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Feasibility Study of Developing Space Syntax Components in the Analysis of Traditional Houses*

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ABSTRACT

Iranian traditional houses have unique features that are not easy to discover only by examining architectural information such as plan, etc. To facilitate the spatial analysis of the house, there is a need for a tool to translate the space into a simple and understandable language. The space syntax method is one of the techniques making it possible to analyze the spatial structures of the environment. This method is based on the use of a tool called justified graphs that explain the relationships between spaces using concepts such as depth, integration, choice, difference factor, and control. However, some spatial features cannot be assessed with the data extracted from these graphs and there is a need to use some other indicators in this field, some of which are "space area", "geographical location" and "the distance between spaces". Therefore, in the present study, considering the claim that analyzing the spatial structure of the environment using graph tools has defects, other indicators, in addition to the space syntax method, are applied in order to provide a more comprehensive analysis and increase the validity of the results from the study of the environment. The research results indicate that in some cases, despite considering the effects of spaces in drawing justified graphs, there is no required delicacy in establishing the necessary distinction between various types of space in these graphs and as a result, the resulting analyses are not very accurate. Also, in other cases, a number of features of the building cannot be generally examined by justified graphs, although they are of the main features of the building and distinguish different buildings in terms of the quality of space.

Keywords: Space Syntax, Syntactic Components, Non-Syntactic Components, Traditional Houses.

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1. INTRODUCTION

Each of the space syntax components has unique features, thereby having a distinct place in the analysis of an architectural structure or urban area so that sometimes, even the most complicated patterns can be recognized with these components and their basic functions (Hillier, Leaman, Stansall, & Bedford, 1976, p. 147). From the results obtained from the study of these components, different analyses can be presented, and consequently, the different characteristics of an environment can be found (Bahrainy & Taghabon, 2013, pp. 8-10). However, analyzing the physical structure of the environment in order to discover its socio-cultural characteristics using the space syntax method has some limitations which usually lead to relative results. That is in the literature on space syntax, the spatial structures of the environment are usually analyzed considering the indicators such as "depth", "integration", "choice", "control" and "difference factor", while parameters such as "space area", "the distance between spaces" and "geographical location of spaces" have not been more considered in this method. For example, in drawing justified graphs as the most important tool used in the space syntax method, each space is represented by a circle and each integration by a line. However, neither circles indicate the space area, nor lines explain the distances between spaces. Moreover, the position of spaces in the structure of the house regarding geographical directions cannot be found in these graphs. Therefore, these indicators seem to play a decisive role in forming the spatial organization of the architectural environment, especially residential spaces. Accordingly, the present study aims to introduce three indicators of "area", "distance" and "geographical location" in the analysis of the spatial structure of the building in order to enhance the validity of the results from the analysis of the spatial structure of an architectural environment. Therefore, the main question of the present study is as follows:

• How can non-syntactic indicators be used in space syntax analyses to achieve more accurate results?

Accordingly, the research hypothesis can be explained as follows:

• Since in the space syntax method, syntactic indicators seem to have no ability to comprehensively analyze an environment, it is necessary to develop space assessment components in order to enhance the validity of the resulting analysis, and this is effective in obtaining results.

2. LITERATURE REVIEW

The term "space syntax" refers to the spatial configuration analysis, which was conceived by a group of architects at the Bartlett School of Architecture and Design at University College London (UCL), with the aim of studying and finding hidden patterns governing spatial forms in indigenous settlements (Hillier, 2007, p. 152). By studying the spatial configuration and the existing spatial discipline among their components, this theory achieves how it interacts with social structures and its users' behaviors and activities. The general idea in this theory is "to make it possible to decompose space into its constituent elements, to analyze it as a network of choices, and to represent it in the form of a map and graph expressing the integration and coherence of these spaces." Here, arranging spaces together means the internal relations between spaces that are used by the consumer. Therefore, by recognizing spatial relationships, the social relations between space users can be understood (Memarian, 1998). In this method, the structure of space is analyzed using two tools including justified graphs and software.

One of the tools used for analyzing the structure of space using the space syntax method is justified graphs, which are formed based on the theory of graphs. Using this tool, the structure of an environment is drawn in the form of a graph in which each circle represents one space and each line represents the relationship between different spaces. Using these graphs, the structure and location of the various plan components are represented very simply and legibly (Brown & Bellal, 2003). Also, another advantage of these graphs is that they make it possible to display relational features within the plan. Due to this important feature, they are applied in testing the internal or general circulation of any space.

Another tool used to analyze the spatial configuration is the Depthmap software, which was developed by Turner and colleagues at the London Academy of Sciences. The software enables researchers to much more accurately analyze space on all micro and macro scales with many more indicators compared to justified graphs. Provided macro (Turner & Pinelo, 2010; Turner, 2007).

