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A MODULAR HOUSING SYSTEM: ARTI[1]

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ABSTRACT
This paper introduces an affordable and rapid-construction housing system. While the target user group may include those from a wide range of economic and socio-cultural backgrounds, the model is primarily considered as mass housing for developing countries. The elements used to improve the model include affordability and self-development characteristics, adaptability with other construction systems and materials, and performance in varying climatic and geographical conditions. This housing model can be described as a semi-open system that is formed by basic modules that can be merged in various ways to build different types of houses.

The development of the ARTI housing system was carried out in three stages: (1) research, (2) design, (3) evaluation. First stage research concentrated on concepts of necessity and demand, cost and financing, housing typologies, construction technology, materials, energy efficiency, ecology, sustainable construction, and so on. The second stage was a design process of a modular housing system that allows the production of various alternatives and self-improvement capabilities. Adaptability and flexibility of space were also considered in the design process. The third stage was a post-design evaluation.

KEYWORDS
Housing, Prefabrication, Modular Houses

1. INTRODUCTION

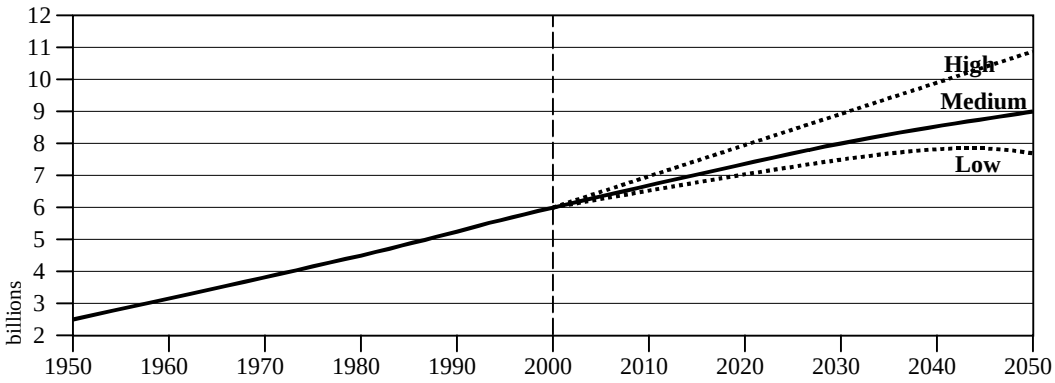
Almost every country in the world is currently faced with significant housing problems. Although all countries share the problem, its scope and dimensions differ widely in various countries, societies and regions. This widespread and multi-dimensional phenomenon brings with it tremendous potentials for work to be carried out in fields such as housing design, research, and production. Among the potential areas to be studied in the fields of production and research are those relative to mass housing, innovative housing, affordable housing etc. Today's conditions and future projections all indicate that the dynamic structure of the housing problem will act to even further deepen the problem in the future and will maintain this issue as a significant problem for years to come, thus indicating the need for continued search for solutions. The housing system presented in this study may be taken as one example of such search for a solution. The purpose of the study is to develop a design proposal that is based on past experience and future expectations and that will provide a physical basis for evaluations and discussions

[1] First stage of the study which of this paper based on, conducted as a post-doctoral study at University of Cincinnati, DAAP (College of Design, Architecture, Art and Planning). ARTI is an acronym of the following adjectives: affordable, rapid, technological and (self)-improvable. It means "plus" in Turkish, thus indicating the basic attributes of the system that are "additive-ness" in the concrete sense, and "positive-ness" in the abstract sense.

relative to providing "a practical system aimed a solving housing problems of the 21st century." The achieved design product represents a concrete framework that can be utilized in the development of implementable systems. While the system originates from a universal perspective, the development and concretization of the solution have been primarily based on the Turkish model. Included among the investigations and research carried out in the creation of the conceptual and theoretical foundation of the proposed design were the use of conclusions drawn from wide-scope research projects that had been carried out previously, advanced perspectives, and generally accepted concepts.

