

Investigating Variations in Space Syntax Indicators for Semi-Open Spaces and their Effect on the Functional Efficiency of Housing (Traditional and Modern Houses of Isfahan, Iran)*

Safoura Yakhchali^a- Neda Sadat Sahragard Monfared^b- Seyyed Abbas Yazdanfar^{c**}

^a M.A. of Housing Architecture, Faculty of Architecture and Urban Planning, Iran University of Science and Technology, Tehran, Iran.

^b Assistant Professor of Architecture, Faculty of Architecture and Urban Planning, Iran University of Science and Technology, Tehran, Iran.

^c Associate Professor of Architecture, Faculty of Architecture and Urban Planning, Iran University of Science and Technology, Tehran, Iran (Corresponding Author).

Received 16 May 2021;

Revised 07 August 2021;

Accepted 07 August 2021;

Available Online 20 March 2023

ABSTRACT

Semi-open spaces have played the role of in-between spaces for closed and open spaces, which have connected inside and outside, and increased the functional quality of these spaces next to each other. The role of semi-open spaces in the transformation trend of traditional to modern houses has unfortunately been neglected to lose their importance for the functional efficiency of housing. Hence, this study aims to investigate the functional efficiency of semi-open spaces in this historical trend based on the space syntax indicators for these spaces. Isfahan City was selected as a case study due to its historical background in housing scope. This study asks how the components of functional efficiency and space syntax indicators of semi-open spaces have changed in Isfahan's houses during different periods. To examine the role of porches and terraces in the houses, 25 traditional houses constructed in Safavid, Qajar, and Pahlavi eras, and 30 houses constructed over the last 30 years in Isfahan were chosen based on the diversity of semi-open spaces in terms of accessibility, area, connections, and form. Finally, duplicate samples were removed then 9 traditional and 14 modern houses were selected. The results indicated that choice, Isovist area, entropy, and connectivity were increased in semi-open spaces of the Safavid-Qajar eras during an evolutionary trend, which led to higher functional efficiency of houses, and the number of descending indicators were increased from Qajar to Pahlavi period. Moreover, only choice and entropy were increased during Pahlavi Period due to the distributive role of porches and the simplicity of spatial organization, respectively. From Pahlavi to the modern period, the smaller size of semi-open spaces, fewer accessibilities, lack of desired organization of spaces, and construction in floors led to a reduction in connectivity, integration, and Isovist area, and even increased control reduced the quality of private modern terraces, which all of the mentioned factors have led to the lower functional performance of houses in modern time.

Keywords: Semi-Open Space, Functional Efficiency, Space Syntax, Housing, Isfahan's Houses.

* This paper was derived from the Master Thesis by the first author under the title of "design of residential complex, by investigating the role of open and semi-open space in improving functional efficiency of housing using space syntax method" guided by the second author and consulted by the third author in Iran University of Science and Technology, 2020.

** E_mail: yazdanfar@iust.ac.ir

1. INTRODUCTION

Open and semi-open spaces are key elements of traditional housing in Iran. Three spatial types were used in different sizes and shapes in most Iranian buildings and cities before Islam and the Islamic period. In general, these three spaces include open, semi-open (covered), and closed spaces that were always shaped simultaneously, and were popular as complementary spaces among Iranian tribes (Rahmani 2011). The open, semi-open, and closed space group do not act separately in the architecture of traditional Iranian houses but each of them become meaningful along another. It means that spaces lose their openness and closeness degree gradually so that one space converts to another one. However, the hierarchy of access to semi-open spaces has changed in modern houses with different layouts in the house configuration.

Vertical expansion of housing and increased apartment living cases have dramatically increased in recent years. Although this process has somewhat met the quantitative needs of housing, it has appeared as a new dilemma since it is not matched the needs of residents living in these houses. In past, residents of houses had many personal and collective experiences shaped in some spaces, such as the courtyard and porch, while they now live in closed spaces only with several windows and one small porch. This trend has prevented terraces from playing their role, which is increasing the functional efficiency of the house.

Many studies have addressed the old and modern shapes of semi-open spaces in traditional houses and those constructed over the last 30 years considering many contexts, such as function, dimensions and size, climatic role, and social-communication role of these spaces. The novelty of this study is an examination of quantitative indicators of semi-open spaces in traditional and modern buildings, by using the space syntax method to find changes in the functional

efficiency of housing.

This study aims to analyze the role of semi-open spaces (porch and terrace) in promoting the functional efficiency of traditional and modern houses based on the space syntax method. For this purpose, the spatial configuration was analyzed in some cases, such as the location of modern semi-open spaces in apartments, desirable space coexistence, and adjacency of this site to one or several sites in the house.

Accordingly, the main questions of the study are as follows:

1. What are the functional efficiency components of semi-open spaces in the space syntax method?
2. How functional efficiency components and space syntax indicators of semi-open spaces have changed in traditional houses of Isfahan during Safavid, Qajar, Pahlavi, and modern eras?

The research hypothesis states: space syntax indicators of semi-open spaces, such as integration, connectivity, choice, depth, and Isovist area have gradually declined from Safavid to modern periods.

2. LITERATURE REVIEW

Many studies have investigated the situation of open and semi-open spaces in the spatial structure of houses. Some studies have evaluated the functional efficiency in spaces with medical, religious, residential, and other functions, and which space syntax method has been used for analysis in each case based on the subject and its approach.

Figure 1 depicts the conceptual model based on which, the literature review is done within three categories: semi-open spaces, functional efficiency, and space syntax method. After mixing these three categories, components of functional efficiency, semi-open spaces, and space syntax indicators related to each component were separately defined.

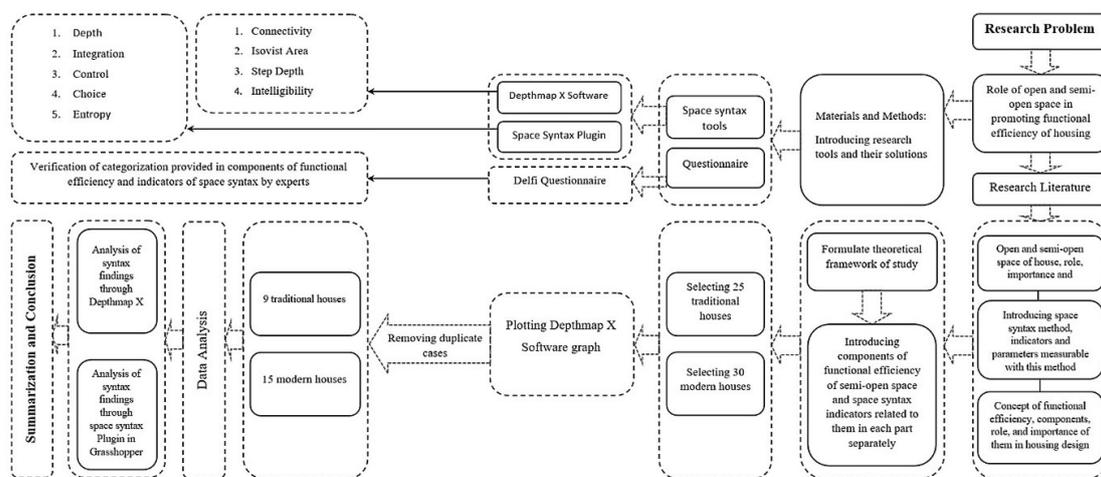


Fig. 1. Conceptual Model of the Research Process

2.1. Semi-open Space

In-between: according to the Dehkhoda dictionary, between is an opposite word that means segregation and difference between two objects (Dehkhoda 1963). Oxford Dictionary defines the word "in-between" as a space or period separating two points, events, etc. (Oxford Dictionary 2010).

