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ORIGINAL ARTICLE

A Proposal for Sustainable Temporary Housing Applications in Earthquake Zones in Turkey: Modular Box System Applications

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ABSTRACT

The temporary housings constructed in the aftermath of every major earthquake in Turkey, an earthquake-prone region, brought about significant problems during their construction and use. A dwelling space, no matter how it is made, should protect the dwellers' physical and psychological health. As the ultimate goal of a dwelling space is to cater for the necessities of individuals' daily lives, the fundamental element that is instrumental in house planning is the structure of the family who will live there as well as how that family live in the house. Various studies are underway in earthquake zones in Turkey covering the subjects of emergency accommodation (tents), temporary housing, and permanent housing. However, emergency and temporary accommodations are in a non-reusable condition, which entails great losses for the national economy. Thus, this study aims to investigate alternative modular box systems for post-earthquake homeless disaster victims in line with the sustainability criteria.

Key Words: : *Earthquake, Modular system, Box Housing.*

1. INTRODUCTION

Turkey is a country that repeatedly undergoes natural disasters resulting in major fatalities and property losses due to its geological and topographical structure as well as climatic conditions. Housing reconstruction after an earthquake is a crucial issue because of its physical, social, psychological and environmental implications. On the other hand, natural disasters may also lead to the generation of physical, social and economic models that enable urban and rural renewal in settlements [1]. In the last 15 years, the Erzincan, Dinar, Ceyhan, Marmara, and Düzce earthquakes have caused thousands of fatalities [2,3]. The Marmara earthquake on the 17th of August 1999 has once again demonstrated that an earthquake, which is in fact a natural phenomenon

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sustaining vital activities on the Earth, can transform into an apocalyptic disaster leading to irreparable results in our country because of unconscious, unplanned, and uncontrolled man-made structures. With about 15 thousand fatalities and over 30 thousand injuries, the earthquake caused deep psychological wounds, as well as physical impacts on the people in the region [4]. Short after the earthquake, as of the 22 August, 1999, emergency accommodation projects were launched to determine the temporary settlement areas and to reconstruct the environmental structure, and teams of volunteers consisting of the technical personnel of the Department of Development Projects conducted these studies in the region. The aim was to produce permanent solutions to the settlement problems of disaster victims once the projects of prefabricated housing sites were over [5]. The construction of post-disaster housings necessarily entails a process radically different from the construction of housings at normal times since the recovery and reconstruction phases in the aftermath of disasters involve policies and approaches particular to crisis management [6, 7].

Accommodation is a major problem following any disaster. The temporary accommodation conditions, created for earthquake victims, aim at overcoming the negative post-disaster conditions and protecting the victims from external effects. The main objective here is to make sure the earthquake victims can resume their daily routines in the shortest time possible. During the process of temporary accommodation, the requirements of earthquake victims need to be addressed in terms of optimum standards [4, 8]. The accommodation problem is generally handled in three different ways:

- Temporary settlements in other regions
- Temporary settlements in the disaster region
- Temporary housings [9].

It is difficult to speak of a consistent policy of temporary accommodation in Turkey in the period from the termination of the emergency aid stage until normal living was established in permanent houses. A review of similar practices shows that as it is the case in many other countries, passing directly to permanent housing from the emergency aid accommodation stage and thus solving the problem of temporary housing is impossible [4, 10]. The most important feature of the construction of post-disaster permanent housings is the production of new housings in place of the destroyed houses in earthquake stricken regions within a shorter time than the normal construction time [9]. Modular box systems can offer a solution to this problem.

Modular box housing systems refer to houses that are constructed in remote areas and are later collected at a required place. By means of the cranes, different modules are assembled in a particular place to construct single buildings for residential purposes [5]. Being industrialized construction systems, box systems are utilized in structures containing a high degree of service units, such as hotels, public housing blocks, student dorms, educational buildings, commercial structures, hospitals, and elevator shafts [6]. All components, materials and tools should always be correctly installed, and every single part checked carefully to make sure that these products function perfectly. For this reason, inspections are more frequent, but easier and more effective with permanent inspectors inside the facility. The scale and repetition that characterizes many multi-family buildings lends itself to an automated solution, especially in areas located near factories. A controlled indoor environment and stable and experienced labor are conducive to assemblies with consistent quality, often at reasonable costs [7].

2. METHODOLOGY

2.1. Housing Proposal for Earthquake Zones: Modular Box Systems

It is possible to carry out fast custom planning using modular box systems, which will achieve the principle of sustainability. Houses are forms of living and settling with accommodation-protection functions developed by cohabiting individuals or families living together, sharing the same environment, and conducting all living actions together, such as sleeping, resting, eating etc. Main living quarters are multi-purpose spaces that human beings use to meet the needs in their active lives; as such, these quarters generally form the largest area in a dwelling environment.

A construction system, on the other hand, provides solutions for the complete building and includes the load bearing structure, envelope, interior fitting-out and building mechanical (HVAC) systems. The prefabricated–housing sector usually offers only a limited number of facilities with inflexible floor plans, fulfilling customer wishes, so to speak, with surface-treatment variety and without sufficient rooms or fitting-out alternatives. In comparison, a construction system can provide various solutions for a wide range of applications. A general solution facilitating simplification through standardized building components, modular assembly and geometric structure makes the complete system comprehensible and optimal. A building system offers the opportunity for industrial and serial production, which makes it possible to take full advantage of the potential of this construction type. As a result, the quality of the design, materials and the whole process is implemented at comparatively low, yet guaranteed, production costs, so that operating expenses are optimized [11].

Developing a general solution is fundamentally different from creating a general model for the form which, with a small number of basic elements, enables the greatest variety of configurations. This can be achieved with adaptable elements and different combinations. The geometry system, based on a small number of basic modules, is an indispensable component of such a solution. The design and marketing systems are integral and iterative processes; the product and customer profiles must be harmonized and distribution networks laid out. The technical implementation of the general design model defines all individual parts of a building and structures them in different hierarchical levels. The relationship of the above-mentioned adaptable elements to one another is of great significance, while connection modules are central elements of a complex system. In conventional buildings, approximately 50-60% of the components are serially and industrially produced. However, connections of these components to each other as well as to components produced on site are imprecise; as a result, the quality suffers. As a solution to this problem, the goal is to produce complex building elements in factory, where production conditions can be organized better, rationalized with automation, and made more ergonomic for employees. Modern construction techniques are characterized by computer operated processing, which forms the basis of prefabrication as a construction technique. With prefabrication, the only work that remains for the on-site stage is assembly. Here, the goal is not to shorten the construction period, but to reduce the entire course of the project by means of parallel production and a standardized planning process. For prefabricated building elements, the capacity of the connections determines the quality of the system [11]. In this study, a sustainable temporary housing model is developed using the modular box system for Turkey.

3. RESULT

3.1. Advantages of Modular Systems

- The modular box system reduces construction cost and provides an economic solution for low-income families.
- These buildings are more environmentally-friendly. Besides, the factory production installation renders the on-site stage less challenging.
- Modular building is invariably completed at a fixed cost, which is achieved even through winter construction periods. Foundation work is usually quite straightforward and is not affected by weather conditions.
- The fixed costs of modular buildings rarely exceed the amounts specified by contracts, except for the cases whereby an agreement is made with the client as the work proceeds [12].
- Modules are produced in the factory with consistent quality control, which helps to produce good quality products.
- Maintenance is minimized, so running costs are low.
- Modular buildings can be altered or moved with lower costs than traditional structures.
- The buildings may be sold and removed if no longer required.
- The modular building system is fast. It helps to complete building earlier, and quicker construction times mean earlier opening times leading to a quicker return on the capital investment of the client [12].
- Modular box houses are built in open an area, which saves 50% of the overall construction time.

Expansion of buildings is simple by adding more modules:

- Standardized design details for modular buildings simplify and reduce the need for specialist design input [13].
- Modular building construction is safer than traditional on-site building.

Compared to conventional methods, modularization brings equipment into the field at a later stage in the construction program, facilitating completion of civil work at the site before mechanical work begins. Also, commissioning can be scheduled with higher degree of precision since equipment and piping are usually tested --and problems resolved-- before shipment [14,15].