The review of literature on space syntax indicates that each of the introduced tools analyzes the structure of spatial configuration using a set of indicators that can be analyzed by that tool. These indicators, which are called syntactic indicators, include depth, integration, choice, control, difference factor, so on, as introduced in detail below. However, studies indicate that there are other indicators influencing the importance of space and its usability, despite not being analyzable by existing tools affect (Bahrainy & Taghabon, 2013, pp. 8-10). These indicators are introduced as non-syntactic indicators in this research and similar studies. One of the most important studies in this field is Nourian et al.'s (2013) research. In their study, by acknowledging such a defect in syntactic tools in relation to the analysis of the spatial structure of a configuration, they introduced an approach to develop this method in analyzing indicators such as the space area, location of various spaces in relation to geographical directions. The results were graphs in which the area of spaces and their positions in relation to geographical

directions were determined (Nourian, Rezvani, & Sariyildiz, 2013). Of course, it should be noted that in this research, the focus of the research is on the design process and the authors attempted to provide more suitable options for designing a plan and in this regard, tools such as Grasshopper software and the like were used. However, in the present study, it is also attempted to develop this method in analyzing the spatial structure of an existing building and this distinguishes it from similar research. According to what abovementioned, syntactic, and non-syntactic indicators used in this study are introduced in the following.

2.1. Syntactic Indicators[1]

In order to explain the space syntax method, it is required to describe its characteristics. This theory is defined by its quantitative and qualitative tools, each of which has its own role in analyzing the configuration of space, as described below.

2.1.1. Depth

The depth indicator is one of the concepts studied in the space syntax method. Using this indicator, the degree of privacy or publicity of each space as well as the amount of desertedness in different types of spaces and their limits, especially in spaces such as traditional houses - where the issue of privacy and communality has a special place - can be examined (Penn, 2001, p. 32). (The greater the depth of space, the greater the amount of space desertedness). In fact, given that the justified graphs determine the depth of spaces, the use of space can be predicted to a large extent (Hillier, 2007, p. 226).

2.1.2. Connectivity (Integration)

This indicator refers to the number of connections between different spaces. From this indicator, the concept of integration can be extracted. This concept determines the rate of passage through space, meaning that according to the definitions of space syntax, the higher the degree of integration (ways to access the building), the greater the likelihood of using space (Hillier, 2007, p. 04). Of course, this amount of use also depends on metric analyses, which cannot be examined by justified graphs[2] (Hillier, 2001, 02: p.24).

2.1.3. Choice

The choice indicator refers to the number of paths that have different values for the user[3] and have different positions in relation to his/her desired destination. As a result, the user will probably choose the shortest path to reach his destination (if familiar with the route) (Charalambous, 2012, p. 58). In fact, space has a great number of selected paths when a large number of the shortest connecting paths pass through it (high spatial value due to high integration with space) (Klarqvist, 1993, p. 12; Charalambous, 2012, p. 58).

2.1.4. Control

The control of each space can be determined by the number of spaces connected to it through connecting paths (Manum, Rusten, & Benze, 2005, p. 97: 2). The fewer frequency of choice a point has than a given point, the less control there is over it (Jiang, 2002, p. 298). As a result, that part of the space can be more spatially separated than other parts.

2.1.5. Difference Factor

The difference factor of space is determined by using the degree or amount of integration of each space compared to other spaces. The degree of integration (number of connections) of space is the relative depth of space in relation to other spaces in a spatial structure, according to justified graphs, and refers to the degree of permeability (in value) in the configuration (Mostafa & Hassan, 2013, p. 452). Studies show that the degree of integration greatly predicts the amount of use of space (lower integration space has less likely it is used). The degree of inequality between integration values indicates the degree of cultural significance established in the integration or separation, meaning that higher inequality (lower values) indicates maximum integration and lower inequality (higher values) indicates maximum separation (Hillier, Hanson, & Graham, 1986, p. 365). In the following equation, the difference factor is examined:

$$H = -\sum \left[\frac{a}{t} \ln \left(\frac{a}{t}\right)\right] + \left[\frac{b}{t} \ln \left(\frac{b}{t}\right)\right] + \left[\frac{c}{t} \ln \left(\frac{c}{t}\right)\right] + \cdots \quad (1)$$

Where, H denotes the relative difference factor for spaces a, b, c, etc., a, b, c, etc. refer to the number of connections related to each of the spaces a, b, c, etc., and t denotes the sum of all the connections of the desired spaces, which is calculated as follows:

$$t = \Sigma (a + b + c) \quad (2)$$

2.2. Non-Syntactic Indicators

In order to scrutinize the results, those items not directly explained by syntactic indicators are discussed below. These indicators include area, distance, and geographical location.

2.2.1. Area

The area is one of the indicators that have no place in the current analysis of justified graphs while it is possible that, for example, two spaces with similar positions in the justified diagram and even the same use, have different positions in terms of internal cultural and social relations, due to their different dimensions (Memarian, 2010, p. 412) and as a result, are different in terms of "spatial value" (Turner, 2007, p. 24). However, nowadays, at the London Academy of Sciences and several other research centers, some studies are underway to add this indicator and some other features to justified graphs[4] (Nourian, Rezvani,

& Sariyildiz, 2013, p. 48 Hillier, 2007, p. 79) (Figure 1). Therefore, according to the mentioned points, in the present study, the area indicator is calculated separately and the results are examined in general in combination with the results from the study of syntactic indicators.

