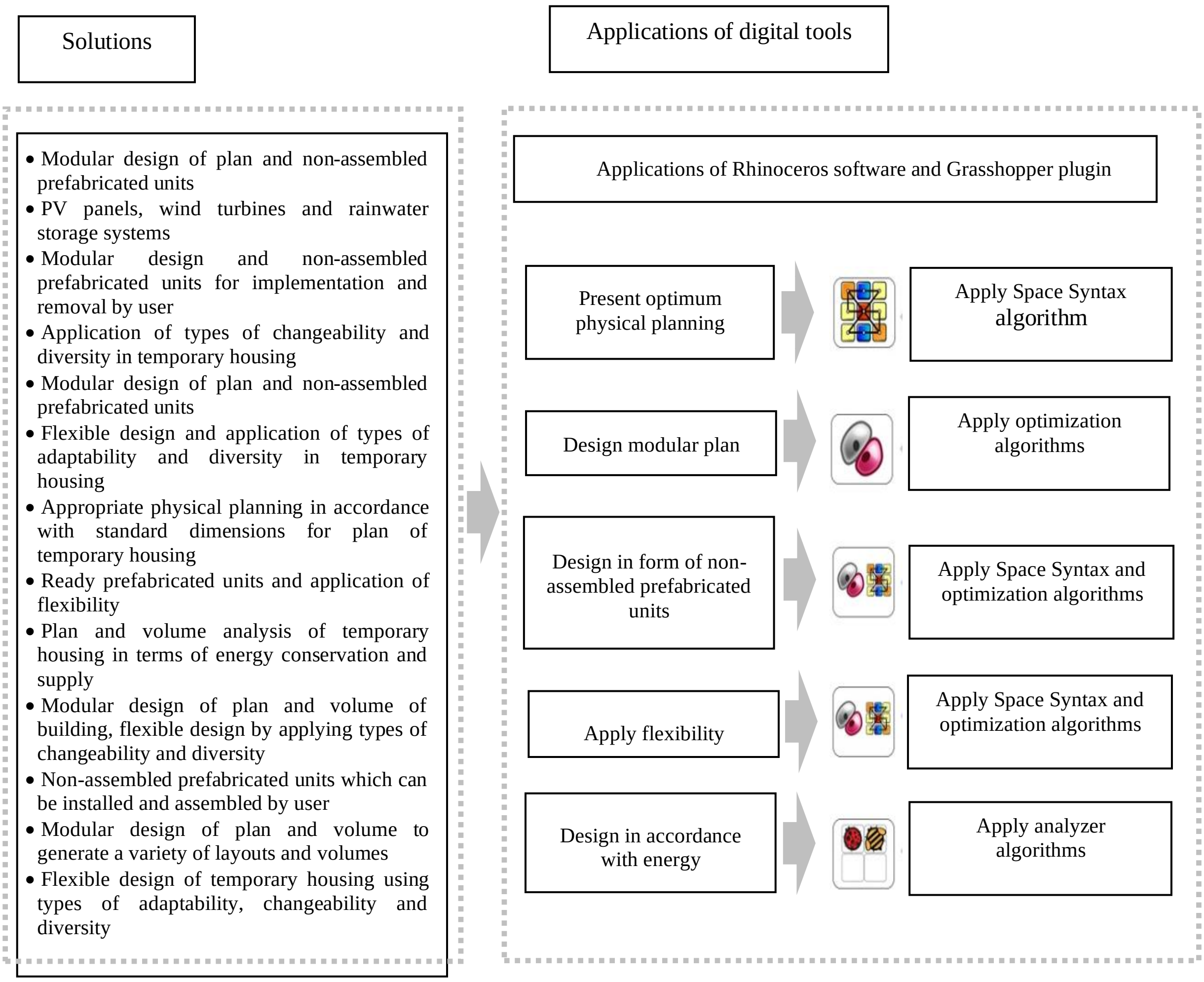


Chart 3. Applications of Digital Tools in Design Components and Solutions (Source: Authors)

