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The Influence of Courtyard on the Formation of Iranian Traditional Houses Configuration in Kashan

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ABSTRACT

“Central courtyard” is an integral part of traditional Iranian houses. In most traditional houses, at least one courtyard can be identified which has been hierarchically located in the entrance of the house and organizes its other spaces. Houses with such spatial system are called “courtyard houses”. Though the design and construction of such houses have been rendered obsolete for many years, many efforts have been made by researchers in the architecture area to take advantage of the social logic of these houses’ spaces due to their proper response to the needs of Iranian life over a long period of time. But it has always led to the shape imitation, and ultimately the design has not been consistent with the needs of today’s life. It seems that recognizing the space syntax of Iranian houses and the application of this logic in today’s design lead to the formation of a genotype containing genes of previous generations, while at the same time is consistent with the appearances and needs of today’s life. Using graph theory and space syntax and justified plan graph (JPG), this paper sought to investigate the spatial influence of the courtyard on the formation of traditional Iranian houses configuration. In fact, the research question is: what is the difference between the spatial influence of the courtyard and other spaces? In this research, four houses belonging to different historical periods are randomly selected in a specific city such that all four houses have one and only one courtyard. The convex map and justified plan graph and, finally, the mathematical analysis of these samples show the impact of each of the spaces of a house on its spatial organization. The courtyard-related data shows the special impact of this space on the formation of traditional Iranian houses configuration compared to other spaces.

Keywords: Space Syntax, Justified Plan Graph, Configuration, Courtyard, Iranian Traditional Housing.

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1. INTRODUCTION

In today's world, the excessive increase in the population of cities, on the one hand, and the lack of development of cities on the other hand, as well as, industrialization regardless of the comfort and health of people in residential areas have put human societies at risk of crisis. In some countries, including Iran, before the industrial revolution and the rapid growth of cities, there has been a good connection between residential space and natural environment which has been lost or faded during the course of community changes. The specific climate of Iran has led to a special diversity and innovation in its residential architecture over history. In general, it can be said that in the residential architecture of Iran, two types of introvert (inward-looking) and extrovert (outward-looking) architecture have been formed with regard to the formation of courtyard next to residential space. In introvert architecture which is the focus of attention, the interior spaces have no particular visual connection with outside urban spaces; and mainly, no openings to the alley or passage is observed in this type of architecture, and if an opening is observed, it has been formed at high altitudes to eliminate direct vision (Dailaman, 1987, p. 17).

Climate is one of the most important factors affecting the courtyard formation in cities and traditional, indigenous architecture of Iran in hot and dry climate. Due to hot and dry weather, sunshine, and specific climatic conditions in this climate, the cities have a compressed and condensed texture. This compression prevents solar radiation. The walls and roofs are usually thick to protect the interior from outside heat. The urban structure is designed in a way to keep the arteries open toward the direction of a desirable wind, and closed toward the direction of undesirable wind and sandstorm (Tavassoli, 1984, p. 62). The compression inside residential buildings is converted to openness which is called "central courtyard". Climate changes have affected the courtyard formation in two ways: First, buildings have become introverted to deal with climatic conditions, and secondly, in most buildings, the building orientation has been remarkable. The vast majority of residential houses were designed in a way that the inhabitants have the least exposure to adverse climatic conditions. The hot and dry weather, low rainfall, and storms that carry sand and dust with them, have all worked hand in hand and pulled the house into inside and center. The focal point of such residential buildings has been the courtyard such that they have been somehow surrounded by the living and active parts of the house. The overall composition of these textures consists of an open space (the courtyard), which has been mainly shaped by building bodies. Christian Nurburg Schultz called it "the principles of creating open spaces by building bodies," and stated that these principles can provide proper space definitions for the courtyard (Schoenauer, 2010, p. 245).

The past architecture of Iran is replete with valuable samples of identity-based housing. The remnants of the historical periods of the brilliant architecture of each city bear witness to this claim. Despite this clear fact, unfortunately, the contemporary history of Iran has been faced with many cultural cessations and breaks from historical experiences and timeless principles of the valuable cultural traditions in many aspects. And one of the effects of this break is to move away from the indigenous identity in today's Iranian architecture. One of the key elements in the design of traditional Iranian houses is the use of a courtyard, which has already been discussed. Using the theory of space syntax, this research intends to answer this question: whether the spatial influence of the courtyard on traditional Iranian houses is significant in comparison to other spaces in the house. How is this significance?