One of the clearest forms of in-between is the space between inside and outside. The difference between



Fig. 2. Traditional Sample
(www.karnaval.ir)

This sense, generally, and external space, partially, shape the body of semi-open space. Semi-open space consists of open and closed and in-between concepts, unity of opposites (open and closed), semi-enclosure feeling, transmission, semi-public, and semi-privacy of atmosphere that is relatively consistent with different types of mental, social, and cultural needs (Zarkesh 2011). According to the definition of semi-open space, it is a space between two parts that provides in-between properties of such spaces, and this space must make the audience feel semi-enclosed beyond the importance of its semi-open body.

Different kinds of semi-open spaces can be named in Iranian architecture, such as porch, Bahar khab, Mahtabi (balcony), Soffeh (estrade), Ravagh (portico), Taremeh (patio) (Fig. 2), and terrace and balcony (Fig. 3) in modern samples.

2.2. The Functional Efficiency of Space

James Gibson was the first person who introduced the concept of efficiency in the residential environment. He introduced the concept of affordance in man-made or built environments but also emphasized the role of it in meeting different needs of people introducing it as a platform used to evaluate the desirability of the spaces (Gibson 1986). In the environment affordance theory, Gibson explains that some physical environments are more capable of providing some behaviors or are suitable for a behavior. Optimal

these two spaces appeared when humans gradually transferred their activities from outside to inside due to enhanced different behavioral patterns (Nooradin 1996).

Semi-open space: semi-open is not quantitative content (half of the body is open and another half is closed) but is a qualitative definition that creates a sense of semi-open status for the audience.



Fig. 3. Modern Sample
(www.archilovers.com)

efficiency of each space indeed means minimizing space-irrelevant activities and placing relevant activities next to each other in each site (Daneshgar and Eslampour 2012). In the Persian dictionary, efficiency means "performance," "function," and "affordance" (Dehkhoda 1963). The efficiency of an architectural work appears in suitable interaction between the physical environment and the various needs of its users. Users' needs are met in form of different activities done in the environment (Reversion 2009; Kiaee, Peyvastehgar, and Heidari 2017). It should be noted that functional efficiency is measured relatively and its definitions differ based on the space use. The low or high rate of an index does not necessarily lead to a reduction or increase in functional efficiency.

Interconnection spaces (semi-open spaces), gatherer, and distributive spaces (open spaces) play a significant role in improving space efficiency, spatial circulation, and daily activities. According to previous studies, four components are examined to measure the functional efficiency of a site in the house: 1. the site position in the whole structure of the building, 2. segregation or integration of considered site concerning other spaces, 3. access to the site, 4. type of site geometry. The space syntax approach is one of the most substantial techniques that investigate the concept of efficiency. This technique can measure the efficiency of space in the configuration structure

of a set of spaces.

2.3. Space Syntax Theory

The space syntax method is a sophisticated approach used to analyze the space configuration of built environments (Manum 2009). This method aims to describe spatial models, illustrate them in form of numbers and graphics, and simplify the academic interpretations of studied spaces (Mustafa and Hasan, 2010). One can use syntax data analysis to examine the relationship between the environment body and people's behavior and predict their effects or variations through time (Memarian 2005).

Syntax means the assessment of the relationship between each space with adjacent spaces in the complex, which resembles the assessment of a word in a paragraph and its relationship with other words (Memarian 2002). The main purpose of this theory is to analyze the syntax or layout of spaces in a spatial structure (Mollazadeh, Barani, and Khosrowzadeh 2012). "Space syntax" is based on the

spatial configuration, and is formed as the connection between interior spaces of architecture with emphasis on the relationship between social spatial systems. This technique indicates that social relationships affect the considered interactions, but also are embodied in the spatial systems (Rismanchian and Bell 2011; Peyvastehtar, Heidari, and Kiaee 2016). The quantitative and qualitative results of this approach help to detect and interpret the social-cultural logic of the space and evaluate and predict the optimum space syntax patterns. Hence, this study used this ability to analyze the role of semi-open spaces in increasing desired spatial function in traditional and modern spaces.

2.4. Introducing Space Syntax Theory Indicators Associated with Semi-Open Space

Figure 4 depicts the graph of space syntax theory indicators, which are the basic and core concepts of this technique.

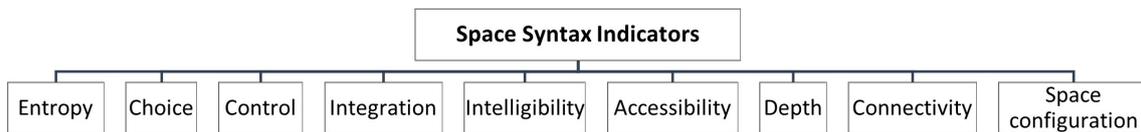


Fig. 4. Space Syntax Indicators

Among the defined indicators, intelligibility and step depth are not considered semi-open space-related indicators due to their holistic software outputs and non-generalization of them to micro-spaces like semi-open spaces. Hence, those space syntax indicators related to semi-open spaces have been investigated herein.

Space configuration: this concept means how spaces are placed next to each other and how are interacted (Kalantari et al. 2017).

Justified Graph: this graph is used to illustrate the internal connection specifications of the plan. This chart consists of a circle and line and its components translate the spatial relations of the building (Gholami and Hedayati 2018) (Fig. 5).

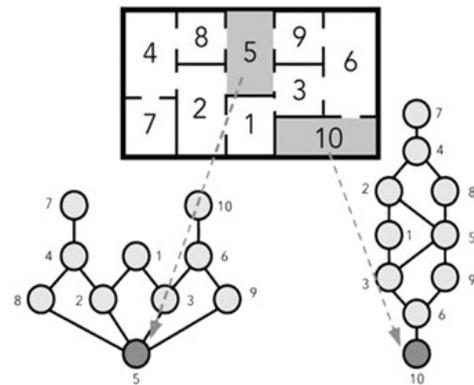


Fig. 5. Justified Graph for a Space (Hillier 2007)

Table 1. Space Syntax Indicators

Index	Definition
Integration	Integration of a point indicates a point continuity with or segregation from the whole system or a sub-system. Connection and integration between two concepts are related to space integration and its influence rate. Space integrity and segregation degree are two factors affecting functional yield when measuring the function efficiency of space with space (Abbaszadegan 2002).
Connectivity	The objective concept of connectivity means spatial connection. The more the connection rate, the more the spatial communication of the considered space with its direct adjacent spaces will be. When a space is applicable for different individuals, it implies the accurate performance of connectivity between spaces (Yazdanfar, Moosavi, and Zargar 2009).