Table 4. Physical Planning of Temporary Housing for Families of Different Sizes

Size of family	Required spaces	Space dimensions (m and m^2)	
1 member family	Lobby	2.00 × 1.50	3
	Bathroom (WC)	2.00 × 1.50	3
	Kitchen	3.00 × 1.80-2.10	6
	Living room	3.30 × 3.45	12
	Area: 24-30 m^2		
2-3 member family	Lobby	2.00 × 1.50	3
	Bathroom (WC)	2.00 × 1.50	3
	Kitchen	3.00 × 1.80-2.10	6-9
	Living room	3.45-4.50 × 3.30-5.00	12-21
	1-2 bedroom(s)	2.60-3.30 × 3.10	9-12
	Area: 36-60 m^2		
3-5 member family	Lobby	2 × 1.5	3
	Bathroom (WC)	2 × 1.5	3
	Kitchen	2.40-2.70 × 3.95	6-10
	Hall	3.00 × 2.00	6
	Living room	3.45-4.50 × 3.30-5.00	12-21
	2 bedrooms	2.60-3.30 × 3.10	9-12
	Storage space (potential space)	3.30 × 3.10	9-12
	Area: 60-75 m^2		

(Source: Authors)

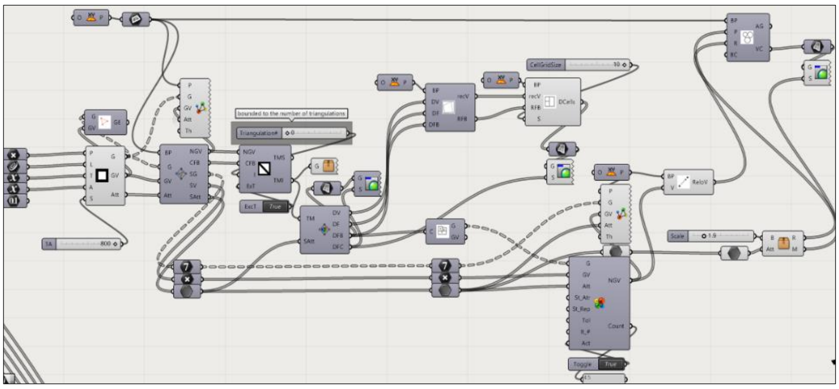
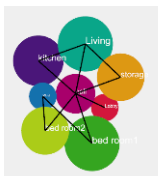


Fig 1. An Algorithm for Drawing a Schematic Plan of Spatial Layout via Space Syntax Plugin and Grasshopper

Table 5. Outputs of the Algorithm Described via Space Syntax for Flexible Temporary Housing Design

	Neighborhood analysis	Selection analysis	Entropy analysis	Integration analysis	Circular diagram	Schematic plan
1 member family	w.c: 0.333	w.c: 7	Living: 0.3111	w.c: 1.056		
	Kitchen: 0.833	Kitchen: 7	Lobby: 1	Kitchen: 1.056		
	Lobby: 0.833	Lobby: 7	w.c: 1	Lobby: 2.112		
	Living: 2	Living: 11	Kitchen: 1	Living: 2.112		
2-3 member family	Kitchen: 0.667	Kitchen: 9	Living: 0.907	B.room: 1.058		
	B.room: 0.833	B.room: 13	Lobby: 0.907	Kitchen: 1.056		
	w.c: 0.833	w.c: 13	B.room: 1.058	w.c: 1.056		
	Lobby: 1.333	Lobby: 15	Kitchen: 1.058	Lobby: 2.112		
	Living: 1.333	Living: 15	w.c: 1.058	Living: 2.112		
3-5 member family	Lobby: 0.167	Lobby: 17	Hall: 0.686	w.c: 0.766		
	Storage: 0.5	Storage: 19	B.room2: 0.924	Lobby: 0.985		
	Kitchen: 0.5	Living: 19	B.room1: 0.924	Storage: 1.149		
	B.room2: 0.667	Kitchen: 19	Lobby: 1.174	Kitchen:1.149		
	B.room1: 0.667	B.room2: 27	Storage:1.375	B.room1:1.379		
	w.c: 1	w.c: 27	Kitchen:1.375	B.room1:1.379		
	Living: 1.167	B.room1: 27	w.c: 1.375	Living: 1.379		
	Hall: 3.333	Hall: 59	Living: 1.436	Hall: 6.896		

(Source: Authors)

With the help of space syntax and analysis of the relationships of spaces together, the best layout with the best possible relationships with the optimal schematic plan is obtained. Given the diagrams, space syntax analyses, and schematic plan, the plan is then designed and organized. Some points must be considered in the design of the plan. Firstly, the plan should be modular to be easily constructed by the modules; secondly, the form of modules should be chosen in such a way that they can be arranged beside each other efficiently and form a space. In this article, a module is considered for each space to be able to separate the bathroom and kitchen module as a wet space from other modules.