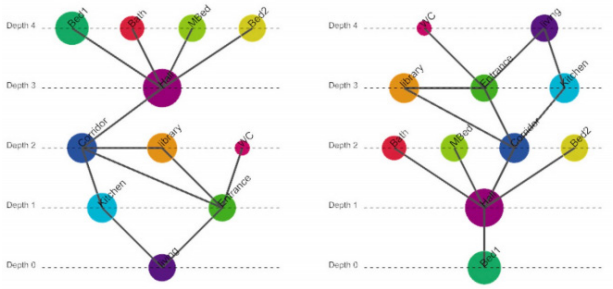


Fig. 1. An Example of Justified Graphs to which the Area Indicator is Added by Resizing the Circles in the Diagram

(Nourian, Rezvani, & Sariyildiz, 2013, 048: p.11)

2.2.2. Distance

Another limitation of justified graphs is that all spaces at the same depth are considered with the same position. While, if the aforementioned spaces are in different positions relative to the root space, they will have different values. In addition, the effective functional radius of any space also changes with distance, even if the spaces are at the same depth (Dalton, 2007, p. 89). For example, the deeper the depth of space, the higher the degree of privacy of space; However, among the spaces at the deepest depth relative to the root space, there is still a space with a higher level of privacy than other spaces of the same depth, and it has longer trip distance, i.e. the distance traveled from the entrance (Figure 2) (Stahle, Marcus, & Karlstrom, 2007, p. 39). In uses such as the house, those spaces with a shorter trip distance from the entrance space are usually known as public spaces, and other sections at deeper depth from the entrance space and with a higher level of privacy are considered private spaces of the house. Accordingly, in the present study, in the investigation of the case study, the entrance space is considered as the origin and the distance of other spaces from this part is measured and therefore, the criterion for measuring this indicator is the distance between the center of gravity of space and the building entrance.

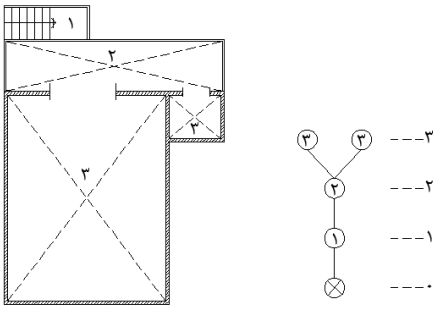


Fig. 2. The Justified Graph and Plan of a Part of a House

Considering that the two spaces 3 are in the same position in terms of depth and number of connections in the justified graph, if the center of gravity of spaces is considered the distance measurement criterion, it can be seen that these two spaces have different distances from the previous space.

2.2.3. Geographical Location

One of the factors affecting the type of spatial organization of an environment is the governing climatic conditions in that environment, meaning that this factor leads to the establishment of spaces on different sides of the building. However, in the space syntax method, justified graphs have no ability to separate or analyze the geographical location of spaces in the structure of the building. For example, the same justified graphs are likely plotted for a series of spaces that are climatically different from each other (Fig. 3). Of course, in various studies, it has been attempted to include the issue of geography in the analytical process of space syntax, which is still in its infancy according to the researchers (Fig. 4).

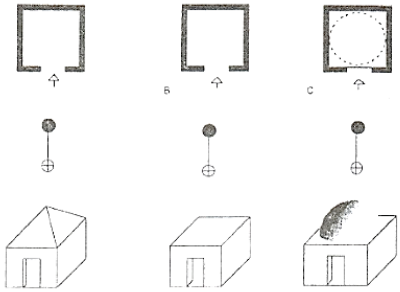


Fig. 3. Simple Example of the Similarity of Justified Graphs Plotted for Buildings Different from Each Other in the Type of Climate
(Memarian, 2010)

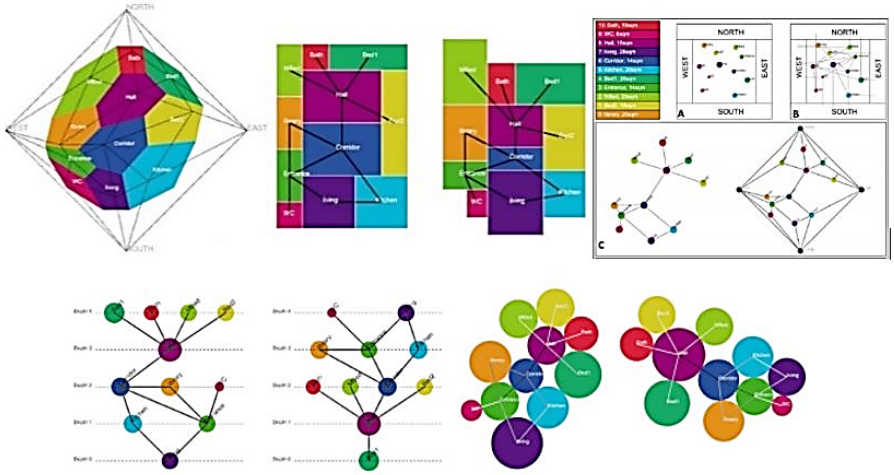


Fig. 4. Inclusion of Geographical Directions in the Process of Space Syntax in Order to Explain the Process of Space Design
(Nourian, Rezvani, & Sariyildiz, 2013, 048: p. 11)

3. METHOD

As mentioned earlier, in the present stud, it was attempted to analyze the three variables of "area of spaces", "metric distance between spaces" and "geographical location" as non-syntactic indicators, along with syntactic indicators, in the space syntax method to make it possible to analyze different spaces with different spatial characteristics in a spatial structure, in addition to the development of this method. Accordingly, after introducing all syntactic and non-syntactic indicators in the research literature, these indicators were evaluated in residential samples. These indicators were studied and analyzed in four traditional houses, two of which are located in Yazd and two in Isfahan. The samples are one-courtyard and two-yard houses and the reason for choosing these two cities is the difference between the houses in these two cities in terms of spatial structure. Despite the similarity between the studied houses in terms of syntactic structure, each of them had special and unique physical features, which led to the selection of them as the case studies of the present research (Table 1).