Index	Definition
Choice	The choice rate is stronger in a space if many communication paths and spaces in the system pass through it. If diversity of space choices exists, space integration will be increased, which subsequently develops optimum spatial circulation (Peyvastehgar, Heidari, and Kiaee 2016).
Depth	Space depth indicates space permeability and integrity, which means the spatial step of each part of space relative to other parts (Hanson 2003). Depth is increased in public, semi-public, semi-private, and private areas, respectively, and the functional efficiency of each area will be suitable at its depth (Peyvastehgar, Heidari, and Kiaee 2016).
Control	Space control indicates the choice degree of individuals when entering that space. This concept for each space equals total accessibilities through adjacent spaces to considered space. Isovist also increases spatial security and decreases the privacy rate of considered space (Klarqvist 1993).
Isovist Area	Isovist area or visual accessibility is the full zone that can be seen from a certain point. Isovist area increases visual control and security while reducing spatial privacy. Isovist area indicates the area of observable space through certain points of space, which porch and terrace were considered as these points used to see adjacent spaces.
Entropy	Entropy addresses the access difficulty of each space compared to other spaces. A space with higher entropy has greater depth symmetry rather than its adjacent spaces, and therefore, the considered space provides more access. However, the lower entropy leads to an unbalanced spatial structure and less accessibility.

3. METHOD

The space syntax indicators affecting the functional efficiency of an environment particularly a residential environment was extracted, by using the descriptive-analytical method and previous studies in the first step of the study. Meanwhile, the defined indicators

were verified by experts through the questionnaire. While defining the mentioned indicators in this step, the factors that can affect the increase in efficiency through the space syntax approach were introduced, which ultimately led to the extraction of a theoretical framework in which, indicators of each component were introduced (Fig. 6).

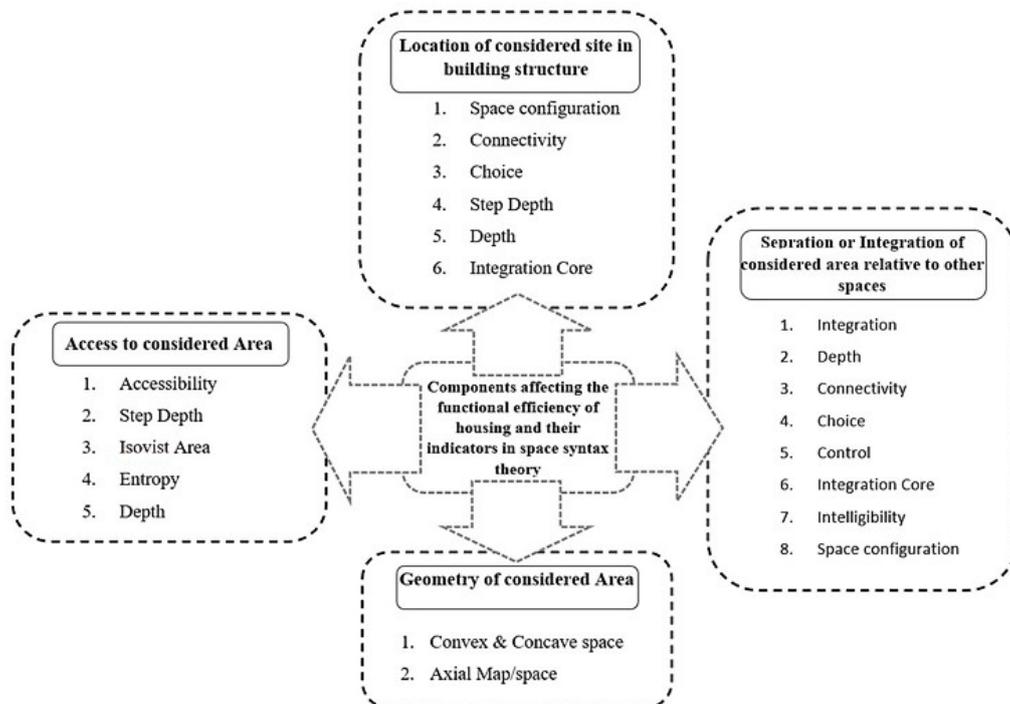


Fig. 6. Theoretical Framework

The case study technique was used in the next step, and case studies of research were introduced first. The selected cases were different from each other in terms of form, dimension and size, Isovist area, enclosure type, depth, and area, and also in terms of number and type of accessibility to other spaces. The graphs of three indicators (connectivity, integration, and depth) was proposed for all cases in this step, and then house analysis was done using Depthmap Software and Space Syntax Plugin through Rhino Software. The quantitative results of all traditional and modern houses were recorded and compared in the relevant table in the final stage.

3.1. Introduction to Case Studies

This study was conducted to examine the effect of semi-open spaces of the house on the design of spaces and the role of semi-open spaces in the functional efficiency of houses. Hence, the statistical society of considered historic houses was selected based on the relevant documents regarding the minimum interference with the form and structure of the main spaces of the house and spatial connections between

them. Statistical samples were selected based on the historical period of houses, and the number of construction aspects that were effective factors in selecting samples. In considered statistical society, one-sided, two-sided (opposite or adjacent), three-sided, and four-sided houses were used. The second point was having at least one semi-open space (porch, Soffeh, terrace, balcony, etc.) in the design and plan of the selected house. The courtyard form and multiplicity were not considered due to their minor effect of them on the space syntax analyses, but several courtyards were taken into account within the preliminary assessment of several houses.

According to explanations given in the first step, 25 historic houses were chosen of which, 11 houses were selected from the Safavid period, 11 houses were from the Qajar period, and 3 houses belonged to the Pahlavi period. The number of these samples reached 9 houses (4 Safavid, 3 Qajar, and 2 Pahlavi houses) in the next step after removing duplicate cases in terms of construction front, form diversity, depth, dimensions, porches' proportions, and accessibility to them (Table 2).

Table 2. The Mean Value of Depthmap Software Output and Space Syntax Extension for Traditional Cases

Porch							
Period	Isovist Area	Connectivity	Depth	Integration	Control	Choice	Entropy
Safavid	359.42	3367	3 out of 6	1.43	0.98	209.23	1.97
Qajar	423.68	4275	3 out of 6	1.35	0.61	222.11	2.05
Pahlavi	258.47	3144	2 out of 5	0.92	0.33	343.28	2.42

Various specifications were considered to select the statistical society of samples constructed over the last 30 years, including the northern or southern side of the building, types of semi-open spaces, types of open spaces, having a courtyard, being apartment or villa structure of the building, form variety of micro-spaces and their spatial connections, diversity in the number of floors, some cases with design limitations, some samples with diverse maps or in form of model and samples with new ideas in the context of open and semi-open spaces.

Since the research area was Isfahan City and the

subject concerned semi-open spaces, the visual quality of these spaces also may depend on the historical and natural background of the city, which was taken as one of the factors affecting the design of housing and 30 buildings constructed over last 30 years were finally selected. In the second step, 14 cases were selected based on the following factors: unidentical samples of apartment and villa structure, samples with semi-open spaces in terms of function, dimensions, proportion, depth, variety of floors, and diversity in plans (Table 3).

