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Evaluation of the Flexible Elements Components in Housing Design to Determine their Priority according to Delphi Design Method

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ABSTRACT: In a different context, the user's needs in a housing apartment are constantly changing; it is required that the provided house, by having flexibility, can always be responsive to the user's needs in various situations, which would be a challenge for specialized areas of housing, including design. To perform a flexible housing design, the architects face many different design solutions and variables, leading to confusion in this field. So, the objective of this study is to identify these variables and achieve an effective solution by considering their priority of them. The variables of this study were proposed in three scales of macro, medium, and micro according to the previous valid research studies in the field of flexible housing. Then, the variables have been evaluated using the specialist's idea through the Fuzzy Delphi method (FDM). The Friedman test has been used to analyze the data obtained from the questionnaires and achieve a valid ranking, which performs the ranking by calculating the mean rank for each variable. According to the results of data analysis, the characteristics of "spatial expansion and division," which means the possibility of space to be expanded (the expansion) or divided (the contraction), as the medium scale of housing design, has the greatest impact on the housing flexibility. On the macro scale, the "structure" component, and the micro-scale, the "use of flexible elements" provide the highest effectiveness in this regard. Moreover, as the medium scale, the modular design of space falls in the second place of influence compared to all other variables. Increasing the properties of spatial expansion and spatial division can be an effective design strategy for achieving flexibility in apartment housing. Also, modular space designing and flexible elements have been introduced as two solutions in the next priorities. All are considered small and medium scales and can be prioritized in designing flexible apartment housing.

Keywords: *Housing, Flexibility, Compatibility, Fuzzy Delphi, Expansion and Division.*

INTRODUCTION

With the concentration of population in cities and the depletion of existing land, housing flexibility has become an important feature in the evolution of our daily lives (De Paris & Lopes, 2018). On the other hand, progress is intertwined with change. Lack of providing the conditions for change will inhibit various events and occasions and prevent the advancement of science (Lynch, 1972, 451). According to 'Till and Schneider' the tendency to design buildings that correspond only to a particular type of house at a specific point in time are the consequence of short-term views on economical condition, and in contrast, having flexibility in design brings the economic and social sustainability (Schneider & Till, 2005). Habraken attributes this kind of approach (flexibility) in the design process to the architects' tendency to recognize the unplanned diversity of user conditions and the unpredictability of the future use (Habraken, 2008), as it can be said that flexibility is a cover for uncertainties (Shi & Daniels, 2003). By pointing to the economic and social contexts, Friedman and Krawitz propose the need for small, inexpensive, and compact homes and the adaptation issue as the only way to respond to the users' variation by introducing 'the next home project' (Friedman & Krawitz, 1998). Flexibility here refers to the spatial flexibility, organizing the artificial spaces and changing their condition to achieve new situations, needs, and applications (Einifar, 2003), which roughly had a similar role of quality twenty

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years ago (Upton, 1995). Groak's definition of flexibility includes the ability of spaces to arrange different physical arrangements (Groak, 2002, 15-17). This approach can still be effective in the housing crisis (Debicka & Friedman, 2009) and is environmentally friendly because it reduces waste from unforeseen changes in buildings. This idea also leads to the optimal use of a unit area, thus reducing the budget required by the government (Elkady et al., 2018).

Since the space elements define that special space, to make a flexible space, these components should also be flexible accordingly; so the house flexibility rate varies according to the available facilities predicted for changing the space (Ghafourian & Aghaei, 2016). This difference in parallel depends on various factors such as structures, construction techniques, furniture, partitions, materials, and dynamics (Abdulpader et al., 2014). From 2005 onward, researches on housing flexibility have been conducted, which in addition to exploring the full and comprehensive terminology and definitions in this area, have struggled form a correct perspective and a clear strategy for a designer in introducing the flexible design strategies and variables and sometimes in analyzing one or more variables separately. But Till and Schneider have comprehensively classified these strategies, including four macro-areas and a final strategy for each (Schneider & Till, 2005). Moreover, the variables affecting flexibility have partially been evaluated, together with some specialized studies; Zikovich et al. introduced the flexible elements and equipment (Živković & Keković, 2014) and, Cellucci examined the variables including modulation, structure, attachments, and facades (Cellucci & Di Sivo, 2015). Ghafourian, in his research (2012), to identify the parameters of flexibility, has introduced four features of multifunctional, expansion, division, and flexible furniture (Ghafourian, 2012). Understanding these variables and the related priority can help the designer design a flexible space.

This study aims to understand the position of flexible housing variables in the design process and rank them based on their effectiveness according to the view of specialists and designers. However, in contemporary architecture, this has been a subject for trial and error, as Habraken believes it may become a sideline issue or a serious architectural challenge, and in this regard introduces 'Avi Friedman' and 'Frans van der Werf' among those few architects who have dealt with the subject of flexibility in architecture practically and seriously as they target all these strategies together (Habraken, 2008). Designing flexible housing requires accurate knowledge of the position of all these variables together, which can affect the final result. Accordingly, the main research questions are:

1- Which components are effective in housing flexibility?

2- What are the priority of components in designing flexible housing?

Theoretical Framework

The theoretical framework of this research study is based on achieving a single concept for flexibility in housing through the study and comparison of all definitions in previous research. Researchers and specialists have proposed various definitions of a flexible architecture and sometimes even initiated their research with different classifications of flexibility; however, what is obvious is the existence of various kinds of flexibility.

This classification is often defined in two sub-categories of flexibility. Adaptability and variability are two different approaches to flexibility; in this regard, most of the previous research has been done on the variability that is sometimes referred to as flexibility in research.