Space syntax researchers have largely used this technique to explore the social logic of architectural types. In this research, using the justified graph method, four houses in Kashan City will be analyzed. These houses were randomly selected from Single-Yard Houses and the qualities of the yard's connection are revealed in these samples compared with other spaces in these cases. In fact, instead of seeking for the social structure of Kashan's houses, the architect's explicit method in arranging space and especially the courtyard inside the form is analyzed.

2. THE JUSTIFIED PLAN GRAPH (JPG) METHOD

Space Syntax changes the architectural understanding from "dimensional" or "geographical" to "relational" or "topological" (Hillier & Hanson, 1984, p. 199). This approach focuses on space, not form, and, more particularly, on non-dimensional qualities of space like permeability, control or hierarchy. This shift in thinking commences with the process of translating architecturally defined space into a series of topological graphs that may be visually inspected, and mathematically analyzed (graph analysis). While Space Syntax research has developed a wide range of possible methods for investigating the built environment, the present paper is only concerned with one approach, i.e. Justified Plan Graph.

The first step in the construction of a JPG is typically the production of a convex map. A convex map is a way of partitioning an architectural plan into a diagram. The special method selected to produce a convex map directly affects the JPG and its findings. For example, for a small house plan, more than 40 convex spaces may be needed to complete the convex map (Hillier & Hanson, 1984, p. 32).

There are a number of alternative variations of this stage, ranging from the highly proscribed to the very general (Hillier & Hanson, 1984, p. 190; Markus, 1993, p. 42). For example, the convex map produced by Major and Sarris (1999) for Peter Eisenman's House No. 1, has 39 nodes or spaces, while Eisenman has only designed seven functional spaces in the house.

The more recent methods more tended to divide spaces in terms of their application, thus the number of nodes is reduced and the JPG becomes more consistent with inhabitation patterns (Peponis, Wineman, Rashid, & Bafna, 1997, p. 773; Bafna, 2003, p. 21). Once the convex plan is constructed, it is converted into a graph diagram in which the nodes display rooms and lines show a relationship between rooms. This graph has various levels, representing zero at the base, regardless of the actual orientation of space in the building (Hillier & Hanson, 1984, p. 63). Once completed, the JPG displays the levels of connectivity and separation between the root or carrier space, at the bottom of the JPG, and all other spaces. Thereafter, there are three common ways to interpret the JPG.

1. A JPG may be graphically or visually analyzed to uncover a range of qualitative properties of the spatial structure, including relative asymmetry, spatial hierarchy (arborescent qualities) and permeability (rhizomorphic qualities). The majority of the examples of this approach are based on the "inhabitant-visitor relations" and they rely on the production of JPGs with the exterior as a carrier (Marcus, 1987, p. 470; Dovey, 2010, p. 52). A small number of examples of visual analysis have multiple carriers and used visual archetypes to investigate the properties of space (Alexander, 1966, p. 48; Ostwald, 1997, p. 30).

2. The JPG may be mathematically analyzed. The formulas for this process may be found in a range of research studies (Hillier & Hanson, 1984, p. 80; Osman & Suliman, 1994, p. 192; Hanson, 1998, p. 92). Additionally, they can be analyzed using several software tools (Depthmap; AGraph). Using mathematical analysis, it is possible to investigate a set of values describing the JPG in terms of Total Depth (TD), Mean Depth (MD), Relative Asymmetry (RA), integration (i) and control value (CV). The i value may be used in architectural analysis to develop an "inequality genotype", which is important in the present research as it has formed the basis for the two major analytical precedents (Major & Sarris, 1999, p. 66; Bafna, 1999, p. 87).

In practice, an inequality genotype is a list of spaces in the JPG, arranged in order from highest to lowest i value. But in order to interpret what this list means, we have to use the graph theory.

3-The visual and mathematical information derived from the JPG may be used to theorize some additional properties or qualities of the building. This approach is very controversial (Dovey, 1999, p. 45), but is necessary to use the JPG in interpreting architecture.