Table 3. The Mean Value of Depthmap Software Output and Space Syntax Extension for Modern Cases

Terrace							
Period	Isovist Area	Connectivity	Depth	Integration	Control	Choice	Entropy
Modern-Last 30 Years	28.33	185.78	3 out of 4	0.65	0.54	41.74	2.3

Table 4 presents the picture and architectural plan of one house of each historical period.

Table 4. Picture Introduction of one House of each Period

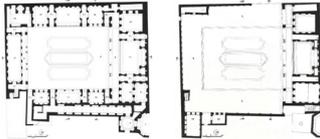
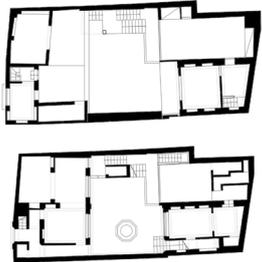
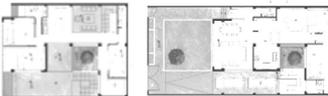
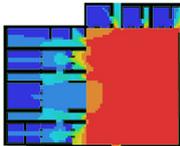
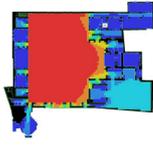
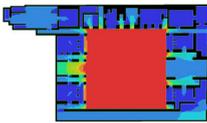
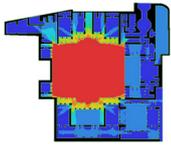
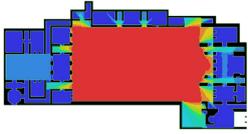
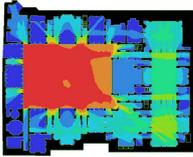
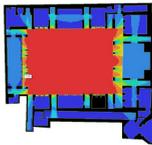
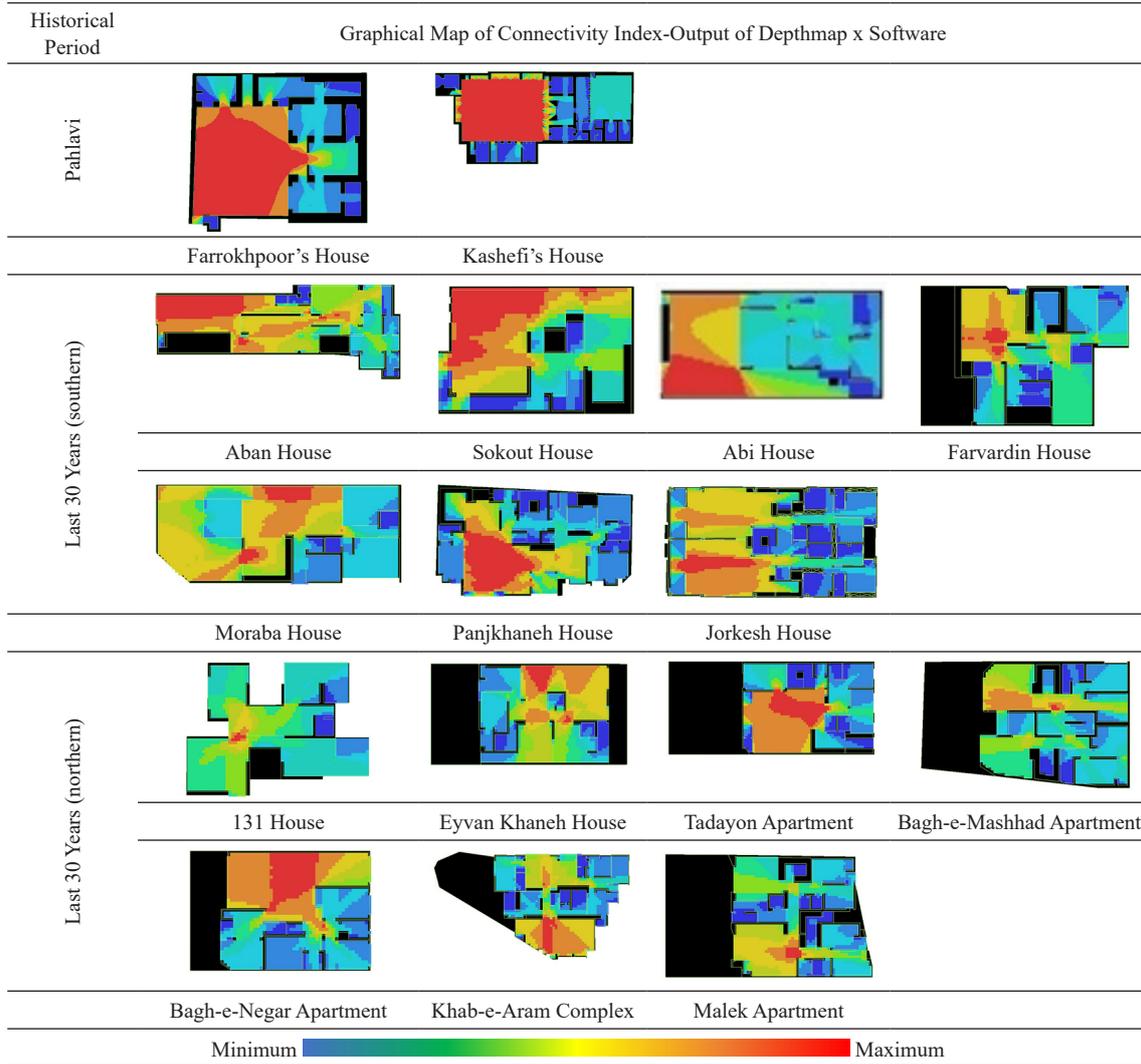
Row	Period	Name	Plan	Pictures
1	Safavid	House of Mosavvar Al Molki		 (Haji Ghasemi, tahbaz, and Moosavi Rozati 2015)
2	Qajar	Alam's House		 (Haji Ghasemi, tahbaz, and Moosavi Rozati 2015)
3	Pahlavi	Beheshti House		 (Database of Isfahan Cultural Heritage Organization) (www.mashregnews.ir)
4	Modern	Abi's House		 (www.caoi.ir) (www.caoi.ir)

Table 5 indicates the analysis map of the connectivity of houses, which is one of the major indicators of syntax space theory.