The studies that have mainly defined variability as their dependent variable are the main focus of this research. In these types of studies, the desired components for flexibility are often defined by reviewing the target case studies. Similarly, by evaluating the case studies, this study has categorized the target components into three levels to form the main basis for the research. (Figure1)

In a research study entitled "Evaluation of flexibility components for improving housing quality," Malakouti et al., reviewing the literature on 'flexibility of housing,' introduced the indicators of housing quality (Malakouti et al., 2019). Furthermore, the Delphi method introduced the most influential components related to the flexibility in housing quality (Malakouti et al., 2019). In similar research, the components of flexible housing were redefined by Ghafourian & Aghaei as a basis for their theoretical framework, followed by analyzing the case studies, relying on a questionnaire-based survey (Ghafourian & Aghaei, 2016).

The Variables

Ghafourian, in his research, has introduced four characteristics to identify the flexibility parameters, including multifunctional features, expansion, division, and flexible furniture (Ghafourian, 2012). In many sources, various factors have been introduced such as 'strategy,' 'variables,' 'approaches,' or 'parameters' that, based on them, the flexibility of the building will depend on the quantity and quality of these factors a project. However, the scale and the degree of influence for these factors will not be at the same level. In this study, the variables related to flexibility have been classified into three micro, medium, and macro scales.

The micro-scale refers to the design and use of equipment, furniture, and materials within a residential unit. The medium-scale points to the components of the organization and the quality of the plan. The macro-scale goes beyond the plan's design and details of a residential unit; it refers to the components of the characteristics of a residential block.

Height Factor (Number of Floors)

The term height in this study refers to the number of floors. In his book, untitled 'Responsive Environments,' Bentley argues that the building flexibility decreases by increasing the

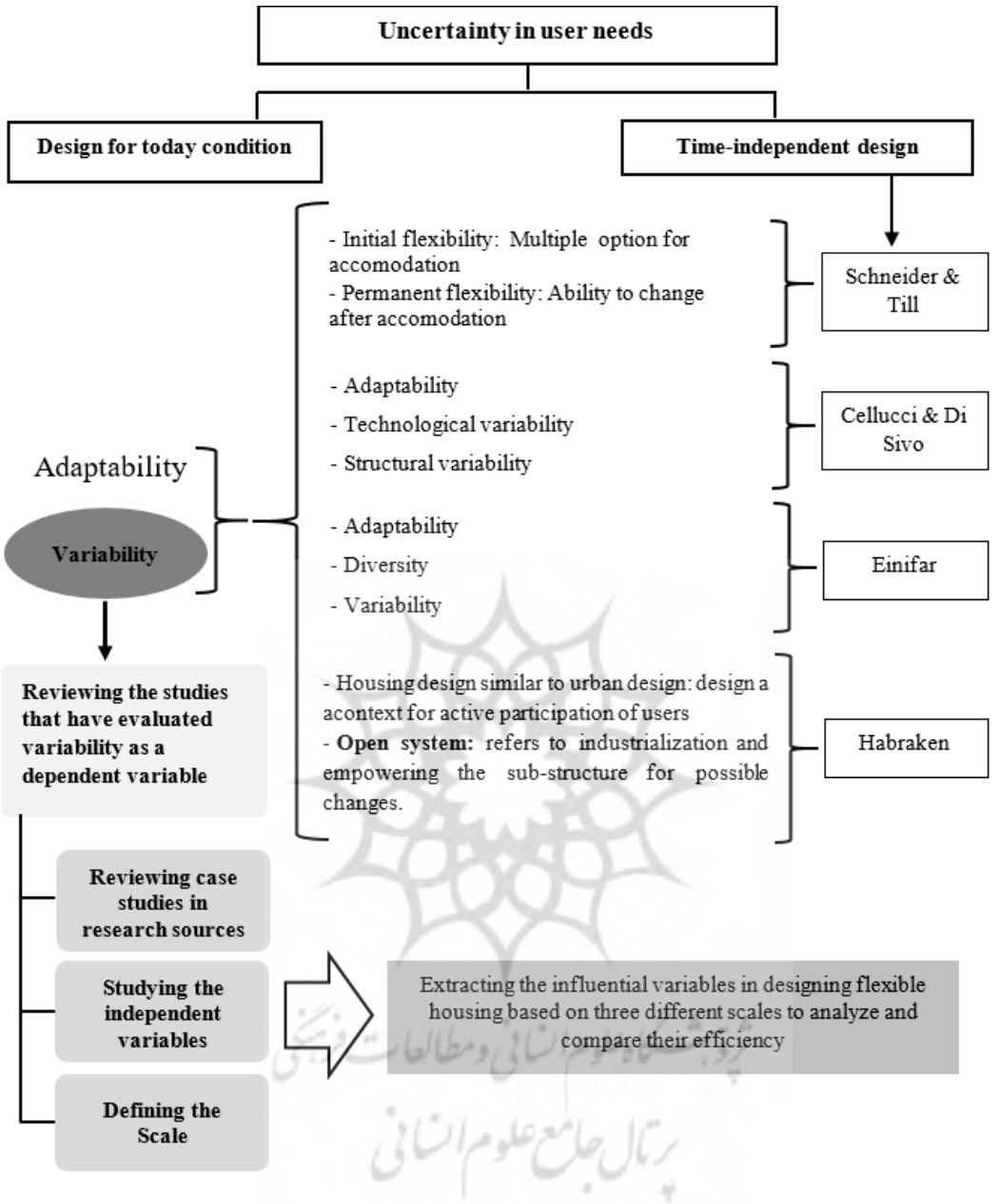

Fig. 1: The Research Theoretical Framework

number of floors by more than four (Bentley, 1985). In high-rise projects with a high number of floors, sometimes, the occurrence of some conditions will reduce the flexibility of the building floors decreases as the number of floors increases (Seyyeddin & Aqli Moghaddam, 2015).

For example, the six-story Georges Pompidou Cultural and Artistic Center, with a height of 60 meters, having large and open spaces, with multiple uses and the possibility of being expanded in the future, can be a reliable project of a high-rise flexible building with multiple floors (Figure 2).

A couple of solutions have been used in this project to achieve flexibility, as the most important of them is the transfer of hard spaces and services to the outside of the project.