One important and central part of industrialized house building is the prefabrication of building parts. However it takes more than only prefabrication to establish a strong industrialized concept [16,17]. Industrialized house- building is today regarded as a complex involving several interacting sub-areas, which may have reached different levels of industrialization. However it is important to maintain a perspective of systems thinking and a holistic view, so that no part is optimized at the expense of the whole [16].

An essential part of industrialization is the systematic use of technical systems and components with different levels of standardization, that together form the unique ends products-the buildings and apartments. Gibb states that the standardization of components and products is a foundation for further development of the house- building industry, achieved through continual improvement, in the same way as in other industrial sectors [18]. The use of standardized technical systems is closely connected to preassembly and off site production of building parts, which range from the level of component manufacture to a complex level where modular building parts are produced and finally assembled at the building site. Four categories of pre –assembly are specified in *Table 1* [18].

Table 1. Four categories of pre-assembly [18].

Term	Description
Component manufacture an sub-assembly	Many components used in construction are manufactured elsewhere and sub-assembled at the building site. These products would never be considered for on –site assembly. Examples of such products are doors, windows and light fittings.
Non-volumetric pre-assembly	Items assembled in a factory or at least off-site and may include several sub-assemblies and constitute a major part of the building or structure. Examples include wall panels, structural sections and pipe work assembly.
Volumetric pre-assembly	Factory-assembled items that are assembled to a volume element and usually installed on-site within an independent structural frame. Examples include toilet pods, service risers and modular lift shafts.
Modular building	Similar to volumetric units but the units themselves form the building but may be complemented on-site. Examples are office blocks, motels and modular units for residential blocks.

The introduction of modular coordination in the industry not only provides dimensional basis for the coordination of dimensions and of those buildings incorporating them, but also it acts as a tool towards rationalization and industrialization of the building industry. Modular Coordination is essentially based on: [18,19].

1. The use of modules (basic module and multi-modules)
2. 2.A reference system to define coordinating spaces and zones for building elements and for the components which form them.
3. 3. Rules for locating building elements within the reference system.
4. Rules for sizing building components in order to determine their work sizes.
5. Rules for defining preferred sizes for building components and coordinating dimensions for buildings.

The use of Modular Coordination as a dimensional basis for the building industry will pave the way for the creation of open design principles and rules which combine freedom in architectural planning and flexibility in the choice of construction method. It offers designers the possibility of incorporating standardized modular components in building projects effectively due to following advantages: [17,18].

1.Dimentional coordination for simplification and clarification of the building process. It provides a common language for the building industry players, thus creating better coordination and cooperation between various parties.

2. Limitation of variants n dimensions of components, reducing design time especially with the use of standardized modular components.

3.Standardisation of building components, thus reducing manufacturing and installation costs.

4.Prefabrication of standardized components to minimize wastage of materials, manpower and construction time.

5.Industrialisation of the building process through the increased usage of modern technologies such as Computer Aided Design and drafting and Computer Aided Manufacturing.

Separating most of the mechanical work from the civil work also provides an opportunity to shorten the project schedule. These two fields of work can overlap during the module fabrication period to a greater degree with less disruption than on a conventional project because module fabrication takes place off site while civil work continues on site. The transition from a general to a specific modularization strategy requires identifying the type, number, and size of modules to be fabricated, as well as establishing a firm project schedule. It is the responsibility of the project management team to formulate detailed plans for design, engineering, procurement of materials, fabrication of modules, shipping, transportation, on-site erection, and commissioning. The handling and lifting contract should be signed before the engineering of the modules is finished. The transportation route survey and any limitations must be confirmed, and the location of lifting or jacking points on the module must be specified, which can affect the design of the steel work for the proposed method of transportation and handling. The specific methods for handling and installing modules at the site will largely depend on the site itself, the type of modules, the contractor's equipment, and the schedule for module delivery [19].

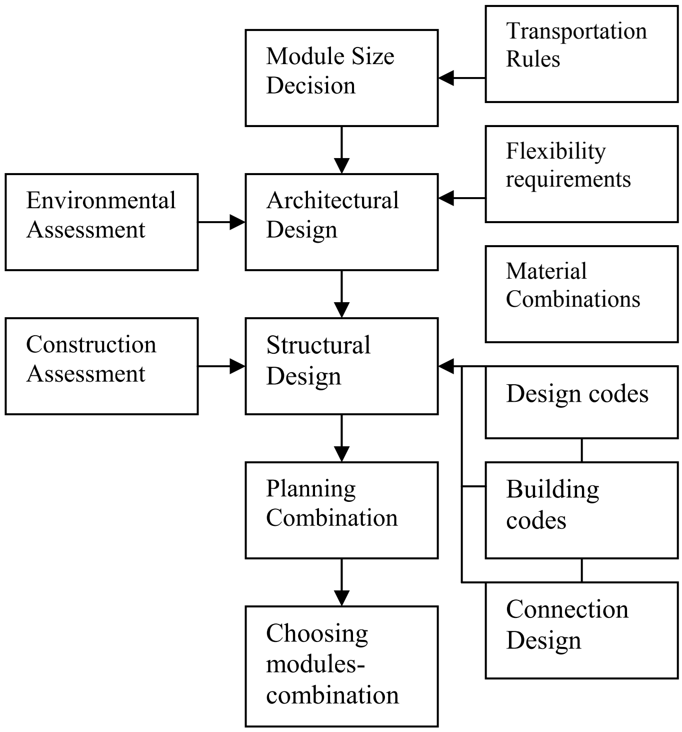


Table 2. The concept of box housing planning.

3.2. Classification of the Box System (Figure 1)

Installation Systems Built into the Framing System Located in Between the Steel Modular Box Framing System: Load-Bearing Modular Box Systems

3.2.1. With respect to the production of box units

a. Systems with Partitioned Box-Units

In this scheme, the prefabricated parts of box-units are delivered to the building site and then assembled to form the box-unit. As an alternative, box-unit components are prefabricated and assembled to form the box-unit in the factory. All necessary finishes are applied, and ready-for-use units are delivered to the site and erected [20].

b. Systems with Monolithic Box-Units

In this mode of manufacturing, the box-unit’s area is cast as a whole and then delivered to the construction area. Since the manufacturing process and transportation of such units cause great difficulties, this method is not common [21].

3.2.2. With respect to design principles of box-units

a. Systems with Open Box-Units

In these systems, the box-units consist of either load-bearing cross walls or load–bearing longitudinal walls and, in either case, the opposite walls are left open. In the case where the module is left open in the longitudinal direction, there are considerable advantages; the spans are shorter and the structural stability of the building is ensured by the cross walls. In addition, cross-walls serve as separate party adjacent dwellings. Alternatively, the modules may be arranged in such a way that each of the dividing walls consists of only a single leaf. In the instance where the module is left open in the longitudinal direction, the span of the floor imposes constraints on the structural design. For this reason, the method has not been widely used [21]. Open boxes have open transverse or longitudinal surfaces. The restricted sides might be the supporting system wall or a separator wall in the supporting system inner wall or supporting system frame. The unclassified side of the modular box unites with the other box, allowing the creation of a larger space. The purpose is to facilitate the transportation of the modular box, or ensure a planning flexibility towards larger spaces created by many united boxes, starting from the unit space consisting of a single box module. Moreover, when the restricted side of a box unites with the unrestricted side of another box, the box is spatially completed. This may lead to material saving. To illustrate, the floor of a box that will go on top of a box not restricted by a ceiling will also serve as the ceiling of the box underneath it. However, the box may also be in the form of a three-dimensional frame in a non-fully-restricted form. This supporting system frame is restricted with the addition of separator walls after it is assembled in the factory or on the worksite. Box components are used in composition with the system in prefabricated or non-prefabricated supporting system structures like the frame, core, tubular, supporting system wall panel or hybrid systems. Boxes are carried by the supporting system structure, rather than the supporting system itself.

b. Systems with Closed Box-Units

In this scheme, the box-units are closed units; therefore, none of the sides of the module are open. All the walls in the unit or, alternatively, the cross or longitudinal walls are employed as load –bearing. One advantage of closed modules is they allow free combination of modules [21]. However, closed modules hamper the flexible layout of a plan and also, from the point of view of economy, they are relatively expensive [20,21].In the closed box system, a space classified with the wall and the flooring and having predefined dimensions will be determined. This box has no growth potential [22]. These are produced in three forms; fully closed forms, forms with open façades, and forms with open upper surface. Closed boxes are boxes that are fully finished at the factory, ready to be mounted. There are no planning flexibilities in buildings made with closed boxes. These systems are greatly similar to “cross-like" systems applied in large-sized panel systems where all walls are supporting systems, or “transverse" systems with the supporting system walls arranged perpendicular to the façade.

a. Closed box unit b. Half closed box unit c. Open box unit

Figure 1. Classification of box units [37].