An investigation on the dimensions determined through the physical planning shows that all values are a multiple of 3, so the work begins using modules with an area of 3 m^3. There are two square and hexagonal alternatives for the form and appearance of modules. Both shapes have the maximum area versus minimum perimeter among other forms and can be easily arranged beside each other due to their regularity. A 6 m^2 module is obtained by placing two 3 m^2 modules next to each other, through which it is possible to create 9 and 12 m^2 spaces. There are a variety of techniques to construct the modules which may be composed of fixed and variable elements. In Figure 2, the purple lines represent sliding partitions utilized to provide flexibility in the temporary housing.

Two states can be considered for the hexagonal module. Firstly, a hexagonal module with an area of 3 m^2 can be considered as the basic module of construction, which consists of fixed and variable elements. Hence it is possible to create spaces with an area of 6, 9, and 12 m^2 by arranging the modules. Secondly, the hexagonal module can be divided into two halves. Hence each space (e.g. bathroom, kitchen, living room, and bedroom) can be in the form of a functional module encompassing the facilities in accordance with the function. Moreover, in this state, the temporary house can consist of 2 general modules which are assembled in situ and allow for interior divisions. The modules of bathroom, kitchen, bedroom, and living room have an area of 3, 4.5, 6, and 6 m^2, respectively, and the module of the house is a unit with an area of 20 m^2. Each space is created through the connection of two modules (Fig. 2).

By determining the optimal dimensions of the plan and the ideal schematic plan, the types of variation in the arrangement of modules next to each other and the conversion of spaces according to the different needs of users and how to use housing day and night are shown in Table 5. Recognizing the variety in the plan has become easier with the help of specified colors for each space. It is clear that the proposal has a great variety for users with different cultures and numbers of people. Obviously, by changing the number of modules, a wide range of layouts can be provided (Table 6).

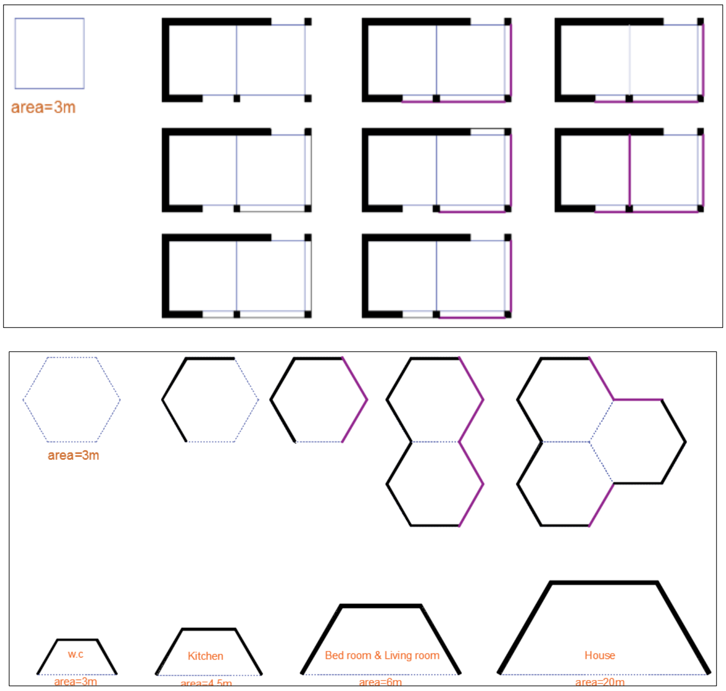


Fig 2. Specification of Square and Hexagonal Modules for the Design of Plan (Source: Authors)