As discussed earlier, in order to evaluate the case studies, first, in the syntactic indicator section, indicators such as "depth", "integration", "choice", "control" and "difference factor" were analyzed using the graphs extracted from the houses studied, and then, in order to scrutinize the quality of the space syntax, in the non-syntactic indicator section, three indicators of "area", "distance" and "spatial location" were examined. In the syntactic indicators section, a qualitative method was used to assess the "depth", "integration", "choice" and "control" indicators, and a quantitative method for the "difference factor" indicator. In order to assess the indicators of "area", "distance" and "spatial location", both quantitative and qualitative methods were used in a combined manner (Fig. 5). To assess the syntactic and non-syntactic indicators, the data measurement tools were justified graphs and objective observations, respectively. The present study is descriptive-analytical research in which the data were collected using documents, library study, and the Internet.

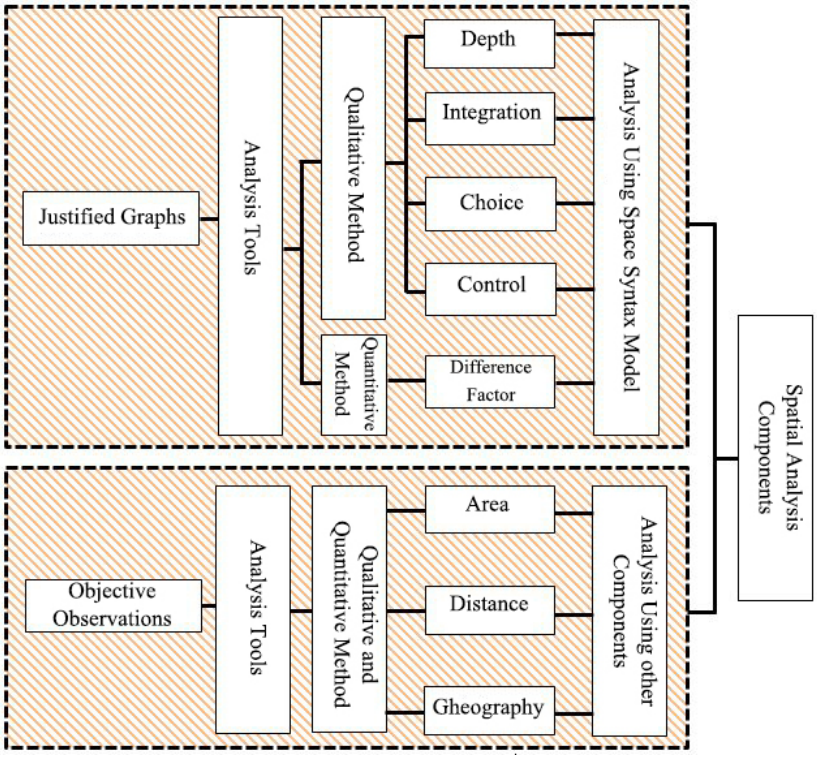


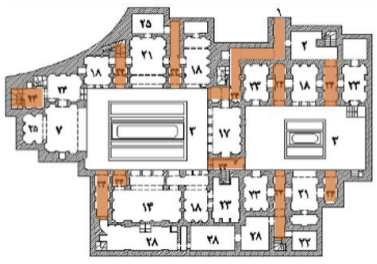
Fig. 5. Research Process

4. DISCUSSION AND DATA ANALYSIS

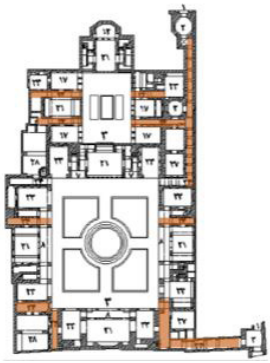
In order to test the feasibility of developing the studied components in the space syntax method, four houses in Yazd and Isfahan were examined. Two houses (Meshkatian House and Gerami House) in Yazd and two houses (Mosaver al-Maleki House, and Etekafzadeh and Sharif House)[5] in Isfahan were selected as case studies. After selecting the case studies, in the first step, the justified graph of each house was plotted considering the entrance space as the root space[6] and then, quantitative and qualitative analyses were extracted based on its syntactic indicators. In the second step, the analyses obtained from the investigation of "area", "distance" and "geographical directions" as well as the related tables were developed and finally, the total results were evaluated in the spatial-comparative analysis.