In closed modular boxes, all sides of the unit are restricted to determine the size of the space. The size of the box is limited to the ability to transport it. The size of the box might cause problems during land transport considering traffic laws and regulations. In this case, the length of the modules in one direction should not be more than 2.40m or 3.30m. As the space dimensions are subject to the box dimensions, these boxes are more suitable for housing structures. Closed boxes have a rigid construction. Bringing them together is the same as in structures with load-bearing walls. Arrangements can be made by putting together boxes of varying sizes on top of each other in different forms.

3.2.3. Flexibility in module design

The most important factor providing flexibility in housing units is the connection between the interior flexibility forming the house block and the flexibility of these elements coming together during the design process. Here, the purpose is to be able to create distinctive interior arrangements.

a. Partition Walls

A window on the façade might prevent the movement of the separator, which is primarily designed to ensure flexibility. By positioning the partition wall, the window opening may be prevented in a desired area. Therefore, the size of windows and their positions on the façade layout are very important. When designing structures for flexibility purposes, the positions of separating elements along open façades should be considered carefully in line with different separation alternatives. They are separated into two parts at the edges of narrow and rectangular projects. So housings with square or near-square rectangular shapes, allowing for the arrangement of two or three different spaces side by side on their façades and facing the sun would be more suitable for flexibility. Another factor affecting different interior arrangements in houses is the position of the house entrance. Depending on the geometry of the area, the position of the entrance determines how many different spaces could be created along the façade. That the entrance is close to the corner of the long or short side increases the arrangement alternatives. Because a big part of the façade is left open, entrances close to the corner allow a higher degree of flexibility.

- The separating interior walls should be of standard dimensions as the industrialized structural elements.
- The separating walls should allow mounting and dismounting with simple tools and by one or two persons.

Different household sizes have different requirements. Household size also varies according to the age of the family members. Depending on time, there is first an increase and then a decrease in the number of individuals in the family. Therefore, the house has to address the requirements of families consisting of varying numbers of individuals. Living styles and changes in the family economy result in the difference in and variation of requirements over time.

b. Installation

The house contains electricity, communication facilities, cable systems, as well as pipe systems, such as the heating, fresh water, waste water, and gas or ventilation systems. However, locations of the pipe systems in the house and their positions both in the vertical and horizontal axis measurements are more important than the cable systems with regard to housings for flexibility purposes. This is because the replacement of cable systems are easier compared to the higher replacement costs of pipe systems. Once close positioning is decided for wet spaces within the whole structure, the position of the core, where different wet spaces meet, needs to be determined for maximum flexibility. Arrangement of wet spaces in the middle of the house might reduce variation of the interior space organization of the house. For this reason, designing the kitchen and toilet close to and the bathroom remote from the entrance might be a good solution for functional variation. On the other hand, if wet spaces are located close to the entrance, or in the middle of the house, the overall floor area of the house unit is divided into two small house units [23,24].

Floor canals, installation walls, blocks or chimneys are used, particularly in multi-storey buildings for vertical distributions of pipes, which form the pipe-based installation system. These canals may be placed onto lower parts of the floor and also arranged at a central point. Vertical installation canals arranged at different points and coinciding with the interior space may fill up the floor space of the house to such an extent that they might restrict flexibility as they are many in number. On the other hand, vertical canals centered at a single point allows for a more flexible interior space organization. With such canals, it will be possible to insert new pipes or renovate the existing ones since vertical installation canals are sufficiently big. Still, it is advisable to change the present location of the installation canals and manage them as part of a fixed structure with a vertical canal containing installation pipes in a house plan design that would allow for changes [25].

Easier to change compared to vertical systems, horizontal systems may pass through ready-made elements passing through upholstery or cabinet finishes after they are connected to structural elements, such as the floor and the walls. For example, changes can be made in horizontal systems with little damage if one wants to reposition the movable separating wall. Another point that needs attention in the design of installation gathering points is the placement of distribution pipes, which enable the connection of installation with wet spaces. Leaving a lower number of changeable bits with more fixed bits in certain module distance might easily address the need for a possible equipment change in wet spaces [26,27].

3.3. A Proposal for Modular Building System

A light steel system is proposed as the supporting system of the modular system. The major reasons for this are first, such systems are easy to make; second they are light, and finally suitable for serial productions [28-31].

For the proposed flexible housing block design, different family types are taken into account. The types of families include:

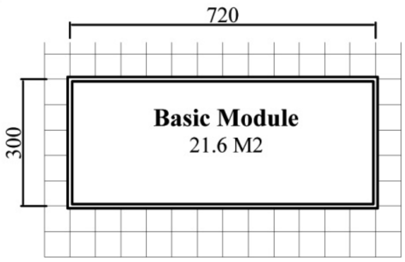
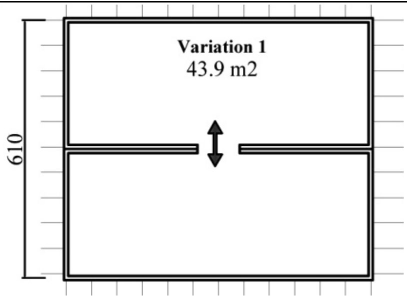
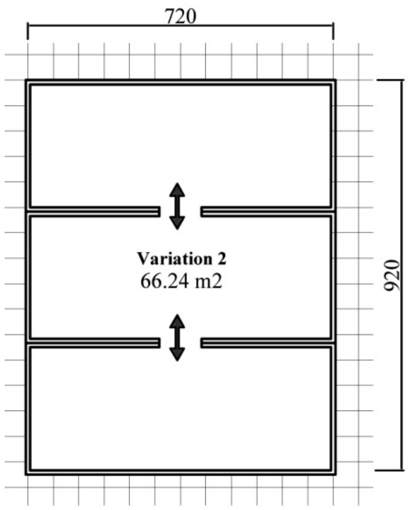
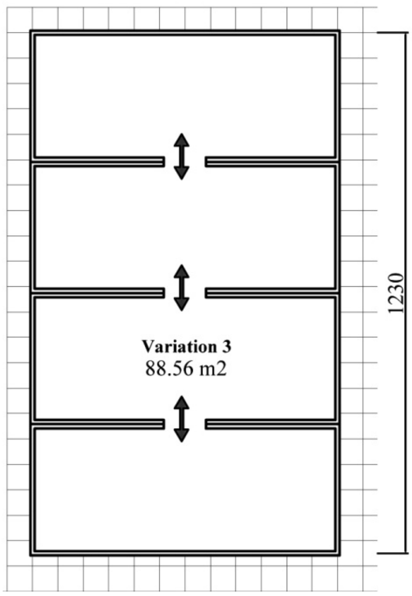
- Dynamic families which are likely to have more children in the future, and are therefore expected to have continuously changing and increasing needs [32,33], thus requiring a high degree of space flexibility.
- Stable families who are not going to have any more children, whose children have left home or are too small to leave home, thus requiring a low degree of space flexibility [34,35,36].
- Stagnant families who are expected to live in the same dwelling for a long time, particularly free-holders [37], and therefore have sufficient opportunity to benefit from flexible building elements, which provide for lower life-cycle costs [38]. In this study, a single module was designed with the following criteria;

  The module size of 3x7.20m, exponents of 60cm, and the transportation infrastructure in Turkey.

The purpose of making a single module is to ensure easy production. The design was made by bringing modules two, three, and four together at the same time to construct forms. Single-room, double and three-room designs were made. The plan sketches contain arrangements of two open or separate kitchen spaces. The light steel system is used as the supporting system.