2. HOUSING NEEDS

According to United Nations Population Divisions' estimates and projections, world population growth tripled in the last 75 years and total world population is expected to be in the range of 7.9 to 10.9 billion in the mid 21st century (UNP, 1998) (Figure: 1). According to this same statistical source the increase will occur primarily in the underdeveloped or developing countries. Despite the fact that Turkey, in terms of all developing countries, has partially managed to bring its population growth under control, it is still listed as a country that is experiencing rapid population growth. The population increased one and a half times in last twenty years in Turkey. Furthermore, urban population increased faster because of migration from rural to urban (DIE, 2000) (Table 1).



Source: United Nations Population Division, World Population Prospects: The 2000 Revision (UNPD, 2000).

Figure 1: World Population (1950-2050): Past Estimates And Medium, High And Low Fertility Variants.

These facts are in themselves sufficient to indicate that the provision of shelter, one of man's most basic needs, will be one of the most important problems faced by Turkey and by most of the world's countries in coming years. Besides the requirements for new housing arising from population increase or migration, there is also a need for housing that will act to increase living standards or provide higher quality living conditions. Relative to this, if we consider the housing needs of people who are today sheltered inadequately or in unhealthy conditions the number of mass housing units required worldwide is staggering. Within this framework it can be calculated that Turkey alone requires approximately 300,000 new units annually. Global figures point to a need for approximately fifteen million new housing units required worldwide for every year. If we also take into consideration the number of new housing units required to replace those destroyed due to often-experienced earthquakes, floods, hurricanes or other natural disasters, this figure surpasses all predictions.

Table 1: Population Growth in Turkey
Source: State Institute of Statistics (DIE, 2000)

Year	Total			Urban			Rural		
	Population	%	Increase Index (1980=1.0)	Population	%	Increase Index (1980=1.0)	Population	%	Increase Index (1980=1.0)
1980	44,736,957	100	1.00	19,645,007	44	1.00	25,091,950	56	1.00
1990	56,473,035	100	1.26	33,656,275	60	1.71	22,816,760	40	0.91
2000	67,844,903	100	**1.51**	44,109,336	65	2.24	23,735,567	35	0.95

According to 1999 data provided for the United States of America, 33 million of the total 102.8 million American households are renters (34%) and half of these renter households (%51) had either moderate or severe housing problems (NLIHC, 2001). This statistic clearly shows us that the housing problem is not endemic to only developing countries but remains a serious problem in even the most developed countries. To conclude, the housing problem—despite the fact that its content and dimension vary according to time and geography—is a severe problem faced worldwide. The problem itself is not limited to its most easily seen and understood aspect, that of providing for human shelter, but encompasses such aspects as determining the most economical use of resources, creating housing sites that are sensitive to the environment and the natural setting, providing for energy conservation, achieving high quality urban settings in terms of design and manufacturing technologies, developing mass housing units that are easy to finance and creating settings in which the user lives in harmony with the built environment. These aspects of the solution will vary in type and dimension according to the unique features of the society and country for which it is being developed.

3. TOMORROW'S HOUSING SYSTEM

Efforts carried out thus far, especially those that have occurred during the past fifty years, have continuously taken on new dimensions. Because initially the solution was considered to be limited to "providing the greatest number of suitable housing units in the shortest period of time," issues such as technology, production systems and materials played defining roles in system creation. Later stages were influenced by social and psychological factors and efforts were based on "human-environment relationships" as the approach was directed towards human aspects. With the inclusion of environmental and ecological approaches as important elements in the overall design, concepts such as sustainability and recycling began to take on increasing importance and became leading elements in these trends and perspectives. The 185 delegates who attended the Habitat II conference held in Istanbul in 1996 came together to discuss the theme "cities and their future" and to develop a platform of debate to discuss the issues that had been developed thus far. The two primary topics, "adequate housing for all" and "sustainable human settlements in an urbanizing world," became the focus of the conference debate. The synthesis arising from this debate was that tomorrow's urban environment had to be designed within the framework of "sustainable development," "human development," and "social development" (Bindé, 1998). These approaches represent, in a sense, the result of the efforts carried out during the past fifty years and also become signposts for the future. When we consider that buildings set aside for housing make up a significant majority of all of the structures found in an urban area, it is evident that the concept of housing systems will be the determining factor in approaches relative to creating urban environments. Thus, while the concept of "constructing the greatest quantity of suitable houses in the shortest time possible" will continue to be important, the housing problem will also be viewed from its social, psychological, and environmental factors.