For example, returning to the inequality genotype, Zako argues that it is "one of the most general means by which culture is built into spatial layout" (Zako, 2006, p. 67). However, the inequality genotype is simply a hierarchical list, and to interpret further how deliberate it is, it must be interpreted with the aid of the difference factor (H). Zako notes that the difference factor "was developed to quantify the degree of difference between the integration values of all three (or more with a modified formula) spaces or functions" (Zako, 2006, p. 67). Therefore, the difference factor, or H, can be used to determine how strong or weak certain inequalities are in the base JPG. Thus, an inequality genotype with "a low entropy (H) value will, therefore, be [a] 'strong' genotype, whereas one that exists, but tends to have high entropy, will be a 'weak' genotype" (Zako, 2006, p. 67). This is a typical example of a reasonably accepted use of mathematics to hypothesize certain qualities about an architectural plan.

A less emphatic interpretation is offered by Hillier and Tzortzi, who proposed that through the application of visual and mathematical processes, a JPG can be used to demonstrate how a "culture manifests itself in the layout of space by forming a spatial pattern in which activities are integrated and segregated to different degrees" (Hillier & Tzortzi, 2006, p. 285). This is possible because the spaces are not just multi-purpose voids awaiting appropriate furnishings and fittings, but they are also locked into a "certain configurationally relation to the house as a whole" (Hillier & Tzortzi, 2006, p. 285). That is why the inequality genotype is used to uncover not only a set of social values or ideals responsible for shaping architecture but also the recurring social values and principles in an individual architect's works.

3. METHOD

The first step in the process of space syntax is the production of convex maps. The Convex Map translates the plan into a diagram reflecting the configuration of the plan's features. Regardless of whether researchers are interested in plan configuration, axial mapping or visual communication identification, the convex mapping is necessary to shift from one plan to a graph (Turner, O'Sullivan, & Penn, 2001, p. 98). In the JPG method, a convex map is presented based on the architectural plan showing the building geography, which is a kind of presentation of visible space. The convex map is such that no line drawn between the two points of space is excluded (Hillier & Hanson, 1984, p. 98). Therefore, an L-shaped room is a concave space and must be divided into two convex spaces so that the analysis can be initiated. In the next step, a basic plan graph is plotted. Generally, this graph does not differentiate between large or small spaces, up or down, and assigns to each node a connection and does not link it to another space or exterior, and it is not shown that this relationship is a door, opening, or staircase and only the existence of the relationship is registered in the graph. This process graphically transforms the convex plan into a diagram. A brief explanation in the graph composition plot is a justification for the graph sorting process based on the relative depth of the nodes from the carrier point, also called the root (Klarqvist,1993, p. 103). So the JPG is built around a series of horizontal lines that are sequentially numbered (the bottom line is zero). Each line expresses a level of separation between rooms and is rooted in the zero line. After this stage, mathematical analysis can be performed on case examples.

Samples from Kashan city, as one of the central cities of Iran with a great diversity of traditional heritage architecture, were randomly selected from single-yard houses. In fact, the categorization of Kashan's homes is based on a wide range of features. One of the methods is the classification based on the number of yards and then on the facades. The reason for choosing this style is the dependency of the organization of spaces on the courtyard in the traditional housing as well as the life style. The number of courtyards is important in the placement of main and service spaces, and finally, the configuration of spaces. Additionally, the way in which the facades are located in the spaces of Iranian houses has a defined relationship with their uses. In general, traditional houses of Kashan City can be divided into three categories based on the number of courtyards: single-yard houses, dual-yard houses, and multi-dwelling houses (complex). What matters is that the dual-yard and multi-dwelling houses have been among prosperous and upper-class houses. The higher number of single-yard houses suggests that these houses have been used by the public and are more common. On the other hand, the building facade is also an important factor in examining the configuration of spaces. Therefore, in order to control the variable parameters, the statistical population is limited to single-yard houses, which itself creates another category of the construction facade. This category is as follows:

1. Single-Yard houses with two sides constructed (facing each other),
2. Single-Yard houses with two sides constructed (side by side),
3. Single-Yard houses with three sides constructed, and
4. Single-Yard houses with four sides constructed.

In order to control the result, samples were selected of all four categories to confirm the research reliability. These four samples are: Neshasteh Pour's house (two sides constructed, facing each other), Karkhanehchi House (two sides constructed, side by side), Bani Ahmadi's house (three sides constructed), Qoraishi's house (four sides constructed). To measure the accuracy of the obtained data, each sample is tested once with mathematical calculations and again with Agraph 3.0 software.