Each house contains an entrance, living quarter, bedroom, kitchen and a bathroom. A house unit is created using at least two modules. Single-room units (two modules) are 43.9m2, two-room units (3 modules) are 66.24m2, and three-room units (4 modules) are 88.56m2 (Table 3). Following the 1999 earthquake in Turkey, containers were used as permanent houses, which failed as they were very simple and primitive applications. Here, the same module is repeated but the design is varied with façade and separating wall alternatives with variously positioned window and door spaces to create solutions with different plans. Thus, alternative plans were made possible. Table 4-5 shows single and two-room plan alternatives with 2 modules, while Table 6-7 shows horizontal and vertical expansion alternatives with 2 modules. Table 8 demonstrates two and three-room plan alternatives with 3 modules, and Table 8-9 shows horizontal and vertical expansion plans with 3 modules. Table 10 demonstrates plans with 4 modules, and finally, Table 10-11 shows plans with 4 modules and combinations of other modules. It is possible to create more combinations using these plan drawings. Alternative solutions are possible with different house units coming together and growing to the size of a neighborhood, and in high numbers as desired (Table 11). We suggest that the modules are made using light steel systems. Wall thickness is specified as 12cm and the 3 m module width includes this wall thickness. Modular sewage systems are brought and placed onto the concrete foundation and concrete floor. The modules allow placement in different forms, one on top of the other. The point that should be noted in modules to be placed on the upper floor is to superpose the wet spaces. Staircases placed outside will provide access to upper floors House units are designed as single floors. In the case of two floors, the staircase will be placed on the blind wall side. The upper floor will have the same plan drawing as the lower floor. Expansion flexibility is an approach taking into account the possibility that new spaces can be added to the houses, which do not respond to changes in the family's social, cultural, economic, and demographic structure. Expansion in the houses is possible in the following ways: As the windows in the modules are 120 cm with an exponent of 30 cm, and the doors are 90 cm with an exponent of 30 cm, a single module of 7.20 m x 3.00 m may transform into boxes with different window and door spaces. This way, 19 different boxes and 13 different types of plans were developed with a single 30 cm façade module.

Table 3. Basic module and the floors of this module.

<table>
<tr><td>Basic Module</td><td>House unit with two modules</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>House unit with three modules</td><td>House unit with four modules</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

This number can be increased more with this method. It is possible to create streets, neighborhoods and a settlement area with the targeted single module and with the repetition of few number of façade modules. Different positions of door and window spaces on the walls lead to a variety in modules that constitute plan schemes.

Boxes/rooms were elevated depending on the space opening in forms. Once door and window sizes are standardized, and exponents of 30 cm are used in planning, room manufacturing is not affected by the spaces opened up depending on the house layout. The number of connection alternatives for modules demonstrated in the tables can be increased.

Table 4. Two modules plan variations.

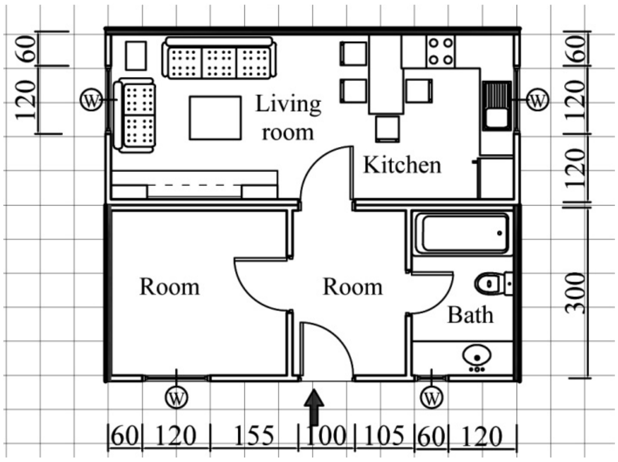
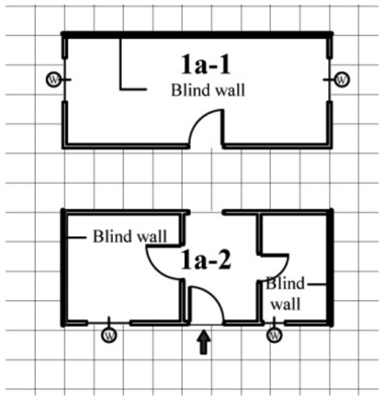
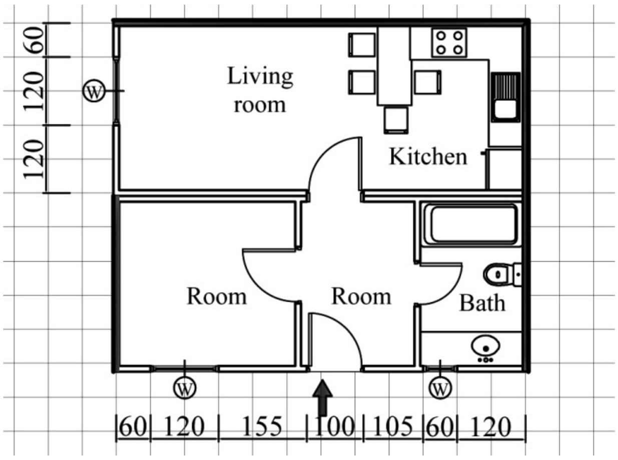
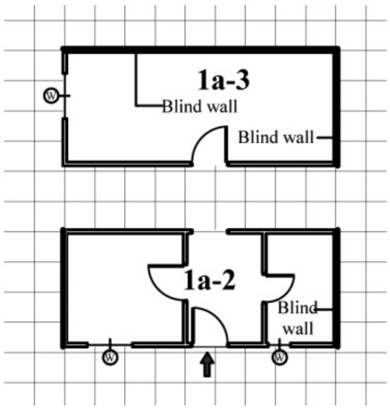
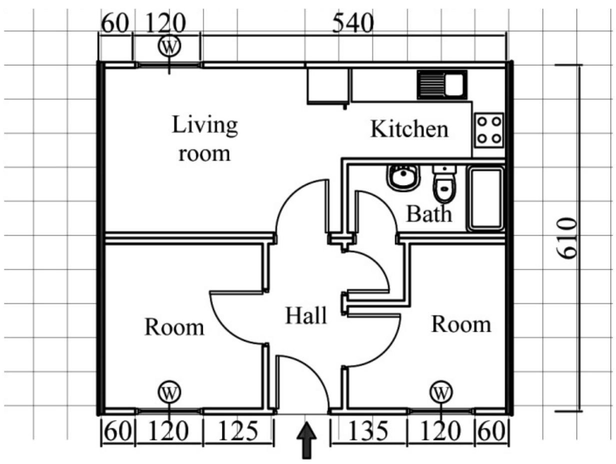
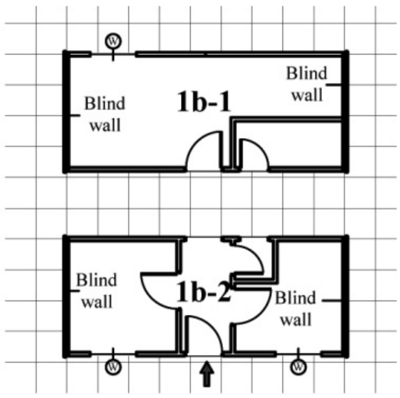
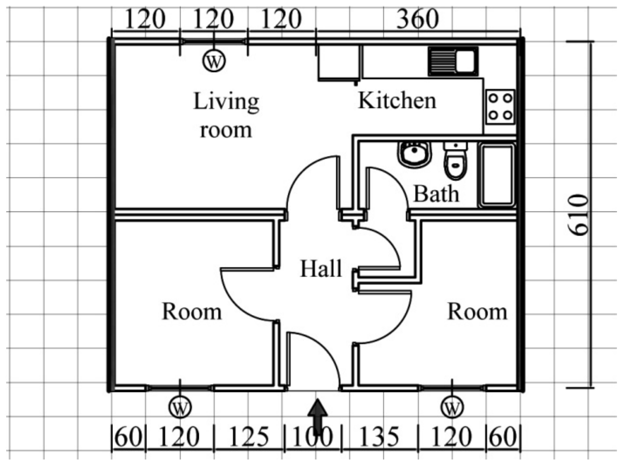
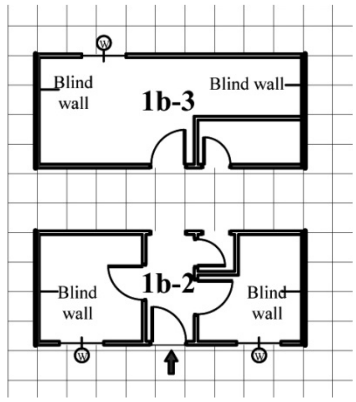
Type Code	Plan Drawing	Spaces in the modules
1a		
1a[1]		
1b		

Table 5. Two modules plan variations.