Table 1. The Plans of the Four Houses Studied

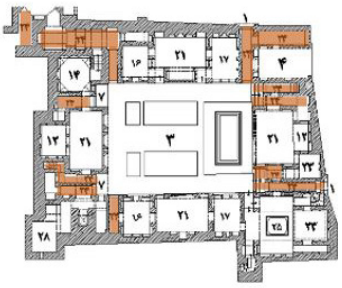
Meshkatian House (Yazd)
(Hajghasemi, 2004, p. 201)



Gerami House (Yazd)
(Hajghasemi, 2004, p. 220)

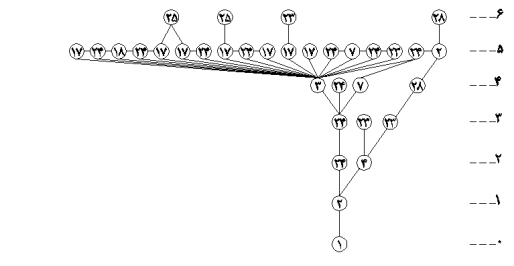


Mosaver al-Maleki House (Isfahan)
(Hajghasemi, 1998, p. 52)

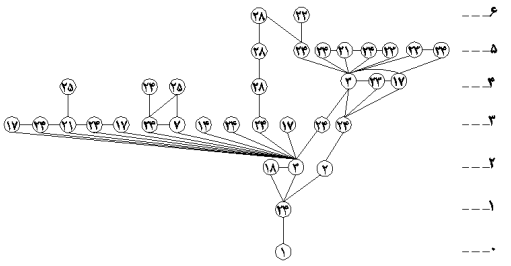


Etekafzadeh and Sharif House (Isfahan)
(Hajghasemi, 1998, p. 102)

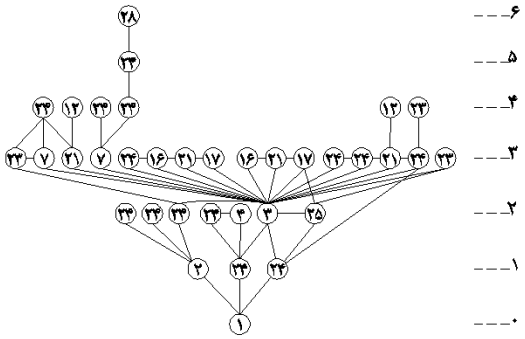
Table 2. The Justified Graphs of the Four Houses Studied



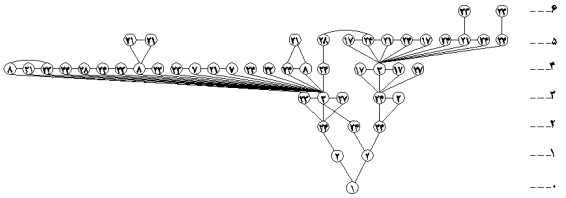
Meshkatian House (Yazd)



Gerami House (Yazd)



Mosaver al-Maleki House (Isfahan)



Etekafzadeh and Sharif House (Isfahan)

After extracting the justified diagrams, the average areas of different uses in the house and percentages of them relative to the total house area were extracted, as listed in Table 3. Also, Table 4 shows the average distance of each space from the main entrance for each of the houses studied[7].

Table 3. Average Area of Various Types of Spaces in the Four Houses Studied and Percentages of Them Relative to the Total House Area (In M^2)

Space Name / House	Entrance Corridor and Space Division (2)	Main Courtyard (3)	Backyard (4)	Common Room (23)	Sash-Window Room or Talar (21)	Eyvan (7, 8, 9)	Panjdari Room (18)	Sedari Room (17)	Dodari Room (16)	Windcatcher (25)	Shahneshin (12)	Kitchen and Storage (28)	Others (22, 24, 27, Etc.)
Gerami House (Average in m^2)	61.9	315	-	30.3	62.5	68	48.7	35.1	-	23.3	-	41.9	-
Percent (Relative to Total Building Area)	2.5%	25.5%	-	6.1%	7.6%	2.8%	2%	5.7%	-	0.9%	-	5.1%	41.8%
Mehkatian House (Average in m^2)	11.1	245.4	60.7	17.8	-	27.5	32.3	21.3	-	31.2	-	35.2	-
Percent (Relative to Total Building Area)	2%	21.9%	5.4%	7.9%	-	4.9%	2.9%	9.5%	-	2.8%	-	6.3%	60.3%
Etekafzadeh and Sharif House (Average in m^2)	37.7	245.1	-	16.6	24.1	7.4	-	15.5	-	-	8.1	21.8	-
Percent (Relative to Total Building Area)	7.3%	31.7%	-	10.7%	9.4%	2.4%	-	4%	-	-	0.5%	4.2%	29.8%
Mosaver al-Maleki House (Average in m^2)	11	205.4	21.9	11.3	25.6	3.4	-	-	14.2	12.5	8.2	27.7	-
Percent (Relative to Total Building Area)	1.2%	23%	2.5%	3.8%	11.5%	0.8 %	-	-	3.2%	1.4%	1.8%	3.1%	50.3%

Table 4. The "Distance" of Different Spaces from the Main Entrance in the Four Houses Studied (in M)

Space Name / House	Entrance Corridor and Space Division (2)	Main Courtyard (3)	Backyard (4)	Common Room (23)	Sash-Window Room or Talar (21)	Eyvan (7, 8, 9)	Panjdari Room (18)	Sedari Room (17)	Dodari Room (16)	Windcatcher (25)	Shahneshin (12)	Kitchen and Storage (28)
Gerami House (Average in m²)	28.3	36.7	-	45	54.2	62.1	31.8	41.8	-	66.7	-	83.4
Mehkatian House (Average in m²)	-	26.7	6.7	21.7	-	27.3	40.5	41.6	-	53.5	-	45.35
Etekafzadeh and Sharif House (Average in m²)	27.4	34.1	-	45.9	45.5	50.5	-	37.2	-	-	42.5	47.6
Mosaver al-Maleki House (Average in m²)	19.4	29.2	41.9	54.1	33.6	27.2	-	41.3	31.1	52.8	39.4	27.7

In the following, the geographical location of each space in the general building structure was extracted for all the four houses studied, the results of which are listed in Table 5. In this table, the cardinal directions are denoted by their full name and the inter-cardinal ones by their abbreviations.