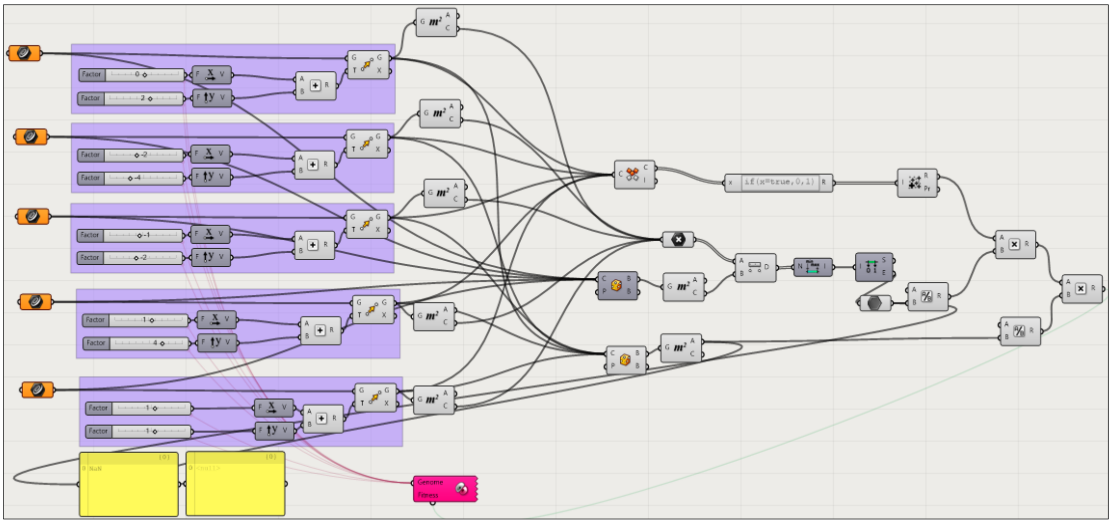
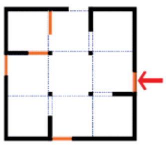
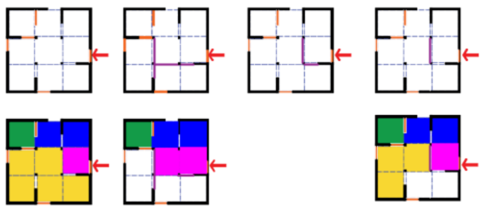
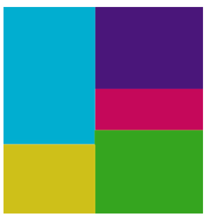
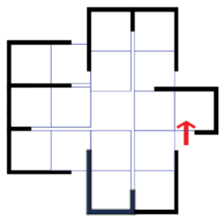
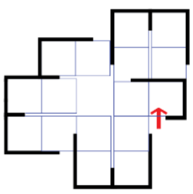
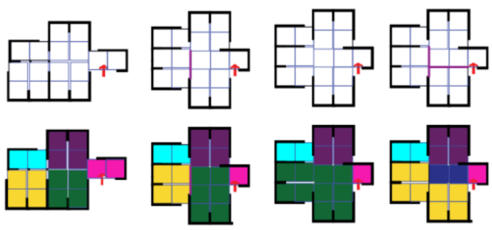
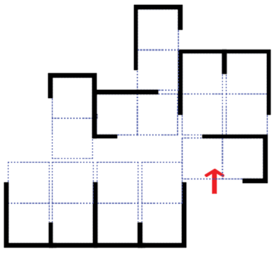
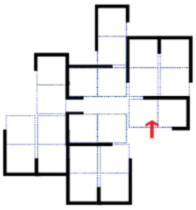
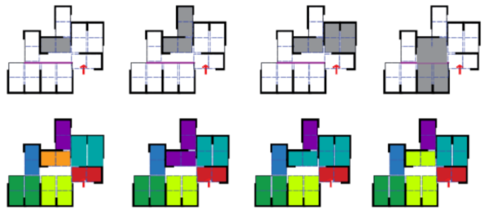


Fig 3. The Algorithm Used for the Optimization of the Area of Plans through the Displacement of Modules by Galapagos (Source: Authors)

Table 6. Plan Designed by Rectangular Modules and Optimized using Galapagos Plugin for Temporary Housing

	Plan			Optimized plan	
1 member family	Spaces	Lobby Kitchen Bathroom (WC) Living room		This form is the most optimum state of the plan using 4 modules.	
	Original plan	4 Modules Area: 27.5		Flexibility states	
2-3 member family	Spaces	Lobby Kitchen Bathroom (WC) Living room Bedroom			8 modules Area: 48
	Original plan	8 modules Area: 50		Flexibility states	

Plan				Optimized plan	
3-5 member family	Spaces	Lobby Hall Kitchen Bathroom (WC) Living room Bedroom 1 Bedroom 2 Potential space	The potential space is a room which may have a specific function or be integrated with other spaces of the house if necessary and expand the spaces.	10 modules Area: 70 	
	Original plan	11 modules Area: 75		Flexibility states	