<table>
<tr><th>Type Code</th><th>Plan Drawing</th><th>Spaces in the modules</th></tr>
<tr><td>1b[1]</td><td>
</td><td>
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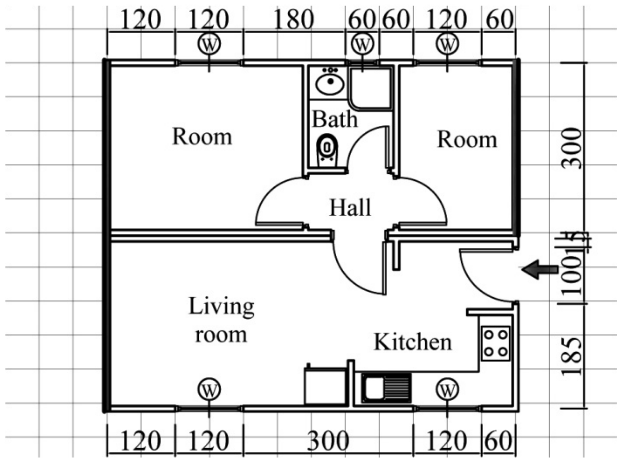
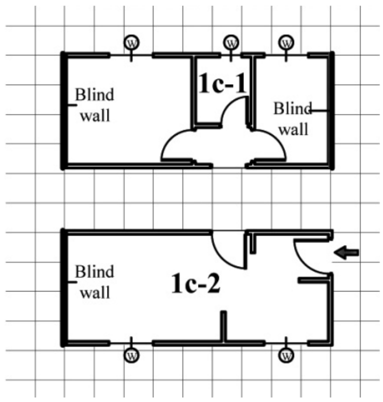
<tr><td>1c</td><td>
</td><td>
</td></tr>
</table>

Table 6. Combination and expansion variations of houses with two modules.

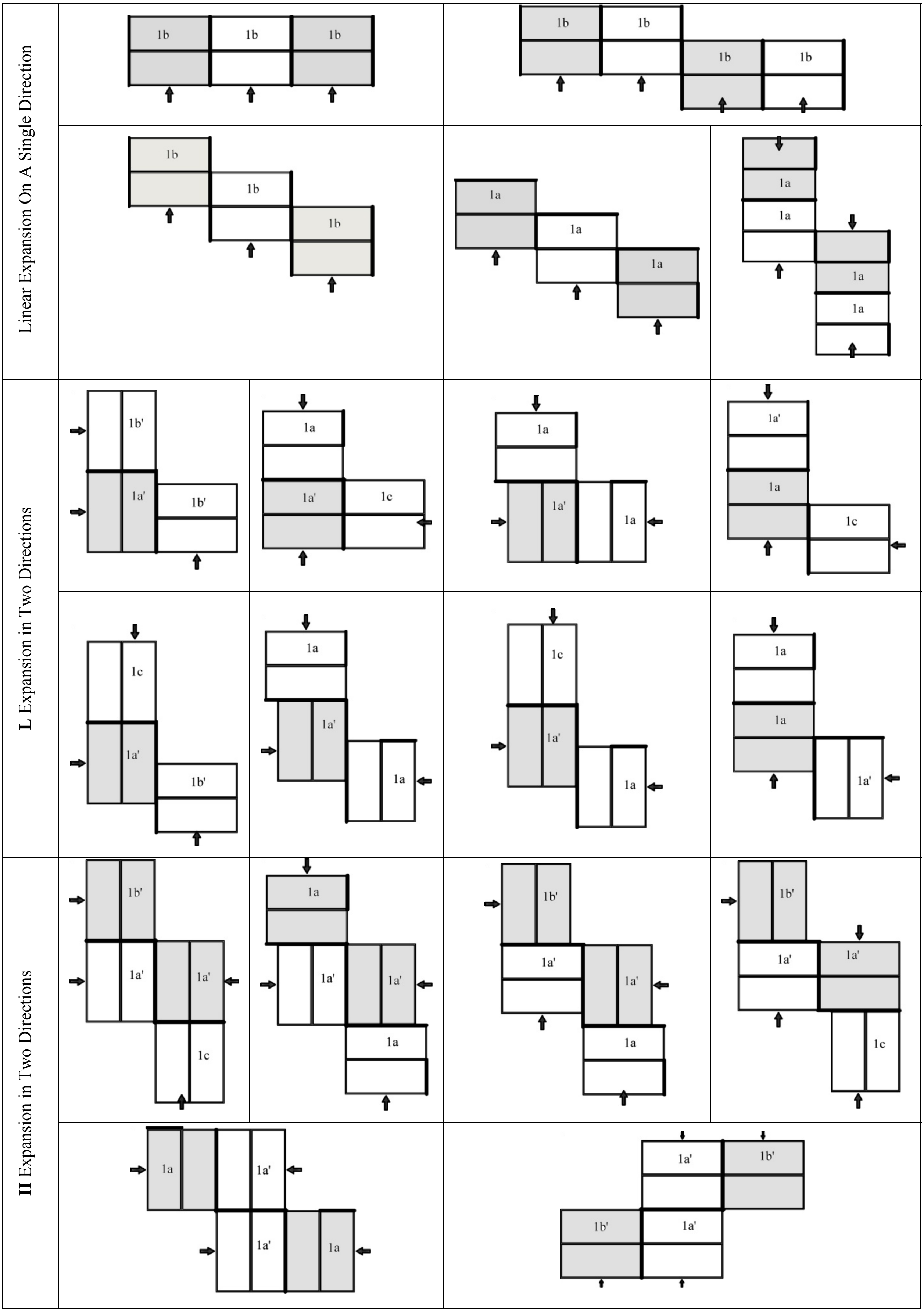


Table 7. Continued.