4. DISCUSSION

At first, architectural plans for each house were prepared and the spaces' names were selected based on the conducted visits and the study of resources. The principle used in drawing convex maps as the basis of the analysis is that the niches and dents in doors, as well as the spaces that have dents due to the change in the thickness of the walls, are not considered as separate convex spaces. In the case of spaces whose dents have not led to a change in space use, and these dents have been created due to structural problems or geometrical reforms, the whole space is considered as one convex space. Due to the age of the studied houses, a space called WC space is not recognizable in most plans, and it is often made in a deep niche located in a part of the courtyard wall and has been covered with a curtain. In order to provide the same conditions for all samples, this space is not considered as a single space. In all plans, the exterior is considered as the carrier and the rooms with the same use are separated by numbers. The results obtained from mathematical calculations and Agraph software for each are as follows:

4.1. Neshastehpour House

The Neshastehpour house is constructed as a sunken courtyard, with its functional spaces located on opposite sides (Fig. 1). On the ground floor, there is a five-door room around Charmi, and two-door rooms are located on its both sides. On the opposite side of this façade, there is an anteroom in the middle and two other rooms are located on both sides. Through stairs, one can go from Charmi to downstairs and courtyard. On the one side, there is a cellar and two rooms are located on its both sides. There are also a kitchen and two underground rooms which are service rooms rather than residential ones (Farokhyar, 2013, p. 90).

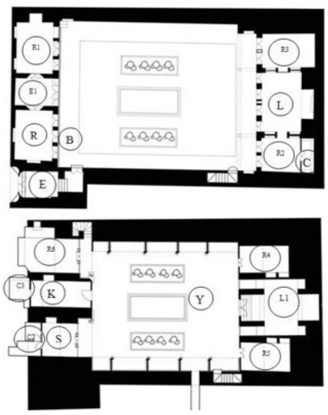

Fig. 1. Neshastehpour House's Ground-Floor Plan (Top) and Basement Plan (Bottom)
(Farokhyar, 2013, p. 91)

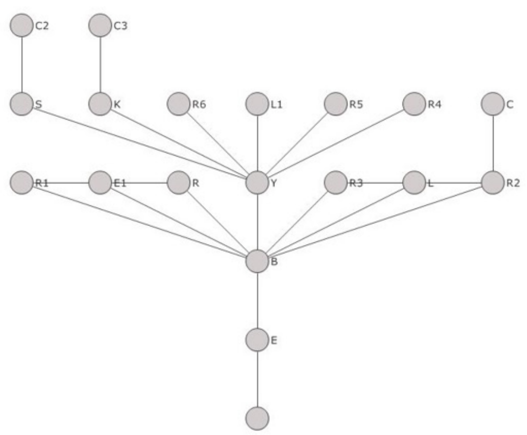

Fig. 2. Justified Plan Graph of Neshastehpour House

The visual analysis of the JPG of this house illustrates that Neshastehpour house's graph is generally arborescent, within which there is a frutescent graph, whose carrier is the courtyard. There are no very deep spaces, and the deepest spaces are stores and service spaces at underground level (Fig. 2).

The mathematical analysis of Neshastehpour house shows that the mean of total depth (TD) is 47.89. And the mean depth (MD) is 2.66. Therefore, all spaces whose mean depth is greater than the mean are of spaces that have been more isolated in the configuration. Among these spaces are the basement stores (MD= 3.50), exterior (MD= 3.44), ground floor stores (MD= 3.39) and four basement rooms (MD= 2.67). Conversely, the spaces whose mean depth is less than the mean are more accessible. The most accessible spaces are porch (MD= 1.67) and courtyard (MD= 1.72), followed by the five-door room and the adjacent room (MD= 2.44) and foyer (MD= 2.50), respectively.

Investigating the integration value clearly shows that more accessible spaces are more integrated and their integration value is significantly greater than the mean integration value of the all spaces of the house (5.75). For example, in the cases of the porch (Charmi) and the courtyard, this difference is about twice the mean. Finally, one can say that the courtyard shows the highest spatial impact (CV= 5.13), which is almost more than four times greater than other nodes, except for Charmi (CV= 3.13) (Table 1).