Natural Light

Bentley also points to the light factor, believing that many activities in space require adequate natural light. Buildings with high depth or length cannot adequately respond to multiple uses and activities of spaces (Bentley, 1985). Half of the building fronts are sky-lighted in the Montereau project (Figure 3), with

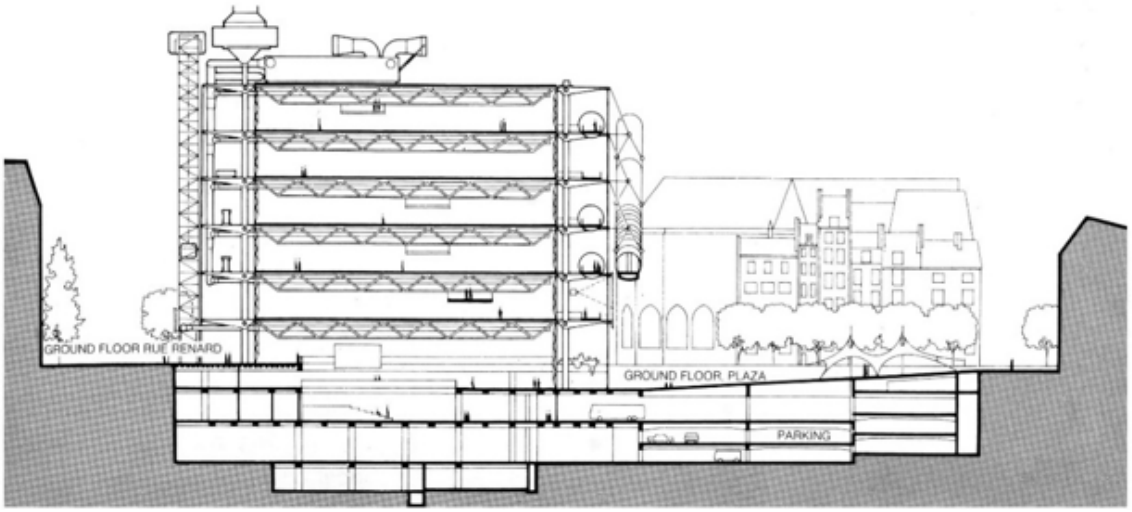

Fig. 2: The longitudinal section of Georges Pompidou project. The project designer: Renzo Piano, Richard Rogers, 1977 France (Source: Atlas of Places, 2017)

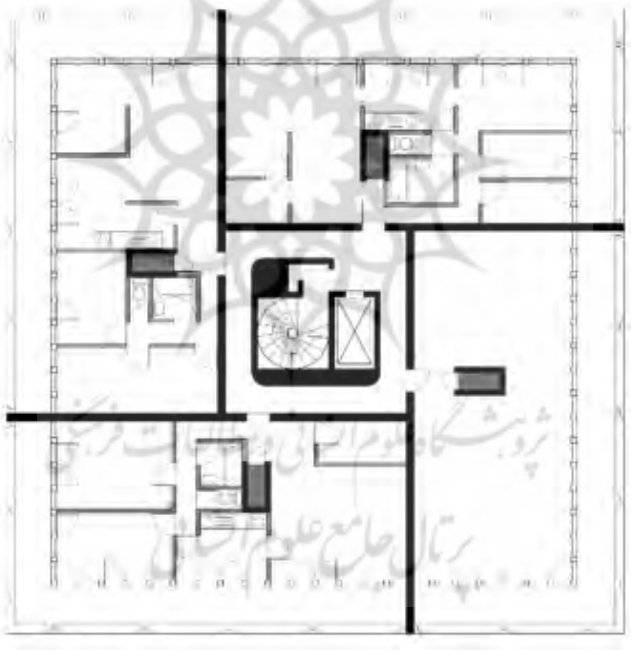

Fig. 3: The Montereau project. The Project Designer: Les frerez Arsene henry. 1971 France (Source: Thaniyabadi et al., 2017)

four free plans. The position of the kitchen in all three different forms of the plan represents the proper lighting of all spaces that have provided multiple places for the kitchen and various types of placement for rooms and living rooms.

The Modular Design

The factor of flexibility is also achieved through the modular design method (Živković & Keković, 2014). Modular-based construction promotes a combination of positive economic and environmental impacts and economic opportunities in various industries. In the modular approach, the product life cycle and cycle are important. One of its goals is to reduce the resources consumed in the production, maintenance, recycling, and manufacturing cycle (Bashkite & Zahharov, 2011).

In designing a plan, a basic module can be reached by considering factors such as construction facilities, user needs,

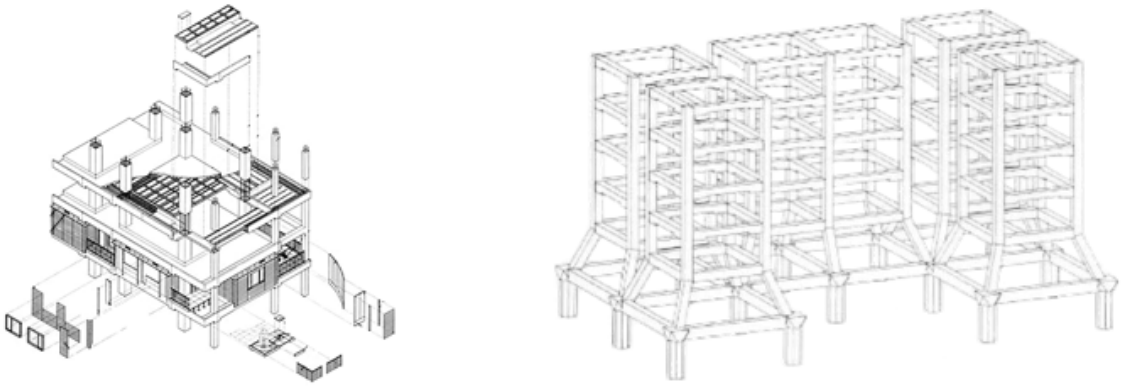

Fig. 4: The structural diagram of NEXT 21 project (Source: Ismail & Rahim, 2011)

structural issues, interior equipment, external proportions, and arrangement of spaces together; The desired module may be a basic space or an essential element inside the housing. This approach can greatly help us achieve the placement and arrangement of interior spaces and the construction and static issues.