Table 5. Graphical Map of Connectivity Index-Output of Depthmap x Software

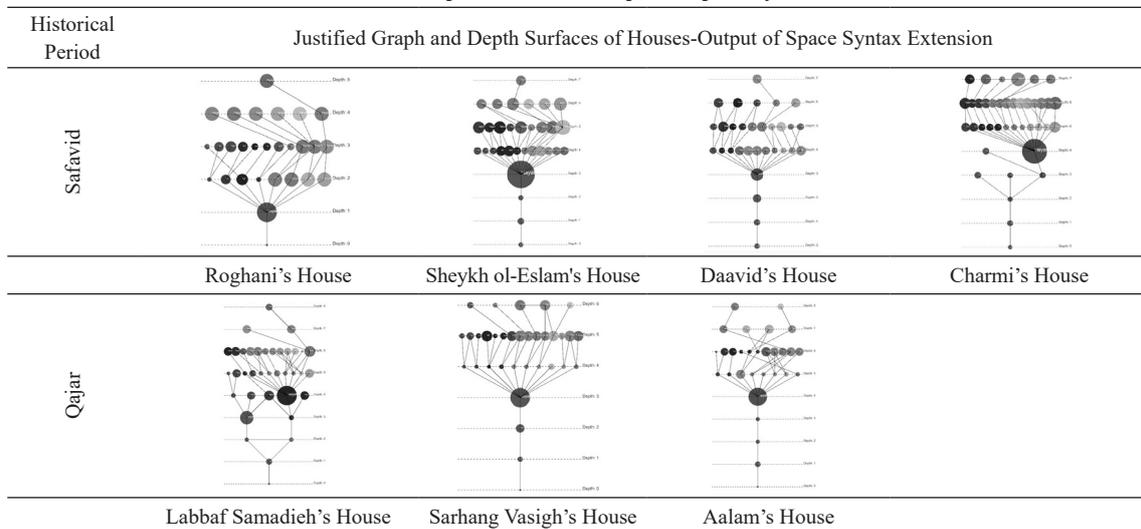
Historical Period	Graphical Map of Connectivity Index-Output of Depthmap x Software			
Safavid				
Qajar				
	Labbaf Samadieh's House	Sarhang Vasigh's House	Aalam's House	



According to the justified graph shown in Table 6, spatial organization's complexity and spatial multiplicity have been reduced during the studied

periods. Moreover, depth levels have been decreased and accessibility to spaces has been increased from Safavid to the modern period.

Table 6. Justified Graphs of Houses-Output of Space Syntax Extension



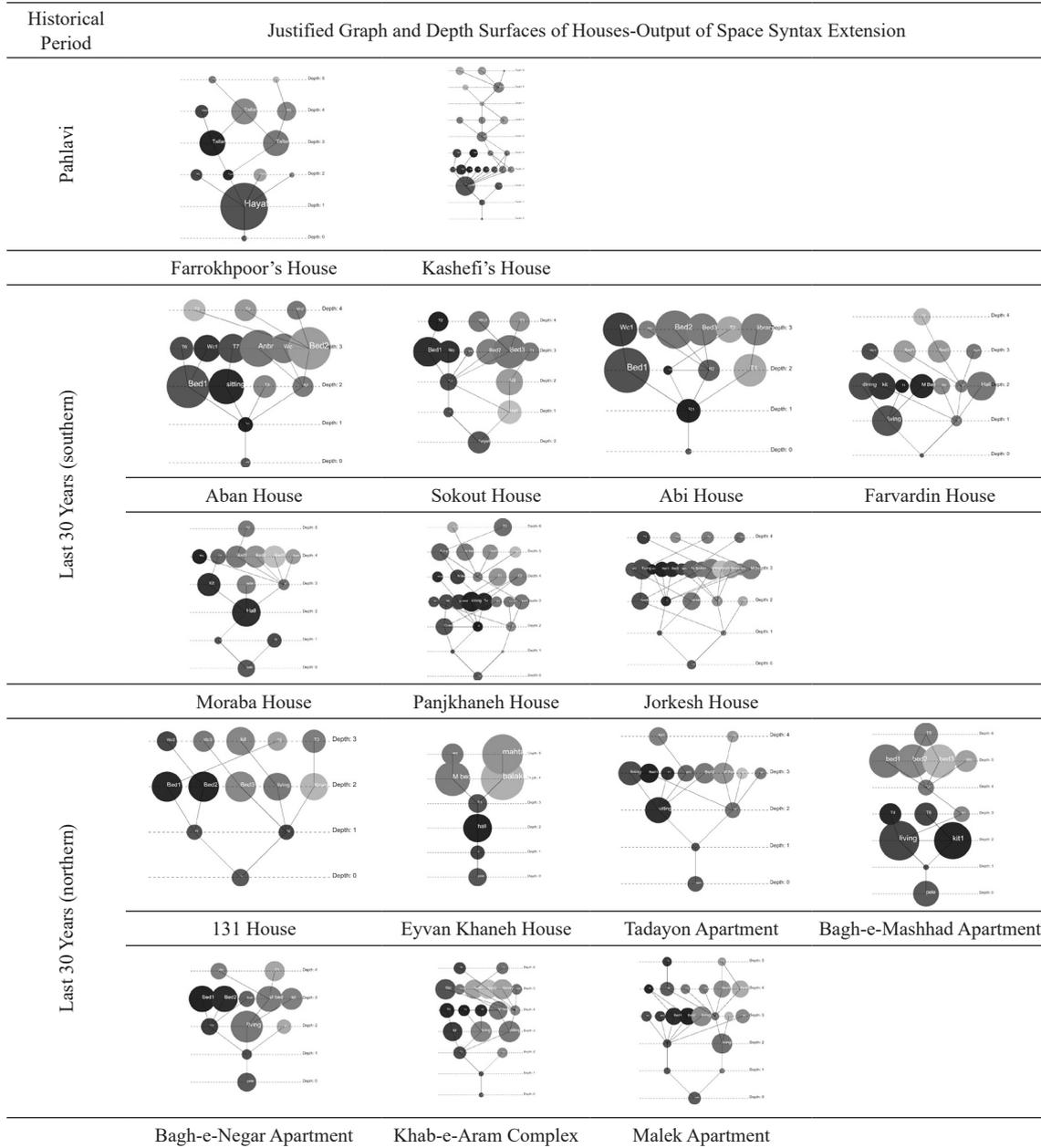


Table 7 reports the range of changes in each index during traditional and modern periods based on the outputs of Depthmap Software and Space Syntax

Plugin, which indicate the dramatic decline in most of the indicators.

Table 7. Comparison between Intervals of Different Indicators for Traditional and Modern Semi-Open Spaces

Comparison between Intervals of Indicators		
Terrace (Modern)	Porch (Traditional)	Index
3-80	150-690	Isovist Area
45-670	1270-7500	Connectivity
0.45-1.15	0.65-1.75	Integration
0.2-1.3	0.7-3.75	Control
20-100	90-860	Choice
1.6-3.30	1.7-2.75	Entropy

4. DATA ANALYSIS

This part of the study analyses the areas and software data of syntax indicators:

4.1. Accessibility of Semi-Open Spaces and Determining the Type of their Areas

Because the type of accessibility to semi-open spaces can determine whether the area is public, private, semi-private, or semi-public, this section analyzed the semi-open spaces based on their accessibility.

Table 9. Total Percentage of the Porch

	Area	Number (N)	%
Porch	Public	14	46.6
	Private	7	23.3
	Semi-Private	7	23.3
	Semi-Public	2	6.66
	Sum	30	100

According to tables 8 and 9, it is concluded that reduced accessibility to terraces that can make a connection with different spaces in a public area while having more optimum indicators such as integration, control, and choice leads to higher functional efficiency of terrace in that area- is one of the important factors that reduced the functional efficiency of semi-open spaces in samples of the last 30 years. As shown in these tables, although terraces and balconies in modern houses have public and semi-public roles, porches had private and semi-private roles with a minor difference. This points to inattention to semi-open spaces specifically for private areas in modern cases, which is an ascending process.

4.2. Analysis of Syntax Indicators of Semi-Open Space and their Effect on the Functional Efficiency

This part of the study analyses all syntax indicators related to semi-open spaces and their effects on the functional efficiency of houses constructed in mentioned periods.