Table 1. Summary of JPG Results for Neshastehpour House

#	Space	TD	MD	RA	i	CV
0	**Carrier**	62	3.44	0.29	3.48	0.5
1	**E**	45	2.50	0.18	5.67	1.13
2	**B**	30	1.67	0.08	12.75	3.13
3	**Y**	31	1.72	0.08	11.77	5.13
4	**R3**	46	2.56	0.18	5.46	0.46
5	**L**	44	2.44	0.17	5.88	0.96
6	**R2**	44	2.44	0.17	5.88	1.46
7	**R**	46	2.56	0.18	5.46	0.46
8	**E1**	45	2.50	0.18	5.67	1.13
9	**R1**	46	2.56	0.18	5.46	0.46
10	**C**	61	3.39	0.28	3.56	0.33
11	**R4**	48	2.67	0.20	5.10	0.14
12	**R5**	48	2.67	0.20	5.10	0.14
13	**L1**	48	2.67	0.20	5.10	0.14
14	**R6**	48	2.67	0.20	5.10	0.14
15	**K**	46	2.56	0.18	5.46	1.14
16	**S**	46	2.56	0.18	5.46	1.14
17	**C2**	63	3.50	0.29	3.40	0.5
18	**C3**	63	3.50	0.29	3.40	0.5
MEAN		47.89	2.66	0.20	5.75	1.0
MIN		30	1.67	0.08	3.40	0.14
MAX		63	3.50	0.29	12.75	5.13

4.2. Karkhanehchi House

The Karkhanehchi house has functional spaces on both the north and west facades (Fig. 3). The entrance is located on the western side and the foyer with steps is lower than the alley. The western side of the building has a three-door hall in the middle and two three-door rooms on each side, which is connected to the main hall through the anteroom.

Under this façade, there is a cellar and a room attached to it, which is accessible through stairs from the courtyard. On the north side, a five-door hall and the three-door rooms with anterooms are located on both sides. There are also a veranda and a cellar in the basement (Farokhyar, 2013, p. 104).

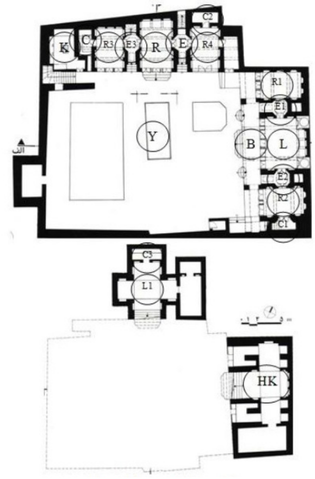

Fig. 3. Karkhanehchi House's Ground-Floor Plan (Up) and Basement Plan (Down)

(Farokhyar, 2013, p. 105)

The visual analysis of the JPG of this house shows that the graph of Karkhanehchi house is generally frutescent, and within which there are two other frutescent graphs, which the root of each one is the courtyard. The spaces are not very deep, and the deepest spaces are the basement rooms (Fig. 4).

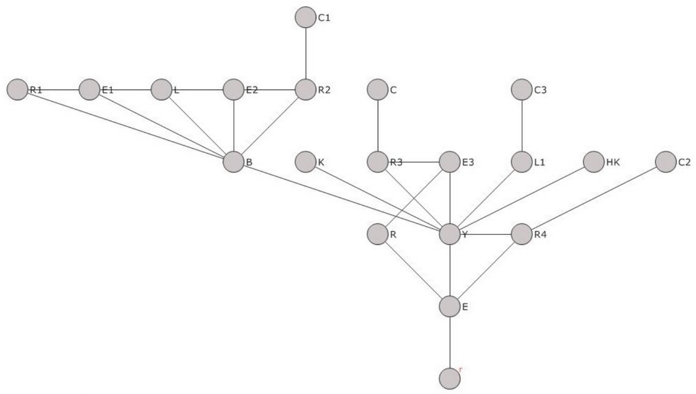

Fig. 4. Justified Plan Graph of Karkhanehchi House

The mathematical analysis of Karkhanechi house shows that the total depth (TD) is 51.6 and the mean depth (MD) is 2.72. Therefore, all spaces whose mean depths are greater than the mean are more isolated in the configuration. These include the exterior (MD=3.21), all basements (MD=3.68, MD=3.26), five-door rooms and anteroom (MD=2.79) and the three-door hall (MD=3.3). Conversely, the spaces with the mean depth less than the average are available, the most accessible spaces are the courtyard (MD=1.63) and porch (MD=1.95), followed by foyer (MD=2.6), other rooms and the anteroom around the three-door hall (MD=2.37), cellar (MD=2.47) and kitchen and cellar (MD=2.5).