Modular design refers to the two concepts of industrialization and architectural design (spatial organization). It decreases the assembly time and costs significantly and increases mass customization (Eghbali & Hesari, 2013). The projects of Raines Court and NEXT21 (Figure 4) are two examples in this field that have used modulation in structures and at the same time in other building systems such as partitions and spatial organization (Ismail & Rahim, 2011)

The modular design and construction approach is also visible in the traditional style of Japanese architecture (Figure 5). The fixed and specific dimensions in proportion to the floor covering and the equipment of the interior spaces are significant. In these spaces, the dimensions of the tatami mats were considered as the basic modulus so that the spaces were able to be expanded based on their dimensions of them and by observing their proportions.

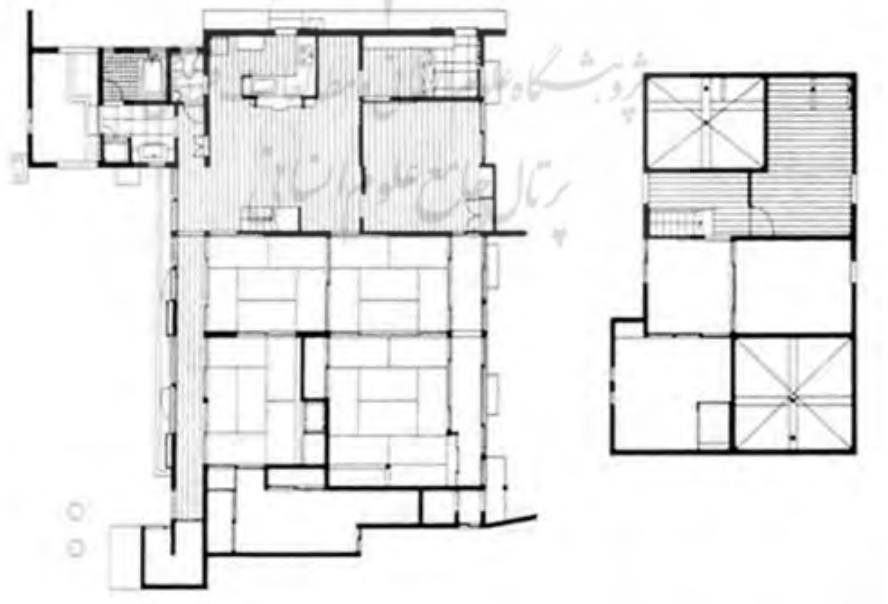

Fig. 5: A traditional Japanese house. Kazuhiko and Kaoru Obayashi (Source: Živković & Keković, 2014)

The Depth of Spaces

The depth of the spaces can also greatly affect the amount of light in these spaces; the maximum flexibility of the interior spaces of a building will be provided when the quality conditions of that space in terms of light and ventilation can be provided naturally. The flexible buildings generally have low depth in the plan (Bentley, 1985). In Am Steinberg project, there is a skylight front (Figure 6), with a low depth as the spaces around the stair box, are organized longitudinally.

Utilizing the Flexible Elements and Equipment

The use of flexible elements such as sliding & folding partitions and moving pieces of furniture can be defined as a key or additional tool of internal flexibility (Živković & Keković, 2014). The flexible elements in smooth interior spaces include sliding, folding and movable items such as lightsome wall partitions and flexible pieces of furniture that allow different placement of interior objects in space and various spatial and functional settings. The flexible elements support the fluid

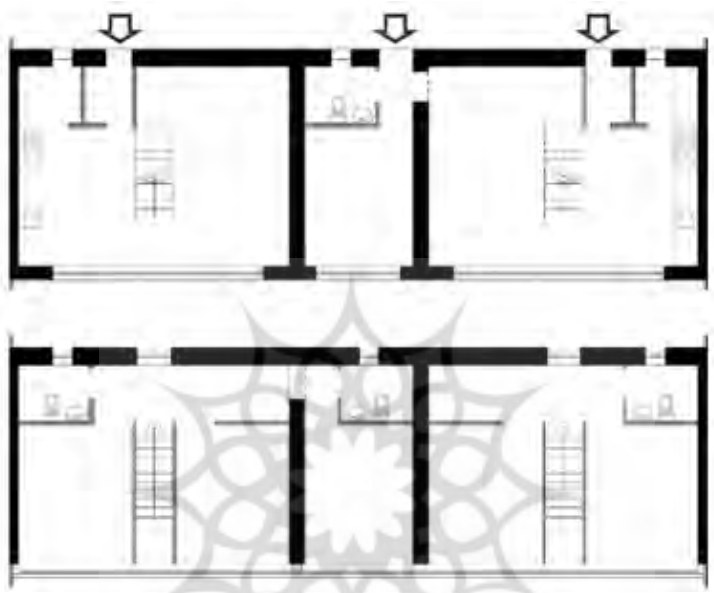

Fig. 6: The Am Steinberg project. Designer: Metron Architekten. 1990. Germany (Source: Thaniyabadi et al., 2017)