Consequently, within this general framework it is possible to determine some features for a housing system to be developed in the 21st century.

- **Prefabrication:** When the continuously increasing "quantification" dimension of the housing problem is considered, we realize that "constructing the greatest quantity of suitable houses in the shortest time possible" continues to be of major importance and that prefabrication is a must. Prefabrication is also the best means for utilizing advanced construction technologies and for making optimum use of time, the workforce and other resources.
- **Modular space organization:** The modular system has many advantages as it allows for user participation in the design and construction processes, achieves affordability by periodic payments with construction distributed over time, provides opportunities for changeable-adoptable-flexible constructions, is free from the monotonous design that is inherent in prefabrication, and allows for the production of various alternatives and for their change and development over time.
- **Open or semi-open system**: Open systems allow for the use of varying materials and adaptation with other construction systems, are not uniform in nature, can be adapted to varying geographical and climatic conditions, and--because it relies on user participation--provides the user with a 'home' atmosphere, rather than just 'shelter' or 'housing.'
- **Potential for individual initiative:** Allotting efforts related to house construction to the individual initiative of the end user, rather than having mass housing construction carried out by public authorities or by large enterprisers, has tremendous importance in terms of the individual's relationship with the environment, acquisition of sense of belonging**,** and adoption of urban values. In the development of a

housing system, therefore, the individual requiring housing should be provided with a system of assistance on a one-time basis.

- **Low density settlements**: When such factors as social and psychological needs, the provision of ecological environments that are in balance with nature, and sustainability are considered, it can be concluded that housing systems that best meet these requirements are located in low density settlements.
- **System with wide socio-economic connotations:** Instead of limiting provisions with systems directed towards "low income housing" or "housing models for high income groups," the housing system provided should meet the needs for a wide range of groups thus having positive effects from societal and social perspectives.

In short, an appropriate housing system should include prefabricated, modular, semi-open systems that allow for individual initiative in construction, that aim to provide low density settlements and that are flexible and rich enough in nature to provide for a wide variety of alternatives. At the same time, the system provides for concentrating the user's efforts and finances on a single house that will be used on a permanent basis. The system is advantageous from social, economical, psychological, and environmental perspectives as it provides for the provision of housing that will initially commence from the concept of a 'shelter' that meets the most basic spatial needs and minimum requirements, and that will through time develop and grow into a 'home.'

This work introduces the ARTI housing system, a system proposal that has been designed within this general framework. While the conceptual framework of the work was carried out within a global approach, the conditions of Turkey were considered in the creation of a physical design. Turkey may be described as a country with advanced construction and prefabrication industries. For many years, a number of prefabricated and advanced traditional systems have been developed and have been used in mass housing production (Tapan and Sey, 1987). However, rather than supporting individual initiative and one-family housing systems, the system in Turkey is primarily directed towards the use of prefabrication and developed traditional systems to build mass housing complexes through the use of public or major enterprise efforts. This despite the fact that systems that permit individual initiative and are directed towards low-density settlements have been proven to be superior to high-density settlements made up of multi-floored apartment buildings. Housing designs in the 21st century should be directed towards this end. From this perspective, Turkey demonstrates both great requirements and potential.

4. A DESIGN PROPOSAL FOR A MODULAR HOUSING SYSTEM: ARTI

The ARTI housing system may be defined as a "semi-open, prefabricated, modular" system. This system has been designed towards the creation of one or two story houses of varying form and size. The modules in this system made up of the assemblage of some structural elements. This feature make the system differ from the customary single bloc modular systems. Thus the system may be described as a combination of panelized, steel frame, structural insulated panels, etc. The system is termed "modular" because space is created through the repetitious utilization of "basic spatial modules." This system of housing construction is composed of three stages: (1) "Basic spatial modules" are created through the use of a variety of construction elements; (2) By combining these spatial modules through the use of multi-faced combination alternatives varying functional use spaces of varying form and size will be achieved. (3) These different spaces can then be combined to form a house of desired size, form, and features. To conclude this is a kind of *Lego* construction system that allows for a wide range of alternative solutions.