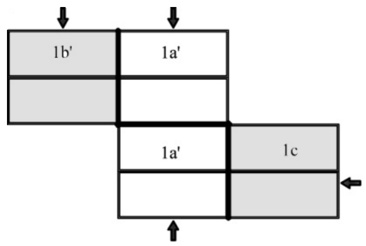
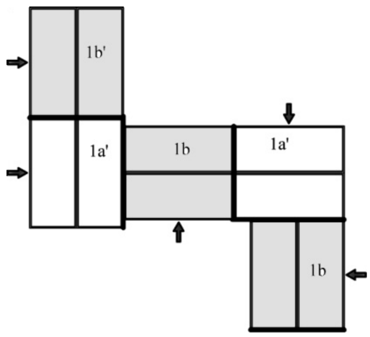
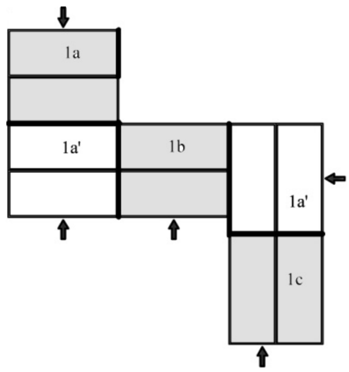
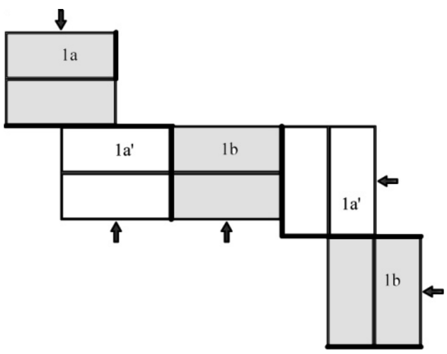
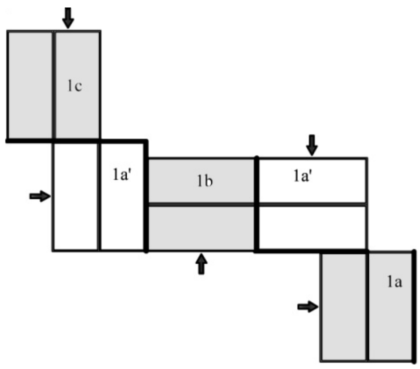
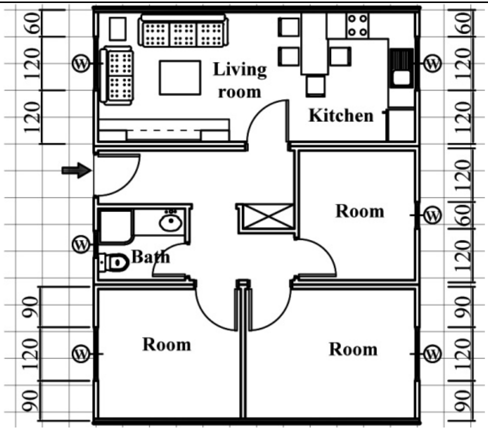
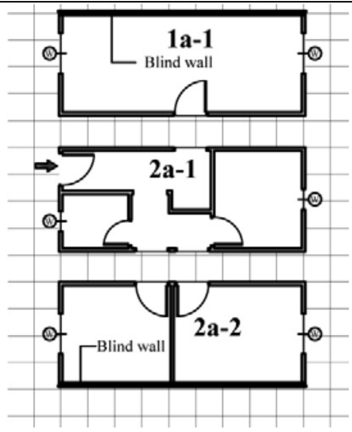
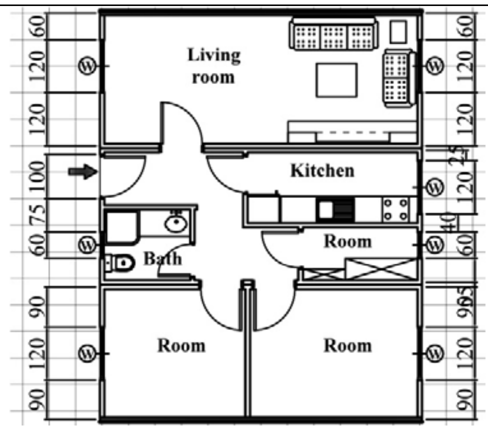
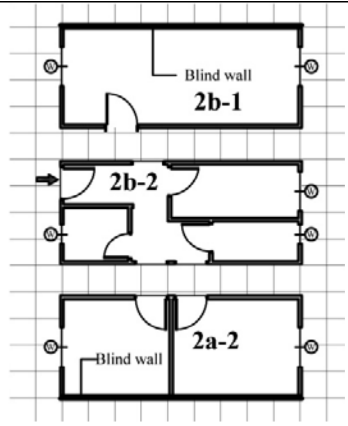
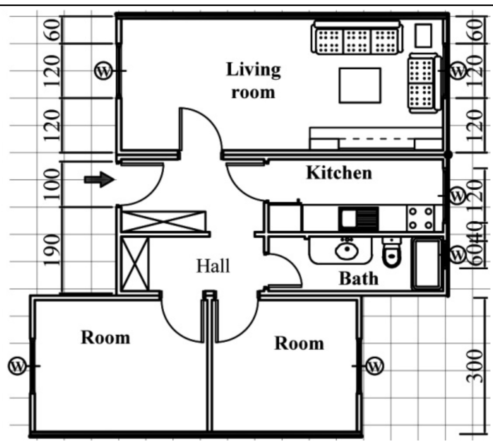
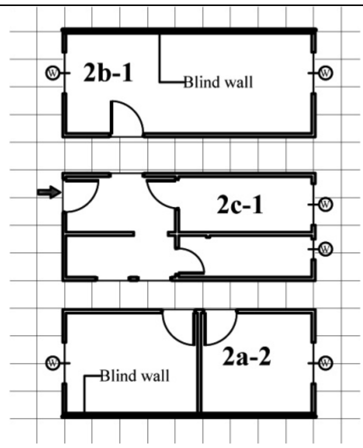
<table>
<tr><td>II Expansion in Two Directions</td><td>
</td><td></td></tr>
<tr><td rowspan="2">Expansion in Two Directions</td><td>
</td><td>
</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 8. Three modules plan variations.

<table>
<tr><td>Type Code</td><td>Plan Drawing</td><td>Spaces in the modules</td></tr>
<tr><td>2a</td><td>
</td><td>
</td></tr>
<tr><td>2b</td><td>
</td><td>
</td></tr>
<tr><td>2c</td><td>
</td><td>
</td></tr>
</table>

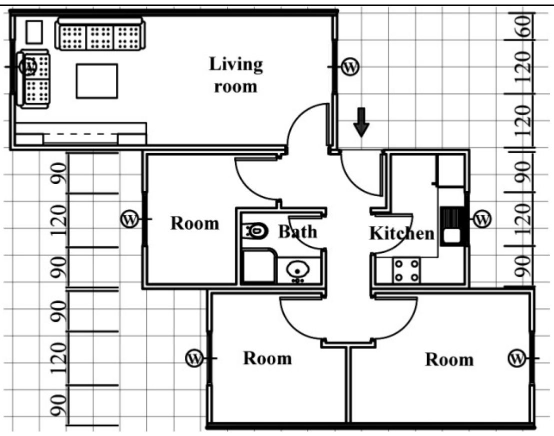
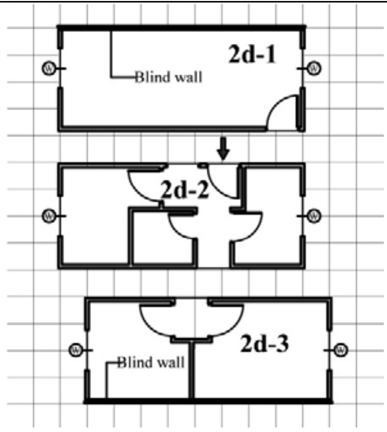
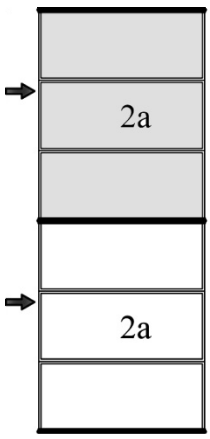
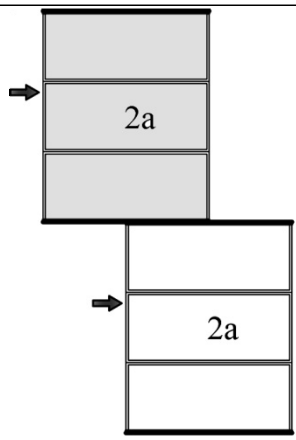
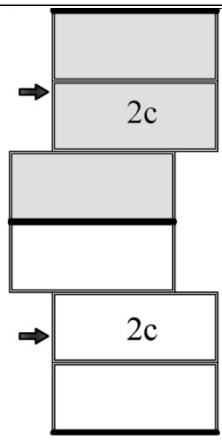
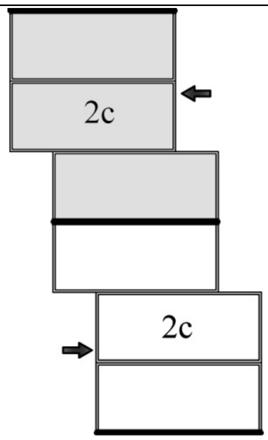
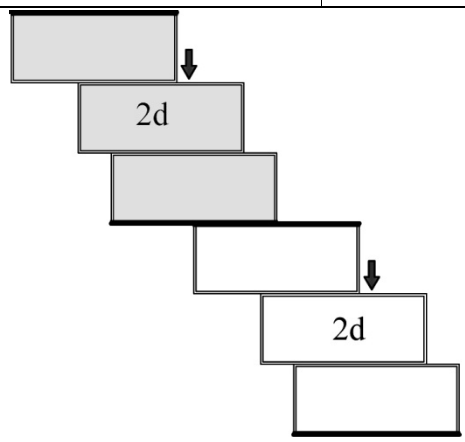
2d		

Table 9. Combination and expansion variations of Type 2 plans.