4.2.1. Integration

in traditional samples, in addition to the courtyard that can be used as a semi-open space for gathering together and even as a distributor space and loop between other spaces, it can contribute to the improvement of functional efficiency of the open space. Therefore, it is required to have a high integration with adjacent spaces, including the courtyard. According to the descending trend of the integration over time, spatial organization's variations have changed from complexity in the plan of space components integration in the Safavid period to considerable reduction in this complexity in the

Table 8. Total Percent of Terrace

	Area	Number (N)	%
Terrace	Public	24	34.3
	Private	18	25.7
	Semi-Private	15	21.4
	Semi-Public	13	18.65
	Sum	70	100

modern period. Therefore, it is required to increase integration and prevent segregation between semi-open spaces (Fig. 7).

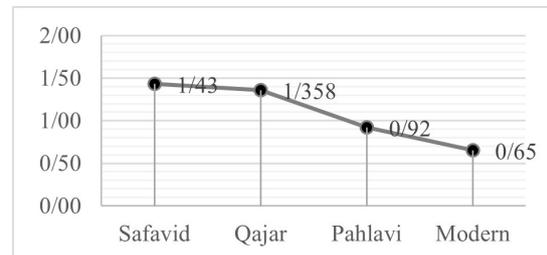


Fig. 7. Velocities in Integration of Semi-Open Space During Periods

4.2.2. Connectivity

semi-open spaces in the house can be more applicable if they play the role of a loop between other spaces leading to higher functional efficiency. If semi-open space is limited to connectivity with closed spaces, the quality of semi-open space is not reduced but also converts the semi-open space to a semi-private or private space. Velocities of the connectivity were increased from Safavid to Qajar and then became descending. In the modern period, semi-open spaces have less connectivity with adjacent spaces. If the terrace is located in a public area, functional efficiency will be reduced and vice versa it increases efficiency in the private area. However, the accessibilities of the modern period indicate the high number of public terraces in this period. Therefore, reduced connectivity leads to lower efficiency of the house (Fig. 8).

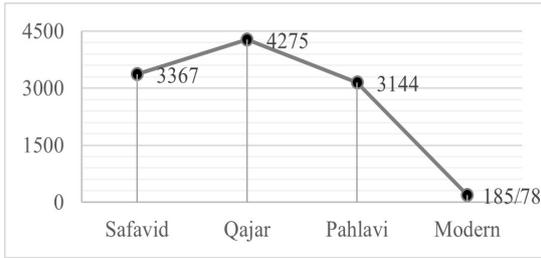


Fig. 8. Velocities in Connectivity of Semi-Open Space During Periods

4.2.3. Choice

semi-open spaces had a distributive role in the past, and it can be stated that the choice had a positive effect on the function of the courtyard, so it increased spatial quality in traditional samples. However, private or public-level semi-open spaces have affected the choice in modern samples. In the case of choice, semi-open spaces had ascending and descending trends in Pahlavi and Modern periods, respectively. This index points to the centrality of space among a set of spaces indicating that porches had higher and more distribute roles, centrality, and collectability features in traditional houses, while they have had a descending trend during the modern period. An accurate combination of semi-open and closed spaces is indeed a factor that increases the positive function of semi-open spaces among other components (Fig. 9).

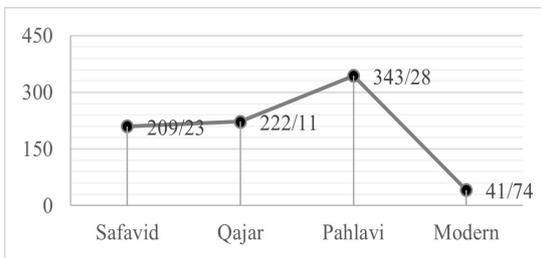


Fig. 9. Velocities in Choice of Semi-Open Space During Periods

4.2.4. Depth

increased depth in semi-open spaces leads to lower accessibility to, the sociability of, and permeability into space. Nevertheless, the spaces of the private area will have better functional efficiency in case of increased depth. Proper depth in semi-open spaces is determined based on the area that considered space belonged to it. Semi-open spaces can play their role in increasing the efficiency of the house in any depth if they are located in the right areas during the studied periods. In general, depth level was considered in this study relative to the entrance, which this area is located at the lowest depth relative to the entrance

regarding the hierarchy of accessibility to semi-open spaces that includes "open, semi-open, and closed" space in a traditional sample. In the modern period, the hierarchy or order of accessibility to semi-open space has changed to "open, closed, semi-open" and semi-open space has located in deeper depth relative to the entrance gate.

4.2.5. Control

all-round porches seen in traditional samples have provided a suitable view to semi-open spaces by accessibility through various spaces, and since this space is strongly connected to open space, it has improved the visibility status of the courtyard and increased its security.

Velocities in the mean value of Control were descending and ascending during Pahlavi and modern periods, respectively. In the Pahlavi period, protruding porches and porches without backward space compared to other houses led to descending trend of control. In modern samples, this index obtained different rates regarding the space's status (being public or private) and the need for high or low visual control. Since lower control in the private area is more favorable and vice versa, the velocities indicate an ascending trend of this index during the modern period, and the high number of public terraces in the modern period indicates that this index is only appropriate for public terraces (Fig. 10).

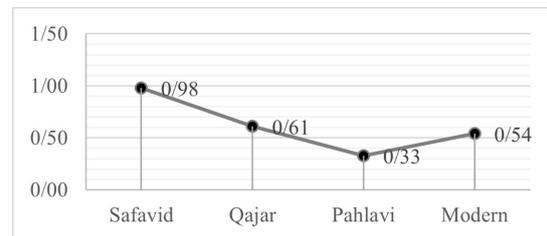


Fig. 10. Velocities in Control of Semi-Open Space During Periods

4.2.6. Isovist

Isovist area may decrease the privacy of adjacent spaces of semi-open area, which occur by affecting the status (being private or semi-private, and or semi-public) of spaces that have under the visual influence of semi-space. Variations in this index are similar to changes that occurred in Connectivity; it means that this index increased at first and then became descending after the Qajar period. Notably, weaker connectivity of modern terraces with their adjacent spaces has reduced this index. On the other hand, the reduced functional efficiency of the semi-open area in modern samples has rooted in limited Isovist areas of semi-open spaces in the public area (in addition to public terraces) (Fig. 11).

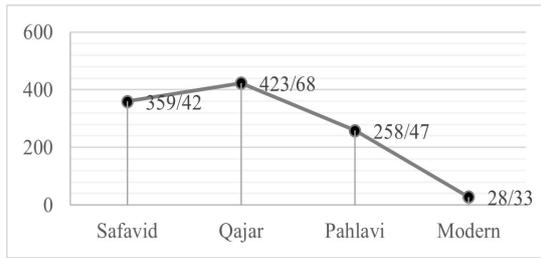


Fig. 11. Velocities in Isovist Area of Semi-Open Space During Periods

4.2.7. Entropy

in semi-open space, higher entropy and more accessibility occur in the samples with various accesses to semi-open space. Hence, traditional samples of semi-open spaces have lower entropy and accessibility to semi-open spaces compared to modern semi-open spaces due to deeper depth levels and space multiplicity. This index has had ascending trend over time and has had a minor reduction in the modern period but this index is higher in the modern period compared to the traditional era. Because entropy measures the accessibility of all spaces, it is reduced in traditional houses due to space multiplicity but increased during other periods due to simpler spatial organization of housing, which led to increased functional efficiency of public areas, and should be controlled in the private area (Fig. 12).