4.1. Construction Elements of the System

As stated above, in this system spatial modules are created through the combination of construction elements in a wide range of alternatives. The sequence of elements is as follows: (a) the horizontal and vertical load bearing elements of the system that will make up the general design, (b) the wall and floor panels that will comprise the horizontal and vertical spatial dividing elements, (c) doors and windows, (d) roofing elements, (e) the various accessories and equipment that will comprise the mechanical elements of the dwelling. These elements may also be categorized in two separate groups. The first "a" group is comprised of basic structural elements. These elements are vital to the construction and are required for even the most basic and smallest of shelters. In other words, these elements share a commonality with all kinds of housing alternatives and because of their wide utilization potential they permit for a broad range of alternatives. The second group, "b, c, d, e" elements, is comprised of wall and floor panels, door and window combinations, roofing elements and other equipment elements. The main characteristic of this group is that altogether different systems and materials can be substituted if so desired. This feature makes

possible the use of different construction technologies and materials. Figure 2 is a graphical representation of the construction components that make up the system.

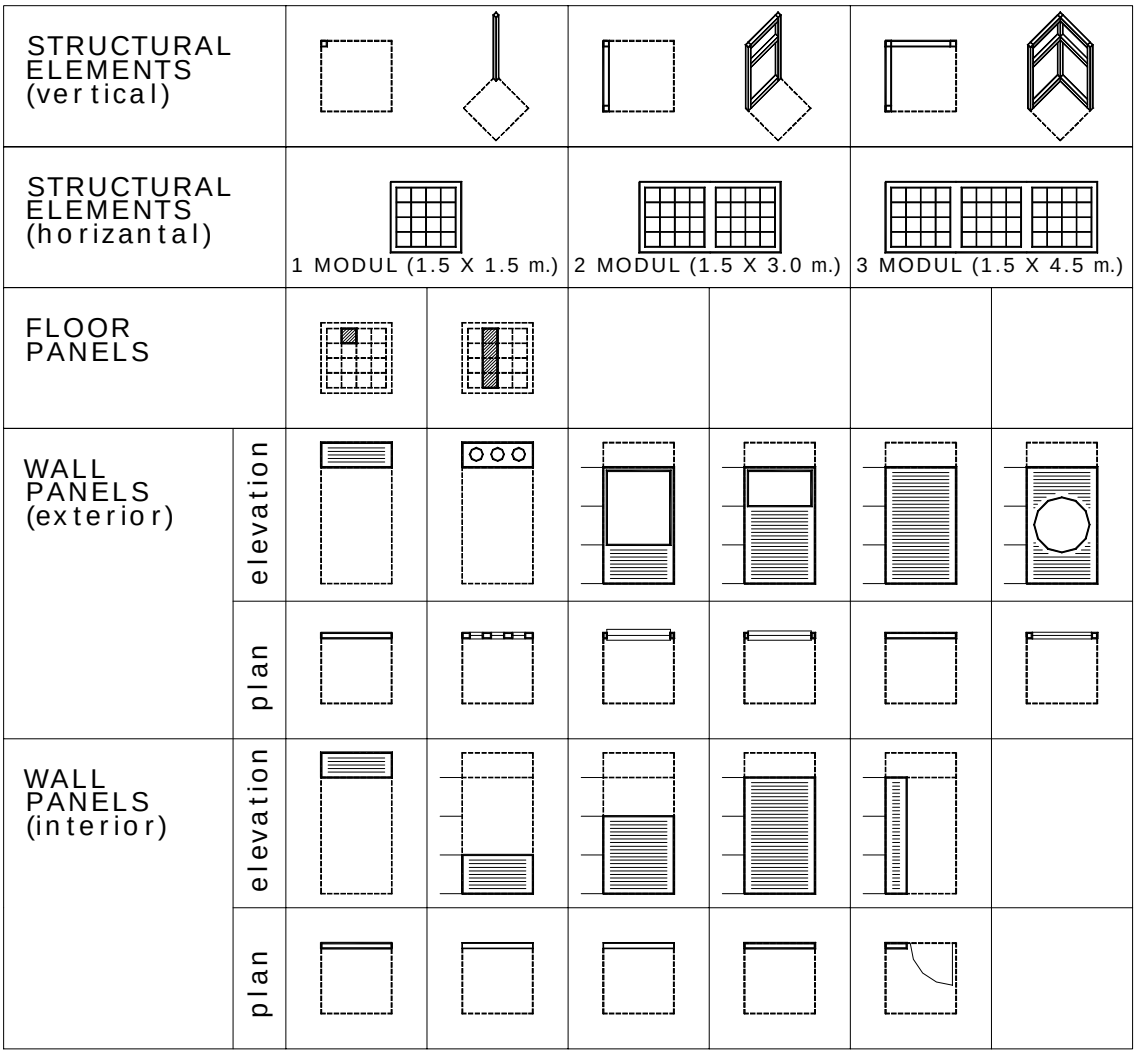


Figure 2: Basic Elements Of The System.

4.2. Basic Spatial Module

As described above, various construction components are combined to form basic spatial modules. This module has a 150x150 centimeters square shaped plan and has a height of 275 centimeters (approximately 5x5x9.5 feet). Generally the basic spatial module is formed by an "L" shaped vertical steel frame and wall panels. Varying wall panels can be selected for the basic module as determined by the function of the space being created: inner or outer wall panels, window or door opening panels, etc. The selection of the floor and ceiling/roofing elements is also made relative to the space or spatial modular group.

The various construction components can be utilized in numerous combinations with the "Lego" system as its basis, thus comprising an extremely varied number of alternatives and selections. In this way the houses in the system do not reflect the monotonous and serial feel of standard prefabricated or mass produced housing units as they allow for unique and individualized solutions and for the input of the user in the overall design. This potential is further strengthened by the fact that differing technologies and construction materials can be used.

Samples of alternatives that can be combined to create the basic spatial module and alternative spaces are shown in Figure 3.