(Source: Authors)

For the design of flexible temporary housing, it was decided that the application of all three types of flexibility in housing was considered. Up to this point, flexibility is applied in the interior of housing through adaptability and diversity. The type of changeability of the flexibility of the outer body of the housing must also be changeable. Therefore, scalability was added to the designed modules in such a way that one of the module walls related to the living and sleeping space has the ability to increase and decrease the length in a sliding manner. The extent of the extension of the length of the housing is determined by the climatic conditions, and light is a factor that has been considered for this purpose. This means that the space is large enough that there is enough light inside the temporary housing to provide the required lighting and that the light warms the space inside the housing (Fig.4).

Considering that the aim is to make it possible to set up temporary housing in different climates, four cities in Iran have been selected due to different climates and conditions. The first city is Tabriz. Because Tabriz is an earthquake-prone city with a cold and dry climate, it has been selected as one of the options. The second city is Tehran. The reason for choosing Tehran is its dangerous conditions for a possible earthquake and the fact that it has a milder climate than other selected cities. The third city, Yazd, is selected due to the hot and dry climate and the selection of the fourth city, Bandar Abbas, is due to high heat and humidity. The extent of expansion and dimensions of spaces is calculated by analyzing climate data for each city. The Ladybug and Honeybee plugins are used through Grasshopper to analyze climate information and determine daylight limits. Figure 5 shows the algorithm scripted using the plugins, and Table 7 shows the results of daylight analysis for the plans.

The recommended light levels in a house include 100 lx for rest, 200 lx for the dining room, and 300 lx for more precise works at home. In each climate, a space can be thus expanded to a degree where necessary natural lighting is supplied. The minimum space required for the analysis and beginning of an expansion is 9 m^2 selected according to the module of the plan. The summer and winter solstices at 10 am and 15 pm as shown in Table 7.

Fig 4. The Extend Part of a Flexible Temporary Housing Module (Source: Authors)

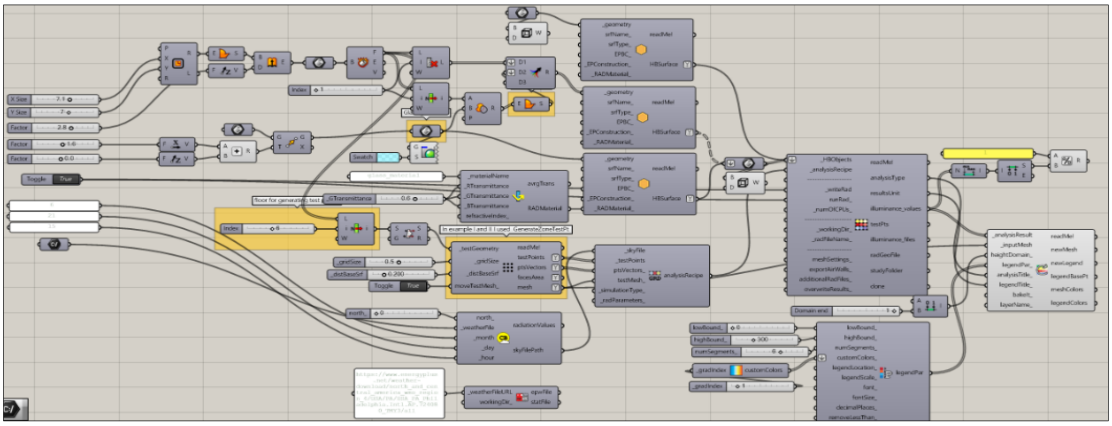
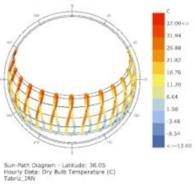
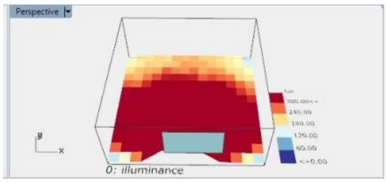
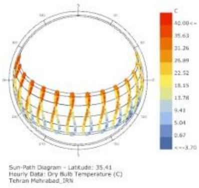
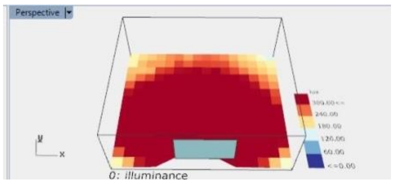
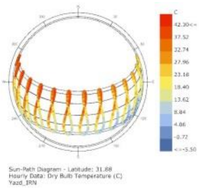
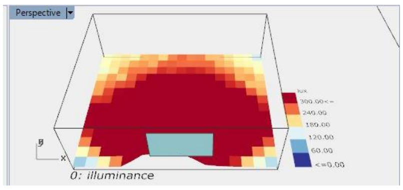
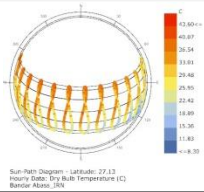
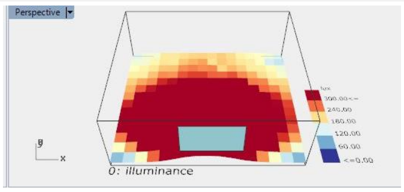