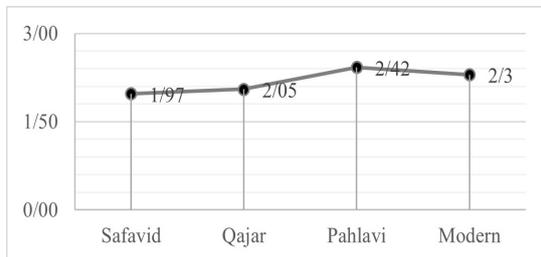


Fig. 12. Velocities in Entropy of Semi-Open Space During Periods

5. CONCLUSION

Because the main problem of this study is the inappropriateness of current semi-open spaces in modern residential houses in terms of spatial organization and design, its direct effect on the functional efficiency of the house is not clear. Hence, this study measured the quantitative indicators related to semi-open spaces and functional efficiency then compared the data of traditional and modern houses and examined spatial structure. According to obtained results, it is concluded that the indicators have been developed from Safavid to Qajar, while these indicators (except for Control) have declined from Pahlavi to the modern period, and finally have led to a decrease in functional efficiency of housing

in the general spatial organization during the modern period.

In general, it can be stated that some design techniques used in houses located in Isfahan during the Qajar period have been inspired by the Safavid period, which are developed in the architecture of the Qajar period. The main changes of the Safavid era can be seen in the construction of a porch as a semi-open space in houses of this period. The construction of the porch in the Safavid period had a positive effect on the climate and provided a solution for visual continuity, spatial openness, the creation of lightness in the building, and dynamism. This model has been created in some houses of the Safavid period only in some parts of the buildings. In the house of the Qajar period, this model has been used in a modern form compared to previous eras through all-round porches used in the Qajar period, which connected the semi-open area to adjacent open and closed spaces and increased Isovist area of this area to other spaces. Moreover, the centrality of this area in creating a connection between other spaces will increase the number of times people pass through the spaces. In general, the porch received less attention during the Pahlavi period, and a considerable reduction can be seen in the Isovist area compared to the previous period, which was rooted in the undesired organization of the area. During the modern period, the Isovist area has reached its minimum level due to some factors, such as limited accessibilities of the terrace, using the terrace as a specific space, smaller area of the house, reduction in the depth of semi-open spaces, and reduced dimensions of the terrace.

It should be noted that plan complexity has been reduced in the Qajar period compared to the Safavid era, and simpler space organization and fewer spaces have led to lower integration of semi-open spaces with adjacent spaces and lower control over this area. Some factors have led to descending trend of integration and control indicators during the Pahlavi and modern periods: the form of closed spaces, limited connection with open space, semi-open space limited to a space, and smaller size of porch and terrace. There has been an increase in accessibility to semi-open spaces and choice of this area during this period, and indeed the ascending trend from Safavid to the Qajar period has occurred owing to simpler space organization and lower spatial multiplicity. Spatial multiplicity also has reduced more in the Pahlavi period when spaces were directly integrated with semi-open spaces, which affected the accessibility to it. Semi-open private and public spaces are seen in the modern period that accessibility to them has not been limited by other spaces, which is favorable for public terraces but not for private ones.

Ultimately, it can be stated that semi-open spaces, during Safavid to Qajar period, had ascending trends, regarding Choice, Isovist area, Entropy, and Connectivity, which led to increased functional

efficiency of houses constructed in this period. The following factors led to this ascending trend: form evolution and changes, accessibility multiplicity, the hierarchy of access to the semi-open area, internal connectivity between rooms and with porch, sequence, and connection of spaces adjacent to each other, and space articulation. The number of descending indicators was increased from Qajar to Pahlavi, and only Choice (due to the distributive role of protruding porches) and Entropy (due to simpler spatial

organization) were increased in the Pahlavi era. From Pahlavi to the modern period, however, some factors (change and reduction in the size of semi-open spaces, lack of favorable organization of this area in addition to other spaces, lower accessibilities, construction in the floor, and lower connectivity of semi-open spaces to courtyard directly) led to descending trend of Connectivity, Integration, Isovist area, and Control, which led to a reduction in functional efficiency of houses during these periods.

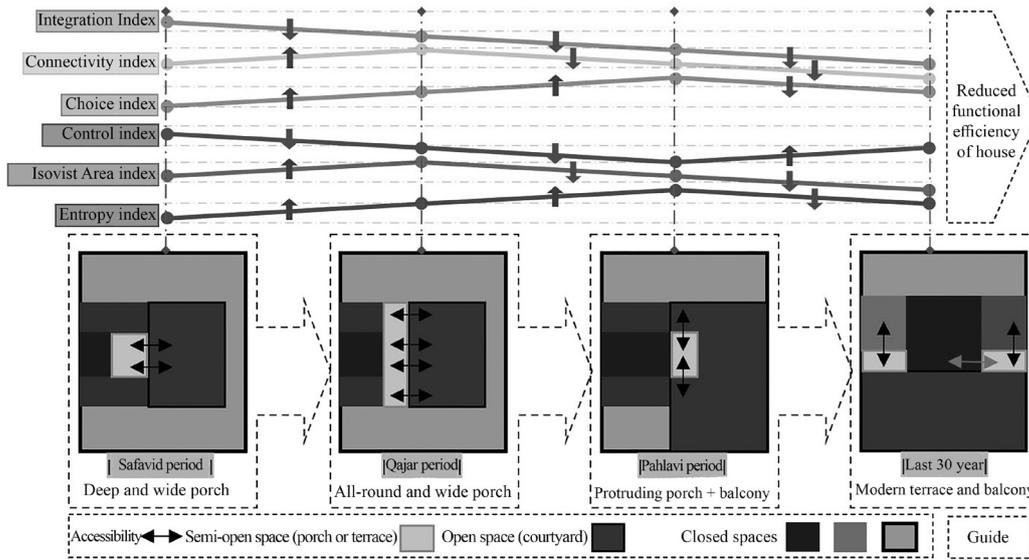


Fig. 13. Change Trend of Form and Semi-Open Space in Plan of each Period and Changes in Space Syntax Indicators

According to illustrated diagram (Fig. 13) and mentioned points, the research hypothesis was confirmed for some indicators, and rejected for other indicators. The considerable result, however, is that descending trend of indicators (except for Control)

from Pahlavi to the modern period indicates the reduction in the quality of semi-open spaces in the modern period, and even an increased Control during the modern period has decreased the quality of private terraces.