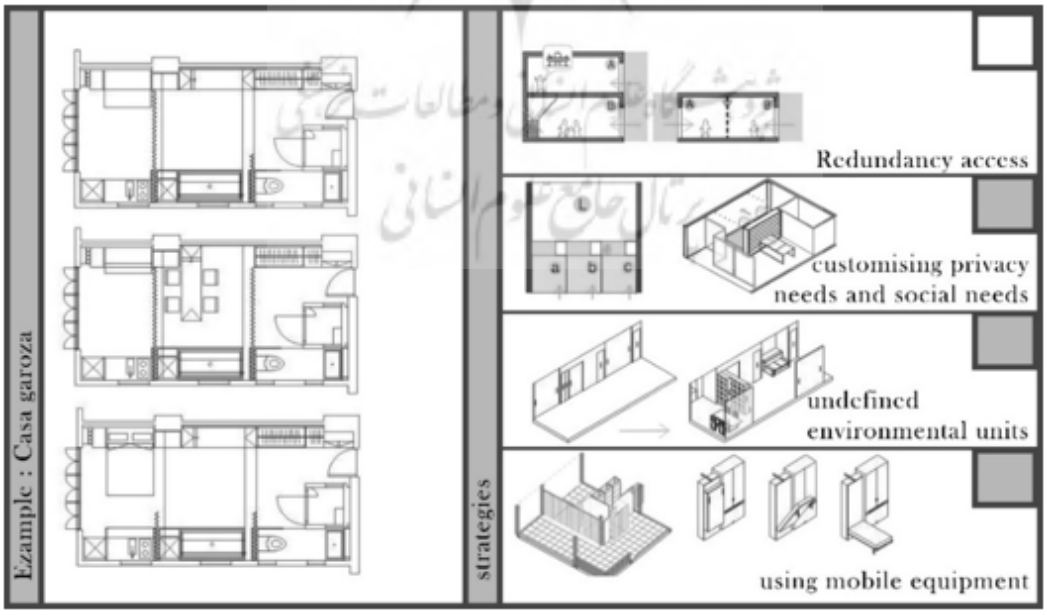

Fig. 7: Representing flexibility at a fixed level. The project of Casa Garoza, Reference (Source: Cellucci & Di Sivo, 2015)

nature of space, which can be divided, separated, attached, or open spaces (Živković & Keković, 2014), depending on the user's needs, preferences and lifestyle. The Casa Garoza project (Figure 7) is a good example of folding furniture and movable partitions to provide unit flexibility.

The Facade Compatibility

The characteristics of variability and compatibility in the building facade are the other variables that introduce the external flexibility of the building and are completely interrelated with the interior flexibility of the building; The other factors such as building structure, modular construction, and connections and joints can influence this factor. On the other hand, in conditions the facade of the building is not flexible, the interior space will be a problem. In this regard, the structure used in the facade of the NEXT 21 project in 1993 is a creative and successful example (Figure 8). In this kind of design, which is a creative idea, the facades can be installed and detached without external scaffolding by using the aluminum panels and applying specific windows and doors, which provided easy compatibility for future applications (Habraken, 2003).

The Ability of Expansion and Division

These two characteristics point to the increasing capacity of space to expand or contract, which enhances the life cycle in that space (Schneider & Till, 2005). The spatial expansion keeps the built spaces dynamic, meaning they can expand, divide, aggregate, contract, and resize depending on the space situation. This factor also depends on other variables, including the structure, modular plan structure, modular and flexible equipment, and partitions. In other words, it can be said that these factors all affect each other. According to Blakstad, the property of spatial expansion is defined as the horizontal or vertical expanded availability of space, as access to such space capacity will be related to the availability of space and the existing structural capacity of that building. Furthermore, he defines the ability of space division by its ability to be divided into different functional areas and based on the possibility of space to access to separate areas (Blakstad, 2001).

In the project of Flexsus House (Figure 9), with the possibility of easy removal and installation of fences and the structures made from slabs and distant load-bearing walls, the distance between the outer walls and the middle walls allows the expansion of the interior spaces (Schneider & Till, 2005). This project provides the desired flexibility by using structures and facilities with high compatibility following the spatial expansion and potential spaces for expanding the unit in two directions (Higuchi & Gotou, 2005).

In the Millennium Village Phase II (Figure 10), the possibility of interior expansion and merging spaces has been provided for adaptability with different scenarios regarding the number and type of user applications.

Fig. 8: The NEXT 21 Project. SHU-KO-SHA arch urban design studio (Source: Habraken, 2003)

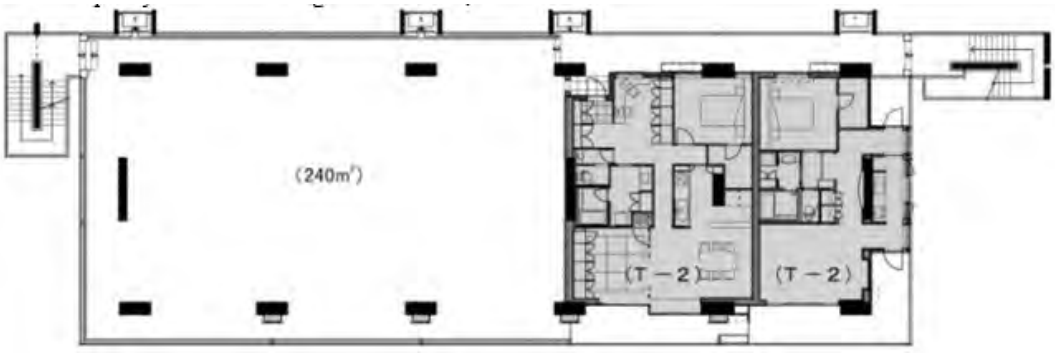

Fig. 9: The project of Flexsus House. Takenaka Corporation (Source: Higuchi & Gotou, 2005)

Fig. 10: The project of Millennium Village Phase II. The designers: Proctor & Matthews (Source: Schneider & Till, 2005)

Using Hard Connections and Joints

The use of hard joints is also another factor affecting the flexibility of the housing. Reducing the use of adhesive attachments and mortars stuff, which are all permanent connections, will be a major factor in changing, replacing, and repairing the connections and physical elements inside and outside the housing. This characteristic also has a significant effect on the dead-load of the building and consequently on the type and structural sections of the building; the expansibility of the spaces and the use of movable and flexible equipment (Figure 11) will all be affected this factor.