Table 5. "Geographical Directions" of Various Types of Spaces in the Four Houses Studied

Space Name / House	Entrance Corridor and Space Division (2)	Main Courtyard (3)	Backyard (4)	Common Room (23)	Sash-Window Room or Talar (21)	Eyvan (7, 8, 9)	Panjdari Room (18)	Sedari Room (17)	Dodari Room (16)	Windcatcher (25)	Shahneshin (12)	Kitchen and Storage (28)
Gerami House Geographical Location (Direction)	NW	NW-SE	-	SE SE NW North	NW SE South	SW	NE	West North NW SE	-	SW	-	SE SE South NW
Mehkatian House Geographical Location (Direction)	South NW	SW-NE	SW-NE	SW SW SE SE SE	-	SE SW	NW	NW North NE East	-	North	-	West NW
Etekafzadeh and Sharif House Geographical Location (Direction)	SE NE East	North-South	-	South NW SW NE SE North	East NW West North South	South West East North	-	West N.E East	-	-	North	South West
Mosaver al-Maleki House Geographical Location (Direction)	NW	West-East	West-East	South SE	East West North South	SW NW	-	South North	South North	-	East West	SW

4.1. Analysis of Syntactic Indicators

To investigate syntactic indicators, four qualitative components and one quantitative component were introduced. The results of the investigation of these components in the four houses studied are as follows:

4.1.1. Depth: As mentioned earlier, the depth factor is evaluated as a subset of qualitative indicators. All four houses studied in this study had 6 levels of depth, despite having different plans, meaning that the deepest space of all four houses is located at the depth 6. The kitchen space (space 28) is located in the deepest part

of these houses (at depth 5 or 6). Considering that women spent a considerable amount of their time in the kitchen, it seems that being placed at this depth shows the importance of the issue of privacy and the considerable amount of desertedness in this space. In the two studied houses in Isfahan city, the space of the main courtyard (space 3) (i.e. the courtyard around which there are more spaces, or in other words, it has more connections than the other courtyard) is at the depth 3. While, in the two studied houses in Yazd city, one of the two courtyards is located at the depth 4. Also, in the samples of two- courtyard houses, the inner courtyard is located at a greater depth than the outer courtyard. It seems that the location of the courtyard, as a distributing space, in the middle depth of these plans, shows the functional and climatic importance of this space.

4.1.2. Integration: Another qualitative indicator is the degree of integration that was discussed in spatial analysis in this research. By examining the justified graphs, it is found that the highest degree of integration is associated to the courtyard space (the most communal space), which can be justified according to its type of function (spatial distribution). Also, the lowest degree of integration belongs to a space such as rooms (spaces 23 and 21), which have the highest amount of privacy and are considered the interior of the house. It is noteworthy that despite a large number of connections between the spaces and also the strong circulatory circulation (high spatial relationship) between them, the issue of desertedness and privacy in the spaces is still maintained, indicating the high degree of flexibility of these houses.

4.1.3. Choice: The choice indicator was also evaluated qualitatively. As mentioned earlier, the higher the number of connections in space, the more choices that space has. In the spatial analysis of the houses studied in the present study, the courtyard space, as a part of the building located in the center, has the shortest path to reach some spaces, so, it provides the highest rate of use or the same choice to reach the destination for the users (this issue will be quantitatively expressed in the subsection of distance). Given what abovementioned, it seems that in addition to the issue of climate, the courtyard also facilitates the movement in the house and the function of the house.

4.1.4. Control: The "control of spaces" factor, as another quality indicator, examines the level of access to a space, and the lower its degree, the less control over that space, and also, the spatial separation of that space increases. By examining the justified graphs related to the houses studied in this study, it is found that most of the spaces (except for some rooms, kitchen, and courtyard) have 3 to 4 connections, they are not significantly different from each other in terms of the amount of control over them. However, the concept of control at home is more related to the issue of the hierarchy of access from the entrance to different types of spaces. In this case, there is less amount of control over the interior spaces of the house than the exterior spaces.