I Linear Expansion In A Single Direction		 All boxes are 2a	 All boxes are 2c
	 All boxes are 2c	 All boxes are 2d	

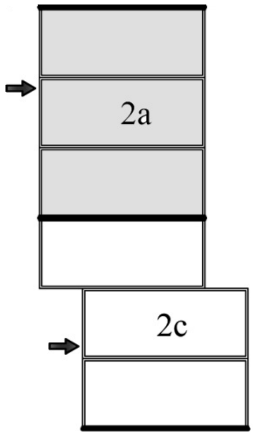
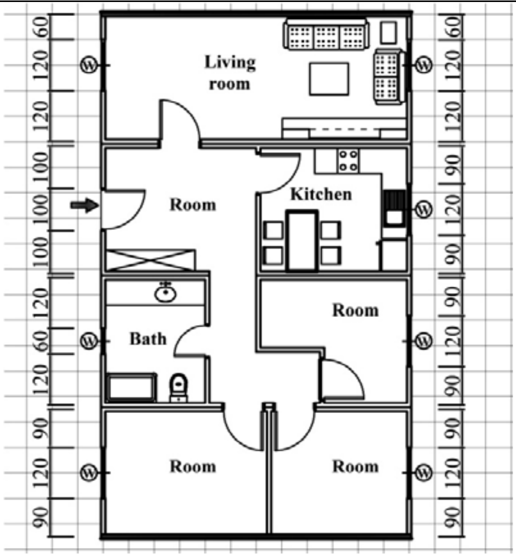
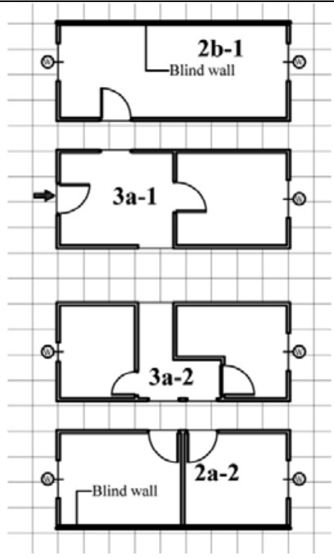
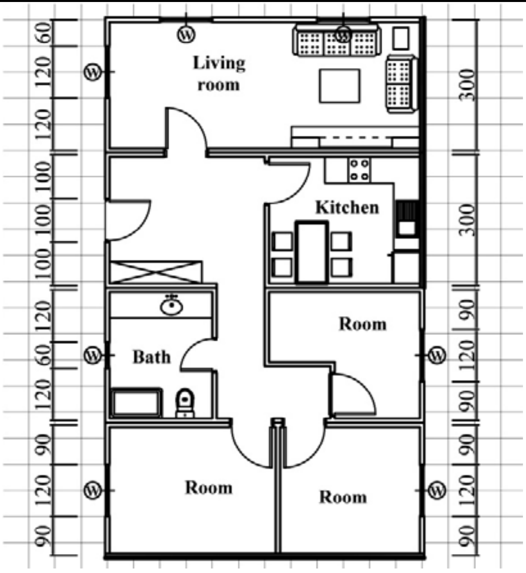
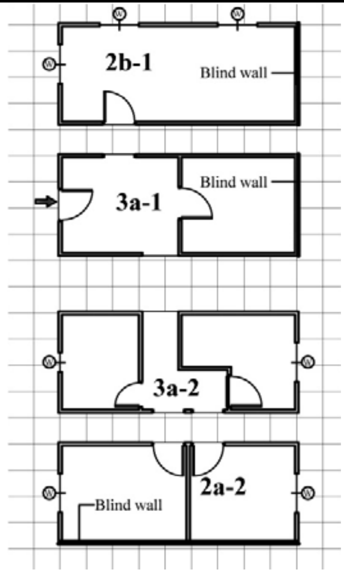
L Combinational expansion in two directions			

Table 10. Four modules plan variations.

Type Code	Plan Drawing	Spaces in the modules
3a		
3a[1]		

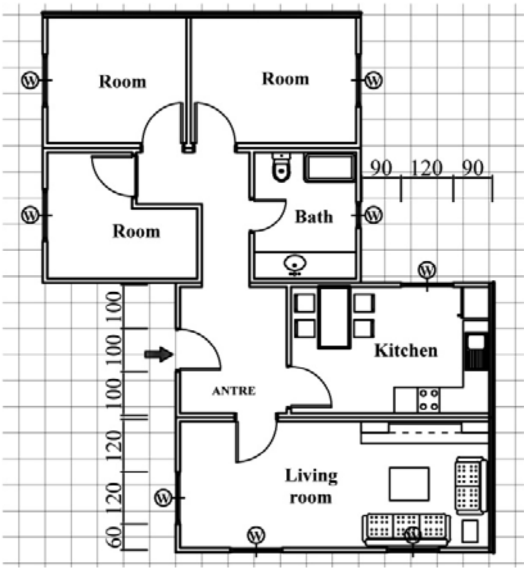
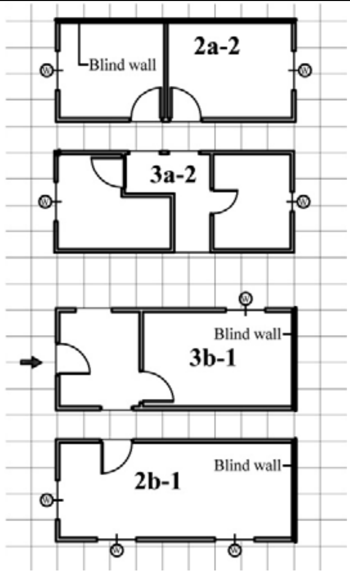
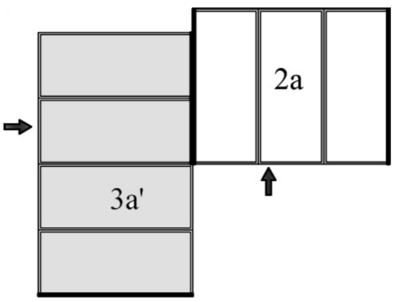
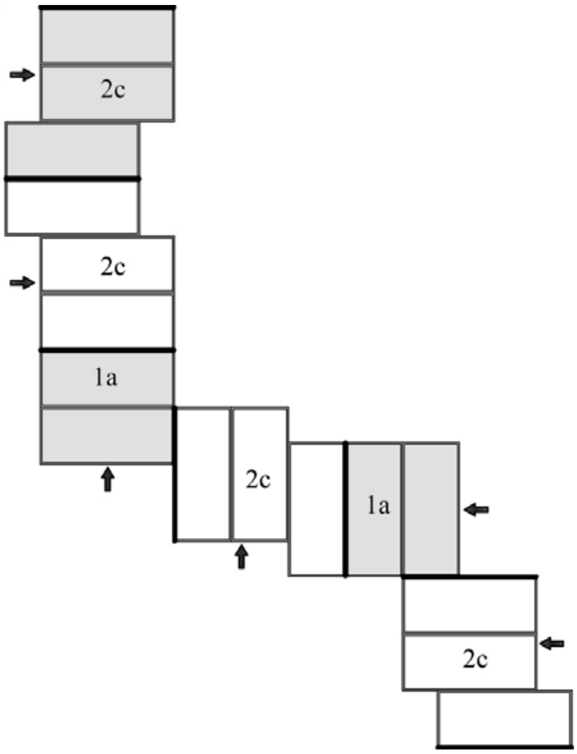
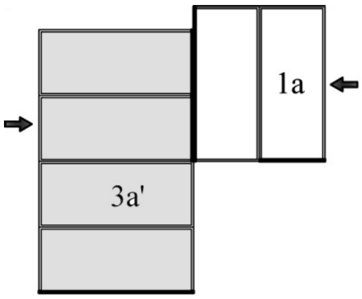
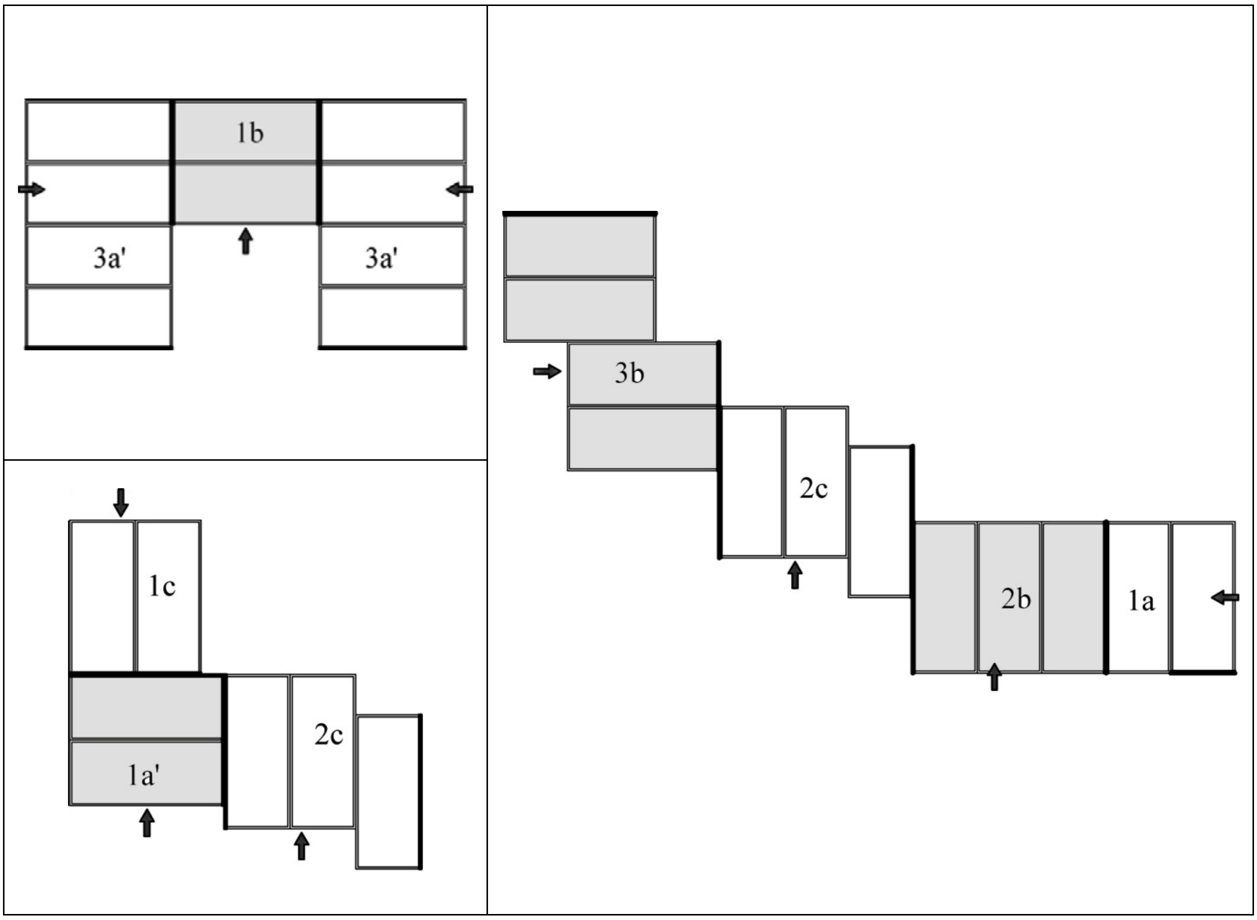
3b		