Accessibility

The building should easily access its interior parts from the ground floor to any direction. The ratio of the front side of the building to the common spaces should be maximized to allow for the highest number of entrances to the building (Bentley, 1985). Moreover, for each unit, the presence of more access units completely affects the level of its flexibility (De Paris & Lopes, 2018, 85). The effect of access and communication

Fig. 11: The type of connections and joints used in the project of Georges Pompidou Center. France. 1977(Source: Denancé & Berengo Gardin, 2017)

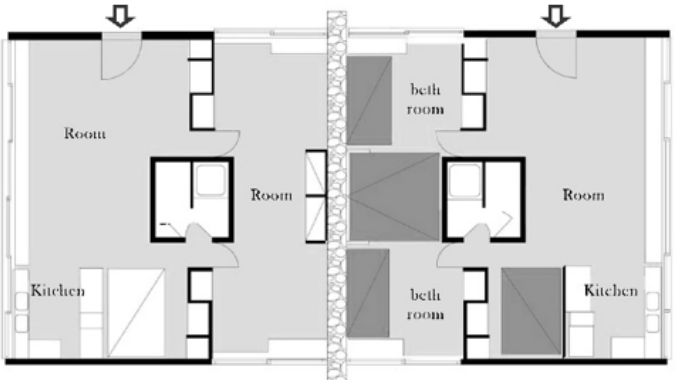

Fig. 12: The design of Maison Loucheur. The designer: Le Corbusier (Source: Till & Schneider, 2005)

spaces on flexibility was investigated by Farhadi et al. in 2017; they have shown the role of communication spaces in various flexible design strategies by analyzing the previous projects (Thaniyabadi et al., 2017). An example of access to interior spaces of the building is the Maison Loucheur project (Figure 12), in which the entrance area is opened directly into one of the rooms building as the access to other rooms is allowed through the same room due to the limitations of dimensions and area for the designer. The two rooms at backspaces are separated by a folding bed that becomes integrated when the bed is folded.

The Type and Quality of Structure

The construction type and structural system should be seriously considered by designers (De Paris & Lopes, 2018) to organize the structural system on a typical standard network to ensure easy building verification. It is required to consider the use of materials that, in addition, let the flexibility of interior spaces ensure maximum reversibility of the system by removing and reinstalling the metal parts. Furthermore, it is essential to provide hollow or rectangular beams to integrate the installation system into the structural form and provide the interior space completely free of restrictions that prevent possible changes (Figure 13) (Cellucci & Di Sivo, 2015).

For example, in the project of Hellmutstrasse (Figure 14), the presence of a structure with load-bearing walls parallel to each other has led the architect to a multifunctional space design approach. It prevents the designer from various other strategies (Beisi, 1995).

Area

According to Bentley, the area of the building is considered as the most important factor; to him, the area or dimensions of the space allocated to a particular housing design will be the most important factor in providing the flexibility of that specific housing (Bentley, 1985). Related research by Aghaei et al. in 2021 on the ability of expansion of the micro-spaces of apartment housing in Tehran-Iran, showed that small apartments with one bedroom have the lowest level of expansion, and in contrast, the apartments with larger space,

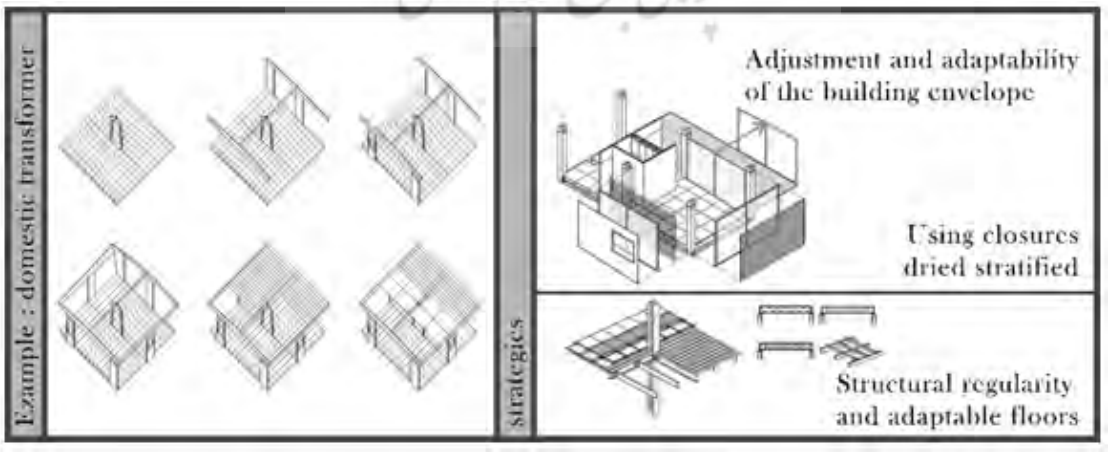

Fig. 12: The design of Maison Loucheur. The designer: Le Corbusier (Source: Till & Schneider, 2005)

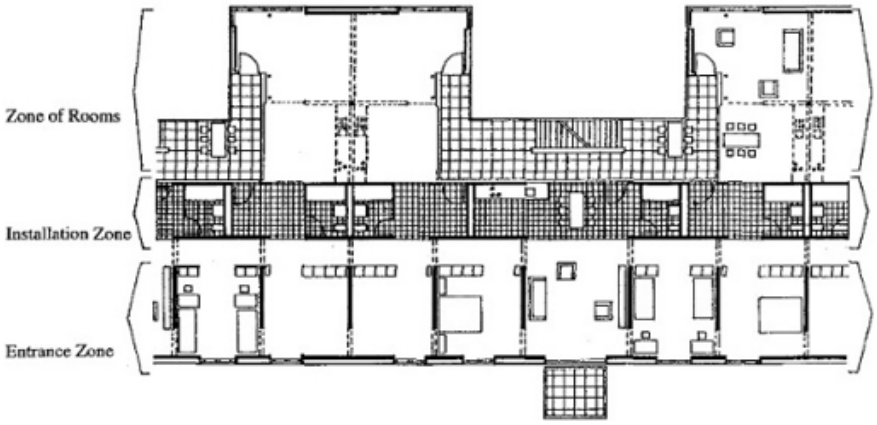

Fig. 14: The project of Hellmutstrasse; The representation of ADP (Architectural Design Planning) (Source: Beisi, 1995)

for example, those which were equipped with three bedrooms, were in better condition of expansion (Aghaei et al., 2021).