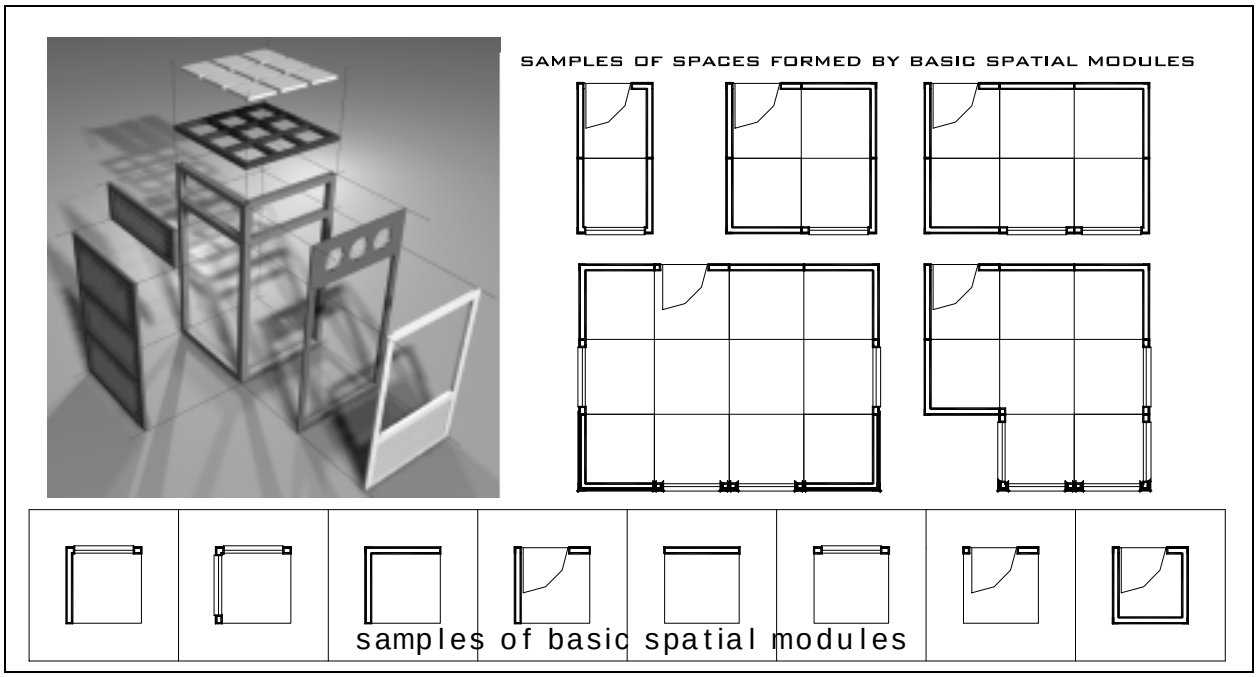
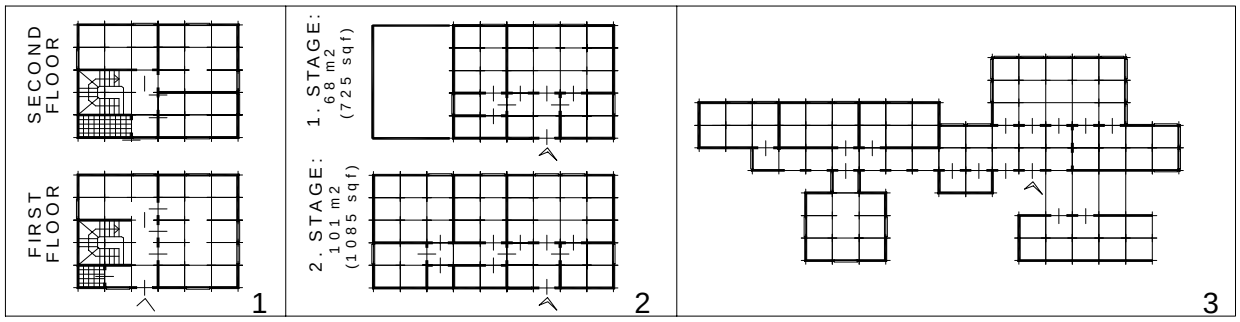


Figure 3: Basic Spatial Module And Samples Of Alternative Spaces.

4.3. Plan Organization

The adaptability feature of the basic spatial module permits the combination of units that differ in both size and form to develop a general plan organization. One of the most important characteristics of this system is that there are countless ways in which these units can be combined into a setting. Because the units can also be dismantled and then reassembled the entire site can also be changed or adapted according to changing requirements. These features provide for a dynamic environment that has infinite possibilities for adaptation, change, additions, and flexibility. A housing system of this nature has the feature of meeting the needs for every kind of house, ranging from the most simple to the most advanced and highly equipped. Another of its most significant advantages is that additions to the house can be made over time, thus spreading the costs of the structure over a longer time period and offering the user greater affordability capabilities. Changes and developments can be made in light of new requirements that arise over time or as the homeowner's financial position strengthens. In other words, the structure may initially be very modest in kind, requiring only minimal financial investment but as time goes on the structure can be modified and developed to meet owner needs and expectations. This capability means that the owner can invest all his/her time and investment into one house that can be lived in lifelong. This allows for optimum utilization of resources, thus providing maximum benefits and quality.



1. A two-story house. 2.Construction stages for development. 3. Dynamic space organization.

Figure 4: Plan Samples That May Be Derived In ARTI:

Another significant advantage of dynamic space organization is that user participation is maximized in the design process. In this way the unique living style to be led within the house can be directly reflected in the design. Additionally, the same individual and unique design that can be realized in the basic spatial module can also be achieved with the entire housing setting. Besides the fact that the system provides for prefabricated, mass produced possibility, each individual unit can also be transformed into a one-of-a-kind and individualized structure. In conclusion, the dynamic structure of the spatial organization means that it can be utilized for a wide variety of functions that range from use as shelters that are limited in nature as "emergency housing", "refugee housing", and "dwelling" to that of a fully developed "detached house."