4.1.5. Difference Factor: This factor is the only quantitative component evaluated as a syntactic indicator in the present study. For this purpose, the value of H was calculated for several spaces (representing all the spaces in the house). Since the difference factor examines the degree of functional differentiation of different spaces in a building, in order to comparatively investigate this concept in different spaces, those spaces that were present in all four houses should be selected. Therefore, among various types of spaces, three spaces of "common room (a)", "courtyard (b)" and "kitchen (c)" were selected. The final results are given in Table 6:

Table 6. Investigation of the "Difference Factor" Indicator in the Four Houses Studied

Space / House Name	H_a(Common Room)	H_b (Courtyard)	H_c (Kitchen and Storage)	Magnitude Ratio
Meshkatian House	0.13	0.16	0.13	$H_c < H_b < H_a$
	0.13			
	0.21		0.21	
Average Value	0.15	0.16	0.17	
Gerami House	0.23	0.34	0.17	$H_b < H_a < H_c$
	0.23			
	0.17			
Average Value	0.21	0.34	0.17	
Etekafzade and Sharif House	0.17	0.21	0.25	$H_c < H_b < H_a$
	0.17			
Average Value	0.17	0.21	0.25	
Mosaver al-Maleki House	0.12	0.30	0.24	$H_b < H_c < H_a$
	0.18			
	0.24			
Average Value	0.18	0.30	0.24	

According to Table 6 and examining the results of the calculation of the "difference factor", it is observed that there are different values of H for all three studied spaces in all four samples, indicating the difference in current function in these spaces. As mentioned in the literature review section, the low values of H indicate the degree of integration of the space with other spaces in the structure of the house and the high values indicate the maximum separation of the space from the overall structure. As found from the data in the table above, the values of H obtained for the room space (space a) in the three Meshkatian, Etekafzadeh and Mosaver al-Maleki houses are greater than the values obtained for the courtyard and kitchen spaces, emphasizing that in these three houses, the rooms were organized in such a way that they are more separated from the overall structure of the house. This implies the importance of the issue of privacy for the room space. While in Gerami House, this issue is observed for the kitchen space, meaning that in this house, the kitchen space is built in the most private place.

4.2. Analysis of Non-Syntactic Indicators

As mentioned earlier, in order to scrutinize the results, considering that the space syntax tools do not directly address the non-syntactic indicators, the following indicators, as non-syntactic ones, are discussed to analyze the spatial configuration. These indicators were extracted from the plans of the studied cases.

4.2.1. Area: In order to investigate this factor, the area of some spaces common in houses was measured by objective observations, and its values are listed in Table (3). Comparing the obtained values, it is observed that a major part of the space is allocated to the courtyard, connecting ways (Fig. 6) as well as piers.

As mentioned earlier, the courtyard plays a key role in improving the performance of the house and has a high spatial value, and a large part of the house area is assigned to it. It seems that the issue of creating an interface space between rooms that could be placed directly next to each other has been formed due to cultural issues, leading to the formation of spaces with a higher degree of privacy. In general, according to what aforementioned, it seems that in the "difference factor" indicator, which examines the value of space in different parts of the house, the space dimensions were ignored. Therefore, using the "area" indicator, along with the "difference factor" indicator, can lead to a better understanding of the relationships and functions in space.

Table 7. Connecting Paths in the Four Houses Studied

Gerami House	Meshkatian House	Etekafzadeh and Sharif House	Mosaver al-Maleki House

After the spaces of the courtyard and corridors, the highest percentage of the total space area is allocated to different types of rooms (spaces 16, 17, 18, 21 and 23). The Dodari, Sedari, and Panjdari rooms (17, 16, and 18) have higher frequencies and greater areas than the Reception hall or Talar (21). The space of common rooms (23), which are generally considered the interior of the house, is one of the common spaces in all the houses studied, and it seems that the allocation of the largest area to these rooms indicates the importance of them for the residents.

4.2.2. Distance: Various types of spaces have certain distances from each other according to their locations and the amount of distance traveled by the residents in each house during the day depends on the locations of these different spaces relative to each other. According to the values listed in Table (4), it is found that in Gerami House, with the longest entrance corridor on average (28.3 meters), kitchen space is further away from the entrance (83.4 meters). Also, the average total distance traveled in the studied parts in this house is more than other houses (Gerami = 50.7, Meshkatian = 32.9, Etekafzadeh and Sharif = 41.3, Mosaver al-Maleki = 36.1). According to these results, the kitchen space in this house seems to have more privacy than other houses.

On average, in these four houses, the courtyard is located at the shortest distance from the entrance ((36.7), (26.7), (34.1), and (29.2)) which is located in this part in order to distribute other space. While in terms of location, it is in a different position in the justified graphs. It can also be stated that although some spaces have a similar position in terms of the number of connections and thereby the degree of control over them, they are in different positions in terms of the metric distance from the entrance, meaning that they are different in terms of the degree of

actual control over them. For example, in Meshkatian House, although several Sedari rooms (space 17) are located at the same depth (at the depth 5) and have the same number of connections (2 connections), they are in different locations in terms of the metric distance from the entrance space and have different spatial and functional positions.

4.2.3. Geographical Location: In general, among the four houses studied, those in Yazd have a southwest-northeast elongation due to the building orientation in Yazd city, and those houses in Isfahan city are located in the north-south direction. In the justified graphs, the spaces around the courtyard are generally located at a higher depth as much as one level compared to the courtyard, while they have different positions in terms of function. For example, although the reception hall (21), Sedari room (17), and Panjdari room (18) spaces in the studied houses are located at a level of depth after the main courtyard, they are located on different sides of the house (north, south, etc.) and as the seasons change, they get different values.