Fig 5. Daylighting Analysis Algorithm for Determining the Range of Deployability of Temporary Housing (Source: Authors)

Table 7. Daylighting Analysis for Determining the Range of Deployability of Temporary Housing in Tabriz, Tehran, Yazd, and Bandar Abbas

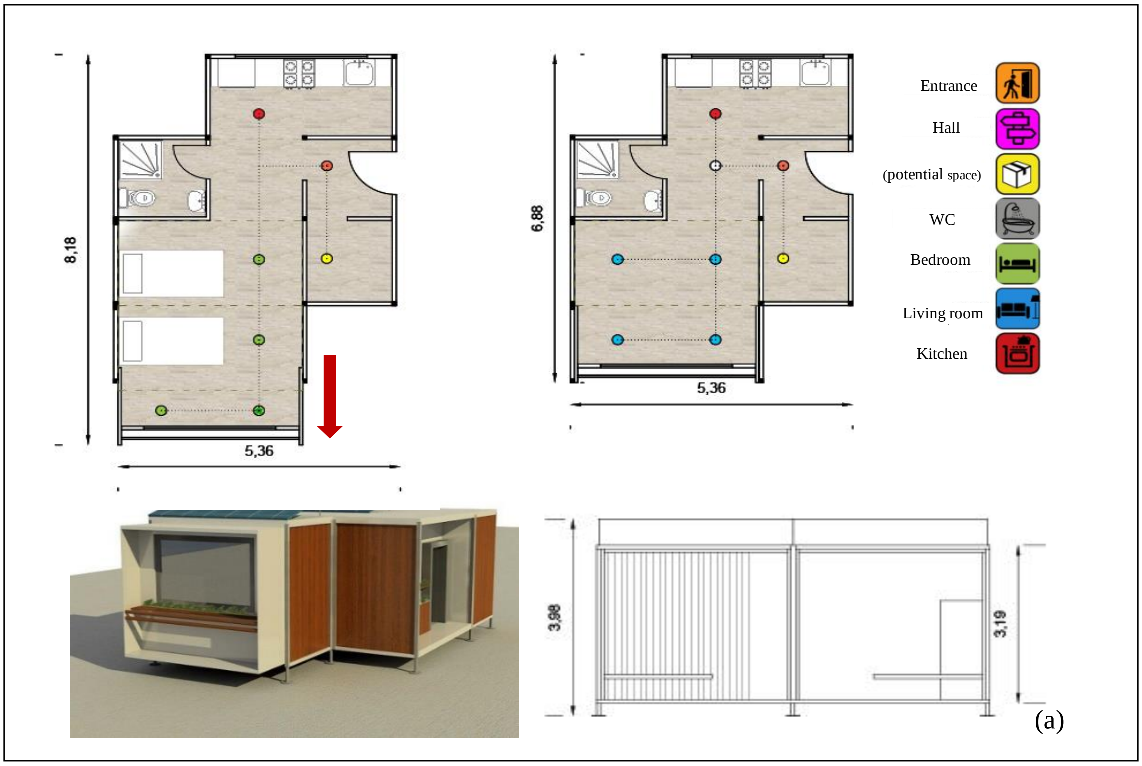
	Stereographic sun path diagram	Space dimensions and time	Results of analysis of solar radiation on plan
Tabriz		Length = 7 m Width = 7 m Height = 2.9 m Month = June Day = 21 Time = 10 am	
Tehran		Length = 8 m Width = 7 m Height = 2.9 m Month = June Day = 21 Time = 10 am	
Yazd		Length = 8.5 m Width = 7 m Height = 2.9 m Month = June Day = 21 Time = 10 am	
Bandar Abbas		Length = 8 m Width = 7 m Height = 2.9 m Month = June Day = 21 Time = 10 am	