REFERENCES

- Abbaszadegan, Mostafa. 2002. Space syntax method in the urban design process with a look to Yazd City. *Journal of Urban Management* 9: 64-75. <https://www.magiran.com/paper/885376> [in Persian]
- Daneshgar Moghaddam, Golrokh, and Marmar Eslampour. 2012. Study of the affordance theory based on Gibson's point of view and its effects on studies of the human-built environment. *Journal of Kermanshah Architecture and Urban Planning* 5(9): 73-86. <https://www.noormags.ir/view/fa/articlepage/1404157/> [in Persian]
- Dehkhoda, Ali Akbar. 1963. *Dehkhoda Dictionary*. Tehran: Tehran University Press. [in Persian]
- Gholami, Mina, and Massomeh Hedayati. 2018. Recognizing principles of applying space syntax theory in the analysis of spatial relations of residential buildings. *Third International Conference of Civil Engineering, Architecture, and Urban Design, Tabriz*. <https://civilica.com/doc/806361/> [in Persian]
- Gibson, James Jerome. 1986. *An Ecological Approach to Visual Perception*. Erlbaum. Mahwah.
- Haji Ghasemi, Kambiz, Mansoureh Tahbaz, and Maryam Dokht Moosavi Rozati. 2015. *Encyclopaedia of Islamic architectural works of Iran (Houses of Isfahan)*. Translated by Clod Karbasi. Tehran: Cultural Heritage Organization Press. [in Persian]
- Hanson, Julienne. 2003. *Decoding of Homes and Houses*. 1st Edn. Cambridge: Cambridge University Press. <https://www.cambridge.org/core/books/decoding-homes-and-houses/D39E8B993595D6A08C5A9DF3E53C4E33>
- Hillier, Bill. 2007. *Space is the Machine: A Configurational Theory of Architecture*. London: Space Syntax Laboratory. <https://spaceisthemachine.com/>
- Kalantari, Saiedeh, Ahmad Ekhlesi, Ali Andaji Garmarudi, and Arman Khalil Beigi Khameneh. 2017. Analysis of the Relationship between Spatial Structure and Motion Behaviors of Users Using Space Syntax (A Case Study of the Central Pardis of Tehran University). *Environmental Based Territorial Planning* 11(29): 215-234. <https://www.sid.ir/paper/130634/fa> [in Persian]
- Kiaee, Maryam, Yaghoob Peyvašteghar, and Ali Akbar Heidari. 2017. Eyvan basic position to improve operational efficiency in mosques. *Journal of Researches in Islamic Architecture* 5(14): 68-83. <https://www.sid.ir/paper/248383/fa> [in Persian]
- Klarqvist, Bjorn. 1993. *A Space Syntax Glossary*. Vol2. Nordisk Arkitekturforskning. <http://arkitekturforskning.net/article/view/778>
- Manum, Bendik. 2009. A-graph complementary software for axial_lineAnalysis in proceeding soft. Sweden. Stockholm. *The 7th International Space Syntax Symposium*, 1-9. <https://www.semanticscholar.org/paper/AGRAPH-Complementary-Software-for-Axial-Line/c2d9dad964398e96c87550ee52bc11836fc303ae>
- Memarian, Gholamhossein. 2002. Space syntax in architecture. *Journal of Soffeh* 35: 74-83. https://soffeh.sbu.ac.ir/article_99829.html [in Persian]
- Memarian, Gholamhossein. 2005. *Review of theoretical foundations of architecture*. Tehran: Soroush-e-Danesh Press. [in Persian]
- Mollazadeh, Abbas, Vahid Barani Pesyan, and Mohammad Khosrowzadeh. 2012. The application of the space syntax of the Valiasr St Basht city. *Journal of Urban and Rural Management* 29: 81-90. <https://www.sid.ir/paper/92238/fa> [in Persian]
- Mustafa, Faris Ali, Ahmad Sanusi Hasan, and Salahaddin Yasin Bape. 2010. Using Space Syntax Analysis in Detecting Privacy. *Asian Social Science* 6(8): 157-166. https://www.researchgate.net/publication/45266213_Using_space_syntax_analysis_in_detecting_privacy_a_comparative_study_of_traditional_and_modern_house_layouts_in_Erbil_city_Iraq
- Nooraddin, Hoshair. 1996. Al Fina' A study of "in-between" spaces along streets as an urban concept in Islamic cities of the middle east with a case study in Cairo. Norway. Trondheim. Department of Town and Regional planning. Faculty of Architecture. DOI: [10.5539/ass.v6n8p157](https://doi.org/10.5539/ass.v6n8p157)
- Oxford Dictionary of English. 2010. Oxford University.
- Peyvašteghar, Yaghoob, Ali Akbar Heidari, Maryam Kiaee, and Mahdokht Kiaee. 2016. Wayfinding process analysis using space syntax in The museum of contemporary art. *Journal of HOVIATESHAHR* 11(30): 45-58. <https://www.sid.ir/paper/154528/fa> [in Persian]
- Rahmani, Elaheh, Somayeh Noorae, and Zahra Sadat Shekar Foroosh. 2011. The developmental process of filled and empty patterns in Iranian contemporary houses. *Journal of Abadi* 70: 62-67. [in Persian]
- Reversion, Francisco olmos. 2009. Developing Partial Configuration Abilities Coupled with the Space Syntax Theory for First Year Architectural Studies. Sweden. Stockholm. In *Proceedings of the 7th International Space Syntax Symposium*, 1-10. <https://www.semanticscholar.org/paper/Developing-Spatial-Configuration-Abilities-Coupled-Reveron/c09d9071517b60b22722038b69742f558d9accb0>
- Rismanchian, Omid, and Simon Bell. 2011. A study over spatial segregation of deprived areas in the spatial structure of Tehran by using space syntax method. *Journal of Bagh-e-Nazar* 8(17): 69-80. <https://www.sid.ir/>

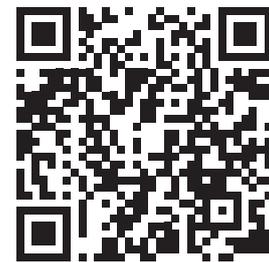
- [paper/125560/fa](#) [in Persian]
- www.archilovers.com
 - www.karnaval.ir
 - www.mashreghnews.ir
 - www.caoi.ir
 - Yazdanfar, Abbas, Mahnaz Moosavi, and Hanieh Zargar Daghigh. 2009. Analysis of the spatial structure of Tabriz in the area of Baroo using the space syntax technique. *Housing, International Journal of Road and Building* 9: 58-69. <https://mitradesign.ir/post/215/> [in Persian]
 - Zarkesh, Afsaneh. 2011. Concept of semi-open space in architecture. *Journal of Ketab Mah-e-Honar* 155: 92-101. <https://www.magiran.com/paper/880846> [in Persian]

HOW TO CITE THIS ARTICLE

Yakhchali, Safoura, Neda Sadat Sahragard Monfared, and Seyyed Abbas Yazdanfar. 2023. Investigating Variations in Space Syntax Indicators for Semi-Open Spaces and their Effect on the Functional Efficiency of Housing (Traditional and Modern Houses of Isfahan, Iran). *Armanshahr Architecture & Urban Development Journal* 15(41): 181-195.

DOI: 10.22034/AAUD.2021.285033.2479

URL: http://www.armanshahrjournal.com/article_168910.html



COPYRIGHTS

Copyright for this article is retained by the author(s), with publication rights granted to the Armanshahr Architecture & Urban Development Journal. This is an open- access article distributed under the terms and conditions of the Creative Commons Attribution License.

<http://creativecommons.org/licenses/by/4.0/>