As stated earlier that this system is based on three stages to the creation of a house, is capable of infinite alterations to the basic design, but is based on a process that has simple parameters and a predetermined construction period. Within this framework a CAAD system can be developed and used during the design process. It is quite simple in this system to create a parametric shape grammar and to transform this grammar to a software program for housing design. CAAD systems based on the parametric shape grammar and the similarity between architecture and language are readily seen in application and theoretical fields (Saglamer et al 1997, Paker and Saglamer, 1993).

Figure 5: 3D Image of a House that May be Produced By ARTI System.

4.4. Technology and Materials

The basic construction system relies on a steel frame system made up of horizontal and vertical load bearing elements. The wall and floor panels are generally insulated, but different materials can be used to meet the unique geographical and climatic features of the utilization area. Problems that arise from using standardized materials in widely differing climates remain one of the most major problems of prefabricated structures (Iwansson, 1993). This problem is almost entirely eliminated with ARTI system as standard shape and size panels can be manufactured using different materials. Highly advanced technologies are not required to manufacture the system's primary components, the horizontal and vertical steel frame that support the weight of the structure. This feature means that initial costs can be kept low. A wide range of products are included in the materials that can be used for wall and floor panels; among these alternatives are wood-based products and sheets, metal sheeting, composite products made up of versions of these materials, and light-weight concrete products. Because the system is easy to assemble and is an open system, in addition to the above it can also make use of local and traditional technologies and materials. Much of the construction work in the ARTI system occurs prior to its on-site assembly. In this way the system benefits from the most advantageous benefits of prefabrication systems including cost advantages secured by mass production, high quality end product due to accumulated expertise of manufacturing personnel, and elimination of the need to transport a great deal of equipment and conduct a lot of work activity at the site. When the house is built entirely of ARTI system components, the work at the construction site is limited to building the foundation and assembling the pre-manufactured elements.

5. CONCLUSION

In almost all societies in the world the desire for ownership of a suitable dwelling remains one of life's very important aims. And throughout a persons' lifetime, the individual expends concentrated efforts and financial resources to achieve this goal. Much of the time the weight of the goal exceeds the means the individual has at hand and the goal can only be achieved through gradual stages. Usually the first thing the people do is to acquire a house that they can afford, even if this house does not correspond to the their requirements or desires. As the individual acquires new resources or new opportunities appear, they may remodel the existing structure or sell-up to a house that better meets their goals and expectations. When they look back, however, and calculate the total costs of their resources and efforts, they understand that these generally greatly exceed the value of the point that has been reached. This occurrence is problematic both in terms of the loss to the life lived and to the optimal use of resources. The core of the problem lies in the lack of planning from the beginning to the end of the process; in other words, the problem stems from the fact that the efforts and resources expended were not concentrated onto the same structure. A housing system that solves this problem will provide substantial opportunities of social, psychological, and economic natures. A system of this type will also be instrumental in providing for planned and high quality environmental settings and for optimal relationships of the people with their environment. It also makes maximum use of available resources, reduces opportunities for profiteering, and eliminates the substandard housing. Another important feature is the relationship that the user forms with the house. Research has shown that the "house" becomes a "home" if it meets the individual aims of its user, provides for independent activities, and accords with the user's individual values (Lawrance, 1987). While prefabricated and mass produced houses are prerequisites in the solution of the housing problem, they do not develop into "homes" due to the fact that they cannot extend the boundaries of regulations or rational parameters. ARTI system, however, derives all of the benefits of prefabricated or mass produced housing while, on the other hand, because it provides for user initiative--as it is based on a system that is open to user participation and modifications--it allows for the positive development of a bond between the user and structure. The design proposal presented in this study aims to provide for a housing model that utilizes these two factors. This design has been made within a concrete framework through model application.

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