(Source: Authors)

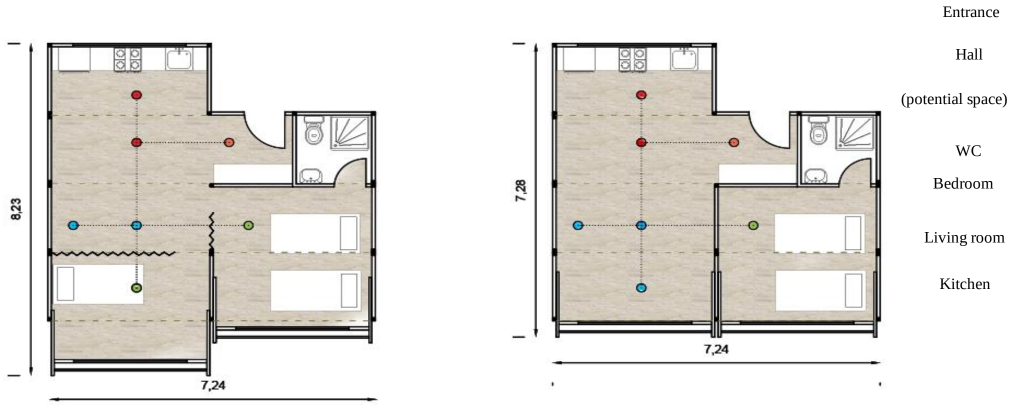
In Tabriz, the maximum and minimum lengths of space with a south-facing window are 8 and 6.1 m, respectively, where adequate daylighting is provided on June 21 at 15:00. In Tabriz, it is thus possible to expand the length of space up to 6 m, or up to 8 m in some seasons. The maximum and minimum values are 9 m and 6.5 m for Tehran, 9 m and 7 m for Yazd, and 8 m and 7 m for Bandar Abbas, respectively. Therefore, the average length of space is 7.2 m for Tabriz, 7.85 m for Tehran, 8.1 m for Yazd, and 7.8 m for Bandar Abbas. The daylighting analysis is also conducted for the width and depth of space. The maximum, minimum, and average depths of space are 8.7 m, 6.7 m, and 7.3 m for Tabriz, 9 m, 7 m, and 7.5 m for Tehran, 9 m, 7 m, and 7.5 m for Yazd, and 8.5 m, 7 m, and 7.3 m for Bandar Abbas, respectively.

It should be noted that the optimum dimensions for the length and width of space are determined simultaneously using an algorithm and the results are extracted separately to allow users to change the length and width of spaces independently. Deployability facilitates the climatic adaptation of temporary housing, in addition to increasing the depth and dimensions of spaces. So, it is possible to enhance shading in hot climates by movable walls and increasing the depth of terrace.

In the design process, the next step is the physical translation of the optimized and analyzed designs into the form. Therefore, volumetric alternatives are provided as planned. In designing the volume, modulation and ease of construction methods are considered. Rectangular boxes with metal frames and panel cover according to the climate, economic conditions, and potentials of the location, including composite, wooden panel, etc. The proposed temporary housing has internal accordion walls and external sliding walls to expand the dimensions of the housing space (Fig. 6)



(a)