Table 11. Combination variations of Type 3 and other types.



4. DISCUSSION

Speed construction methods need to be adopted in order to be able to meet accommodation needs. Accordingly, the earthquake prioritized the need for secure and stable housing in the region, with the preference being in favor of construction of temporary prefabricated houses. Based on the preliminary studies conducted by local governments considering a possible earthquake, it was resolved that the planned prefabricated structures be well-built because the construction of permanent housing would last longer than planned and due to the lack of permanent housing projects for the entire population victimized by the earthquake [30,42].

Financing initiatives for restructuring neglect the needs of the poorest victims. Acting in haste to recover social and economic functions of the society might leave it susceptible to future disasters. In order not to encounter such problems, the society needs to have pre-disaster restructuring programs or recovery plans [41]. Besides, particularly the developing countries experiencing earthquakes should see these natural disasters as opportunities to minimize future earthquake risks, determine land utilization and building plans, and rethink the building methods and regulations. Despite many earthquakes in Turkey, disaster management has so far focused on the emergency situation and the post-emergency situation, never yielding any signs of systematic consistency [42].

Reserving housing areas in highly disaster-prone regions and the allocation of some resources for infrastructure works in such areas, though ostensibly uneconomical in the beginning, will prove how dire the situation is at the post-disaster stage. The scenarios for Istanbul show that there will be major chaos and that we should prepare ourselves for the earthquake with such projects. Both decisions on temporary housing areas for disaster victims and plans for permanent housing areas have been delayed too much in Turkey, and in some cases realized only years after [38,43].

In order to provide sustainability, earthquake houses should not be built temporarily but permanently, or if they are temporary, the aim should be their reuse in the future for other functions. The concept of sustainability, in the general sense, means the natural use of all renewable/non-renewable resources across the world and managing their consumption.Production of sustainable structures offers humane and economically fair facilities and structures in harmony with the environment, aiming to create a system that is based on the conscious consumption of resources. Once this is achieved, both natural and energy resources will be saved by making changes in the houses suited to the use of different users and rehabilitating them, instead of producing ever-increasing mass housing projects.

Since the Industrial Revolution, particularly with the rapidly developing technology and production, there has been an intensive consumption of resources in varying degrees in almost every area of life. Today, this consumption level has reached the point where natural resources, vital elements of natural life, and man-made values are exploited with the motive of facilitating the lives of human beings. This has detrimental effects on natural balance, resulting in all types of environmental pollution that negatively affects the livelihood of living beings in the air, water and soil as basic elements of nature. As a solution, instead of new buildings in the construction industry, the existing buildings need to be rearranged for different uses. And from this perspective, it is apparent that the modular system is a system ensuring reusability in the temporary housing concept [44,45].

There is a growing demand for prefabricated methods to minimize material waste and environmental impact. The modular system development will include specific explorations into the planning flexibility potential of modular systems, the structural robustness of the modules themselves and the resulting structure, as well as the relative environmental and sustainable performance of modular systems [46,47,48].Industrialised house-building differs from traditional hse building in several ways. A central aspect of industrialisation is the pre-fabricatio of structural elemants, but changes in products and processes are also required to achieve efficient construction methods [48].

5. CONCLUSIONS AND RECOMMENDATIONS

Today, modular box systems are and should be preferred considering the possibility of constructing buildings with no damage to the natural environment, their contribution to sustainability by reducing time on the worksite, the minimized problems and noise pollution, and the elimination of negative issues, such as disturbing the neighbors or disrupting the environment with large-size projects. With respect to traditional building methods, these systems damage the environment less, and their structure allows for easy expansion and reuse. Temporary housings made as earthquake housings should not only meet the accommodation needs until the completion of permanent housings, but also maintain the victims' environmental and social lives. Therefore, they should not be flat and ordinary, but rather should fulfill the criteria demonstrated in the table above, and social areas should be created in different architectural forms in consideration of their relation to the environment etc.

This study concludes that many houses can be produced by opening different spaces on the façade panels of the 3mx7m foundation. The placing of window and door spaces are determined according to the proposed plan types. In this way, it is possible to create many types of plans by making use of the different combinations of the modules. With this arrangement, it will be possible to create streets, neighborhoods and settlement areas with a non-monotonous living architecture. Units that have served their function can be reused in other regions. Despite the presence of such applications in the past, the main difference here is the ability to create custom plan drawings and offer the users the alternative to choose the plan that is most suitable to their specific conditions and needs. Otherwise, it is not possible to accommodate everyone in houses with the same plans, albeit temporarily. The aim should be, even for a temporary amount of time, to ensure that people can live in spaces where they can overcome the trauma they have recently experienced in the post-earthquake period with a level of comfort, and studies should be conducted to this end. Studies should aim for sustainability and use non-monotonous materials and colors. This study will only be sustainable and useful when considered on a street and neighborhood basis and with façade arrangements using high quality materials.

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