Block Connections

Bentley also points to block connections on a larger scale; according to him, the houses with less connection with the adjacent units have a better condition for building expansion, construction, and structural junctions than other types of connectors (Bentley, 1985). The extracted variables have been presented in Table 1.

MATERIAL AND METHOD

The methodology of the research includes three stages of collecting the components of housing flexibility by library-based method and doing a literature review, evaluating these components by specialists through fuzzy Delphi method, and then performing Friedman test on the gathered data to achieve the average rank test for each component and ranking them (Figure 15). The Delphi method is flexible and can be applied with quantitative and qualitative data sources. Furthermore, it is impossible to generalize the results based on a single sample in this method. It uses purposeful sampling from individuals with specific expertise in the target subject (Brady, 2015, 2). Another reason for performing fuzzy Delphi in this study was the possibility of obtaining the expert's agreement on finding the most effective components. In this research, before

Table 1: Variables affecting housing flexibility

Scale	Variable	Reference
Macro	Block Connections	(Bentley, 1985)
	Height (increasing the floors)	(Bentley, 1985)
	Structure	(Živković & Keković, 2014) (Cellucci, & Di Sivo, 2015) (De Paris & Lopes, 2018)
Medium	Area	(Bentley, 1985)
	Depth	(Bentley, 1985)
	Light	(Bentley, 1985)
	Modular design	(Živković & Keković, 2014) (Cellucci, & Di Sivo, 2015) (Ismail & Rahim, 2011)
	The ability of expansion and division	(Cellucci, & Di Sivo, 2015) (Habraken, 2003) (Schneider & Till, 2005) (Ghafourian & Aghaei, 2016) (Blakstad, 2001) (ghafourian, 2012) (Malakouti et al., 2019)
	Accessibility	(Bentley, 1985) (De Paris & Lopes, 2018)
	Facade compatibility	(Cellucci, & Di Sivo, 2015) (Ismail & Rahim, 2011)

Continiue of Table 1: Variables affecting housing flexibility

Sclale	Variable	Reference
Micro	Using/utilizing a hard connection	(Cellucci & Di Sivo, 2015)
	Using/utilizing flexible elements	(Živković & Keković, 2014) (Cellucci, & Di Sivo, 2015) (ghafourian, 2012)

obtaining this consensus, the Delphi method was performed in three stages before acquiring the experts' agreements: selecting variables, proposing questions, and finally answering the questions.

The Fuzzy Delphi method was initially proposed by Ishikawa et al. and was adapted from the traditional Delphi method and 'Fuzzy Set Theory' (Ishikawa et al., 1993). This method can be used for two purposes: 1- Indexes screening and 2- Predicting the relationships among them, which this study pursues the first one and has an exploratory aspect. In this category, researchers seek to identify the most important essential elements of a phenomenon, and one step is required to achieve the general agreement of expert opinions.

The questionnaire has 36 questions designed from twelve variables extracted from research sources. Each variable comprises three questions for specialists from three different aspects. The phrases of questioner have been proposed in the form of sentences. The specialists have been asked to determine their agreement level (by confirming that all variables are effective based on the previous research).

In this research, the 'purposive sampling' method has been used to select the panel members to increase the accuracy of their comments. Moreover, snowball sampling has been used due to the limitation in recognizing and selecting specialists who had maximum awareness of the research subject. The experts were selected from the faculty members, doctoral researchers, and professors at scientific centers, including Shahid Beheshti University of Tehran, Tarbiat Dabir University, Shahid Rajaei University of Tehran, Tehran University of Science and Technology, and also from a group of consulting engineers in Iran. The number of interviewees is usually set in 15 to 50 subjects. However, some studies have reported 10 to more than 2000; but 15 to 10 interviewees are generally sufficient in homogeneous communities. In the present study, a population of 31 subjects was selected.

The analytical techniques are not specifically related to the method in all Delphi studies. Rather, they are adopted based on the research aim, the target design, and the type of data collected during the research process (Brady, 2015, 4). In this research, the Friedman test was applied, making it possible to rank each variable by calculating their average test rank finally.

RESULTS AND DISCUSSION

Result

To analyze the Friedman two-way analysis of variance (ANOVA) rank test, the null hypothesis states that repeated measurements of K or homogenous groups come from the same population or the same average population (Siegel & Castellan, 1988). According to the Null Hypothesis (H0), the test requires the sequentially measuring variables. The Friedman test determines whether the sum of the ranks for each condition differs significantly from the expected values for random variables (Pereira et al., 2015).

The various parameters, including mean value, the sum of scores, minimum score, maximum score, scores range, variance, and standard deviation for all variables, have been presented in Tables 2 and 3.

According to data presented in tables 2 and 3, the highest total score is related to the variables of spatial expansibility, modular design, and use of flexible elements with a total score of 431, 423, and 419, respectively. Accordingly, the lowest total scores are related to the depth, structure, and height variables with 231, 254, and 257, respectively.

The highest mean values according to the tables belong to the variables of spatial expansibility and division, use of flexible elements, and modular design with the values of 13.90, 13.65, and 13.52, respectively. Furthermore, the lowest mean value is associated with the variable of 'depth' with a value of 7.45.