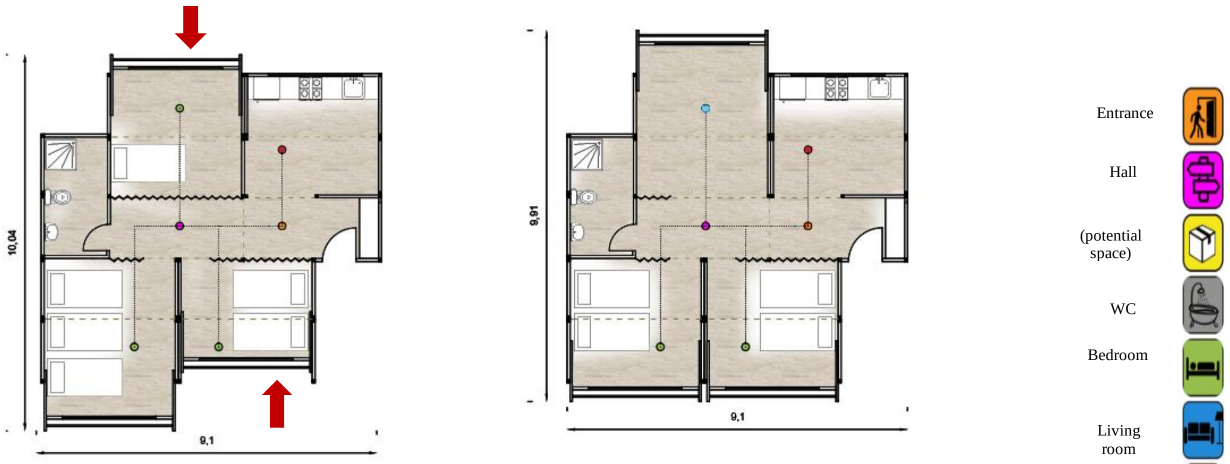
- Extension of bedroom and living room of temporary house towards the south and expansion of space
- Accordion folding partition to convert living room to bedroom at night
- Movable beds which can be folded on wall when not in use.

- PV panels for energy supply
- Plants for mental recovery of survivors and creation of sense of belonging
- Adjustable height bases allow housing to be erected on uneven surfaces with level differences. It also prevents water and insects from penetrating into the temporary shelter.

(b)

- When exterior walls move toward indoors, space decreases in size and becomes ready for rest.
- Accordion folding partitions to convert living room to bedroom at night
- Movable beds in living room convert the space to bedroom if necessary

(c)



- When exterior walls move toward indoors, space decreases in size and becomes ready for rest.
- Accordion folding partitions to convert living room to bedroom at night
- Movable beds in living room convert the space to bedroom if necessary

Fig 6. (a) Optimum model of temporary housing for 1 member family in plan and perspective; (b) optimum model of temporary housing for 2-3 member family in plan and perspective; (c) optimum model of temporary housing for 3-5 member family in plan and perspective (Source: Authors)

It should be noted that the arrangement of the modules side by side and on top of each other as a group for the family to live together has been examined, which is shown in Figure 7. With the possibility of grouping the modules together, psychological security is created for families with a family relationship and the pain caused by the accident heals faster (Fig. 7)

Fig 7. Possibility of Grouping Temporary Housing Together (Source: Authors)

4. CONCLUSION

Temporary housing for survivors of natural or unnatural disasters must satisfy them. User satisfaction with the appropriate response to temporary housing depends on their material and psychological needs. This article examines the problems of temporary housing in different periods, evaluating instability and inconsistency. Once problems are described and evaluated, solutions to solve or eliminate them are explained. In this paper, the challenge is how to translate the design components derived from the proposed solutions to the problems. Solutions are described in terms of appropriate physical planning according to the needs, flexibility, and energy of users. Therefore, temporary accommodation should have all the necessary spaces for the victims to live, the dimensions of the living space should be in accordance with the existing standards, and families with different sizes should be considered. Given flexibility, temporary housing should be able to respond to a variety of cultural conditions that are achieved through adaptation, diversity, and variability. In terms of energy, temporary housing should be able to provide the energy it needs and respond to potential climate change. In this paper, algorithmic tools are used to translate design components. To design an ideal design that can meet all the needs of users, Space Syntax and Galapagos optimization algorithms are used to achieve a flexible layout, and Ladybug and Honeybee analyzer algorithms are used via Rhinoceros and Grasshopper energy plugins manually. An optimal physical model for short-term temporary accommodation has been proposed using this design tool, which is efficient in terms of energy, dimensions, and spatial ratios and can expand and increase the space for different purposes. Hence, optimal temporary housing is able to respond to cultural and climatic diversity. It can be easily transported to different parts of Iran and used in different climatic conditions and adapted to nature and climate with minimal changes in the outer body.

In this study, energy is evaluated in terms of daylight indoors. In future projects, energy-related topics can be emphasized. Solar radiation on the outer walls of the physical body and the conditions of thermal comfort are topics for further research. It is also possible to consider more variables to improve the quality of housing and temporary housing complexes and adopt other design approaches.

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