Given the above, it can be concluded that non-syntactic evaluations can meet some defects of syntactic analysis. The following diagram, in summary, shows the process by which non-syntactic analyses enhance the accuracy of syntactic studies to some extent (in the form of thesis and antithesis).

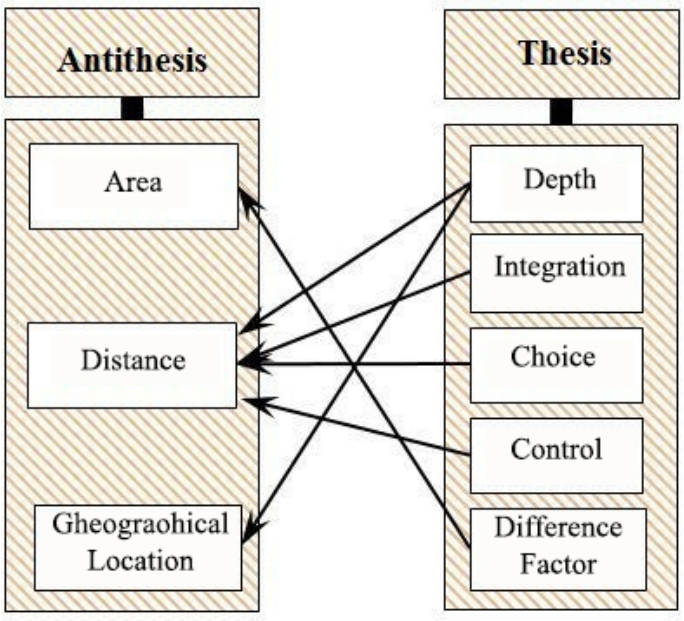


Fig. 6. Relationship between Syntactic and Non-Syntactic Indicators

5. SUMMARY AND CONCLUSION

In the present study, in order to investigate the hypothesis, first, the spatial structures of all four houses studied were analyzed and studied using common indicators in the space syntax method. In the next step, using a series of non-syntactic indicators, other analyses were performed on the spatial structures of the samples. It should be noted that the results of these analyses could not be extracted by syntactic indicators. Thus, in this way, it was made possible to extract the weaknesses of syntactic indicators in the analysis of the spatial structure of architectural environments.

According to the results of syntactic analysis, it can be found that in some cases, the obtained data alone are not able to analyze the spatial structure of the environment. These defects can be examined from several perspectives:

1. A number of spaces, despite having the same position in the syntactic analysis, have different values in terms of use and current functions in them. Therefore, while the spaces may have different degrees of permeability and thereby different degrees of function, no difference has been considered between them in the justified graphs. For example, the "vestibule" and "Sedari room" spaces in Meshkatian House are both located at the depth 5 and have 3 connections while there are very different in terms of amount and type of use.

2. Some spatial characteristics cannot be studied with current justified graphs. For example, "piers" are not evaluated in space syntax analyses and have no effect on them. However, according to the structure used in the houses, on average, a significant percentage of the total area is occupied by the piers and influenced the distance between the spaces. Therefore, by increasing the number of spaces in the house, the total area of piers increases, and this influences the spatial circulation as well as the distance traveled by users in order to reach different parts of the house. Also, in some cases, it can change the social organization of the house.

3. The geographical locations of spaces in the structure of the building can affect the type of use of different parts of the house during the year, which has no role in drawing justified graphs. However, many of the

utility-related characteristics of the space depend on its location in the correct geographical direction, and this also affects the optimal functionality of the space.

4. The user travels different distances to reach different spaces, and this indicator can affect the value of the space or its type of use. However, it is not considered the syntactic indicators of space.

5. The area of a space can provide or remove some opportunities to perform some activities in that space and the type of activity performed in space affects the value of the space although this issue cannot be studied in the syntactic analysis of space.

Considering what abovementioned, it seems that using the syntactic indicators alone, a comprehensive analysis cannot be provided on the spatial structure of architectural environments and in some cases, there are some defects. Therefore, by adding some non-syntactic components such as area, distance, and geographical location, the spatial structures of built environments can be more accurately analyzed, and thus the research hypothesis is confirmed.

END NOTE

1. It should be noted that there are many syntactic indicators that can be analyzed using syntactic tools including graphs as well as Depthmap software. However, due to the space limit, the present study only examines those indicators that can be analyzed using justified graphs and therefore, it was avoided to address those indicators that can be analyzed using software.
2. The space syntax theorists suggest the use of Depthmap software to solve this problem. Using it, one can perform some metric calculations (Van nes, 2011, pp. 167-170; Turner, 2007, p. 43).
3. Choice is a kind of integration. The difference between the two is that in the study of integration indicator, all lines connected to space have the same value, while in the stud of ty of choice indicator, these lines have different values.
4. According to the inventors of this method, the process of adding indicators such as area and distance to the justified graphs is still in its infancy, and it is possible that in some cases, the results of the analysis are not accurate.
5. A one-courtyard house has a main courtyard and a backyard, and a two-courtyard house has two main courtyards (interior and exterior).
6. The root space is a space that is placed at the depth zero in the justified graph, and the depth of other spaces is measured considering being in the next levels relative to the entrance space.
7. In this study, spaces such as piers and connecting paths have been considered as other spaces. Also, in some houses, there were spaces such as stables that was seen in only one sample. These spaces are also of other spaces.

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