The rankings obtained from the Friedman test for the effectiveness level of variables have been presented in Table 4,

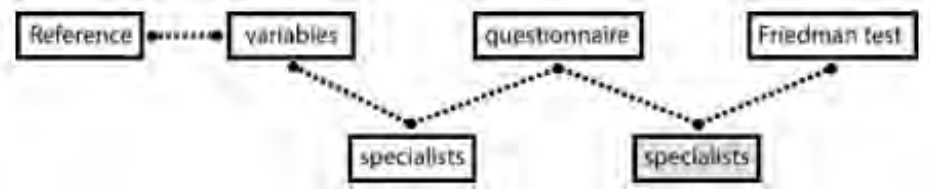

Fig. 15: The research process

Table 2: The statistical comparison of the scores of flexibility variables (According to SPSS data)

Statistics							
	height	Modular	Depth	Continuity	Exponent	Extensibility	Connections
N Valid	31	31	31	31	31	31	31
Missing	0	0	0	0	0	0	0
Mean	8.29	13.65	7.45	7.97	10.03	13.90	11.39
Std. Error of Mean	656.	316.	627.	621.	501.	243.	409.
Median	9.00	14.00	8.00	8.00	10.00	15.00	11.00
Mode	3[a]	15	3	5[a]	9	15	11
Std. Deviation	3.653	1.762	3.491	3.459	2.787	1.350	2.276
Variance	13.346	3.103	12.189	11.966	7.766	1.824	5.178
Range	11	8	12	12	12	4	9
Minimum	3	7	3	3	3	11	6
Maximum	14	15	15	15	15	15	15
Sum	257	423	231	247	311	431	353

a. Multiple modes exist. The smallest value is shown

Table 3: The continuation of data in Table 2 represents the statistical comparison of scores of flexibility variables (According to SPSS data)

Statistics					
	Access	Flexible	light	Structure	Area
N Valid	31	31	31	31	31
Missing	0	0	0	0	0
Mean	11.06	13.52	12.32	8.19	8.71
Std. Error of Mean	401.	274.	381.	693.	648.
Median	11.00	14.00	12.00	7.00	8.00
Mode	9[a]	15	12	6	7
Std. Deviation	2.235	1.525	2.120	3.859	3.607
Variance	4.996	2.325	4.492	14.895	13.013
Range	8	4	9	12	12
Minimum	7	11	6	3	3
Maximum	15	15	15	15	15
Sum	343	419	382	254	270

a. Multiple modes exist. The smallest value is shown

5, and 6 and the mean test rank, respectively.

The value of the chi-square test with 11 degrees of freedom and the significant level of the test is zero, which indicates that the null hypothesis is rejected. Accordingly, there is a significant difference between the variables affecting housing flexibility with the ranking shown in Tables 4, 5, and 6.

Discussion

By conducting the Friedman test on the data obtained from the questionnaires, the hypothesis was confirmed that there is a difference between the effects of housing flexibility variables at a significant level according to the Friedman test, which is statistically reliable. Finally, based on the above data, according to target experts and large-scale, the highest priority for the flexible housing design belonged to the "structure" component. The medium-scale was linked to the "spatial expansion and division" component. At the micro-scale, the "use of flexible elements" and the lowest rank were related to the variables of "continuity," "depth," and "using hard connections/ joints" in the three scales, respectively.

By comparing the variables scores in Tables 4, 5, and 6, it can be seen that the components of the two scales of medium and micro have the greatest effect on housing flexibility, and these two scales should be more considered than the macro scale in the design process.

The property of spatial expansion, known as the expansibility, which has been introduced as the most important factor in this method, has been mentioned in most of the studied sources as well, to the extent that Till and Schneider introduce it as a design approach (Schneider & Till, 2005). Moreover, Cellucci

Table 4: The ranking of variables affecting housing flexibility (macro-scale) (According to SPSS data)

Mean test rank (Friedman). Macroscale		
Rank	Variable	Mean test rank
1	Structure	4.17
2	Height	4.07
3	Block attachment	3.60

Table 5: The ranking of variables affecting housing flexibility (intermediate scale) (According to SPSS data)

Mean test rank (Friedman). Medium-scale		
Rank	Variable	Mean test rank
1	spatial expansibility and division	10.12
2	Use of modulation in design	10.02
3	Providing natural light	8.63
4	Adequate access	6.93
5	Facade compatibility with internal changes	5.85
6	Area	4.37
7	Depth of space	3.03

Table 6: The ranking of variables affecting housing flexibility (micro-scale) (According to SPSS data)

Mean test rank (Friedman). Microscale		
Rank	Variable	Mean test rank
1	Using the flexible elements	9.60
2	Using hard attachments	7.62

believes that using this variable has economic benefits (Cellucci & Di Sivo, 2015).

Till and Schneider introduced the terms soft and hard as two design approaches. Those ideas that result in certain indeterminacy in the plan and create raw spaces in the project are subsets of soft strategies. Accordingly, spatial expansion and division are a subset of flexible housing design soft strategy (Till & Schneider, 2005). Similarly, Malakouti et al., by investigating the most effective components of flexible housing in the field of housing quality, relying on the Delphi method, have introduced spatial expansibility as one of the most effective components (Malakouti et al., 2019).

The Study Limitation

The main limitation of this study was the dispersion of specialists and the lack of easy access to them to perform the Delphi steps in a coordinated manner. Most of the specialists in Delphi only wanted to complete the questionnaires through face-to-face interviews and did not accept sending and completing the questionnaires via the Internet. The face-to-face access to all professors in universities and consulting engineers is associated with many barriers to research. This factor caused only 31 out of 45 sent questionnaires to have the conditions for analysis in this research.

CONCLUSION

In designing a project with a flexible approach, considering the variables with the highest effectiveness can greatly prevent the architect from confusion. Based on the results of this study, the variables of the "spatial expansion and division," the "modular design," and the "use of flexible elements" with the highest level of intervention and effectiveness on the flexibility of a project are the best suggestions for the designers to be considered. However, the "structure" component has the highest priority on the macro scale.

Studying the relationship and the correlation between the four variables introduced above will bring us one step closer to a proper understanding of flexible housing design. This could be a real challenge for future research.

The desired Delphi method has frequently been conducted among specialists in housing architecture, and the acquired results have been greatly influenced by the areas of interest of these specialists. However, researchers in environmental psychology can use this Delphi method to achieve new results.

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