For example, in the courtyard, this difference is more than twice the mean. Finally, it can be said that the courtyard shows the highest spatial impact (CV= 3.92), which is three to four times greater than other nodes (Table 2).

Table 2. Summary of JPG Results for Karkhanehchi House

#	Space	TD	MD	RA	i	CV
0	**Carrier**	61	3.21	0.25	4.07	0.25
1	**E**	43	2.26	0.14	7.13	1.96
2	**R**	57	3.00	0.22	4.50	0.58
3	**Y**	31	1.63	0.07	14.25	3.92
4	**R4**	44	2.32	0.15	6.84	1.38
5	**L1**	47	2.47	0.16	6.11	1.13
6	**E3**	45	2.37	0.15	6.58	0.96
7	**R3**	45	2.37	0.15	6.58	1.46
8	**C**	63	3.32	0.26	3.89	0.33

#	Space	TD	MD	RA	i	CV
9	**K**	49	2.58	0.18	5.70	0.13
10	**B**	37	1.95	0.11	9.50	1.96
11	**R2**	52	2.74	0.19	5.18	1.50
12	**E2**	52	2.74	0.19	5.18	0.83
13	**L**	53	2.79	0.20	5.03	0.83
14	**E1**	53	2.79	0.20	5.03	1.00
15	**R1**	54	2.84	0.20	4.89	0.50
16	**C1**	70	3.68	0.30	3.35	0.33
17	**HK**	49	2.58	0.18	5.70	0.13
18	**C3**	65	3.42	0.27	3.72	0.50
19	**C2**	62	3.26	0.25	3.98	0.33
MEAN		51.60	2.72	0.19	5.86	1.00
MIN		31.00	1.63	0.07	3.35	0.13
MAX		70.00	3.68	0.30	14.25	3.92

4.3. Bani-Ahmadi House

The courtyard of this house is much lower than the street level and the spaces are located on its three sides (Fig. 5). Though the courtyard of this house does not have the special architecture of sunken courtyard houses, the high depth of courtyard is significant compared to the height of the courtyard facades. The entrance is opened to the foyer which is connected to the yard with seventeen steps. In the northern complex of courtyard, there is a portico. The five-room hall is located in the middle of the portico and the two-door rooms are located on both sides of the hall. In the middle of the eastern façade, there is a vast spring house. There are two symmetric two-door rooms on both sides of it. On the third side of the yard, service spaces are located, such as the kitchen and storehouses. The visual analysis of the JPG for this house indicates that Bani-Ahmadi house's graph is generally frutescent. Deep parts are visible in this house and they form a relatively deep graph (Fig. 6).

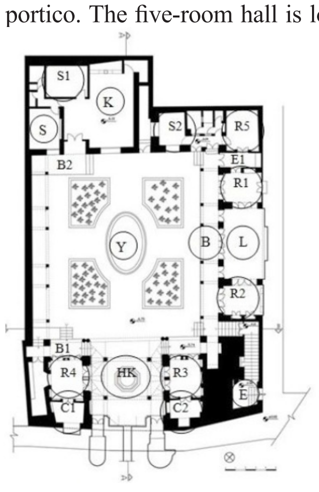

Fig. 5. Bani-Ahmadi House's Ground-Floor Plan
(Farokhyar, 2013, p. 175)

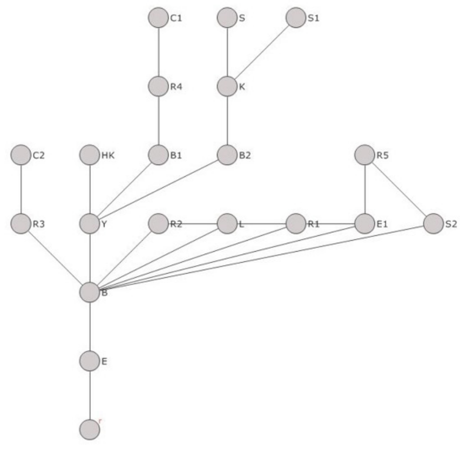

Fig. 6. Justified Plan Graph of Bani-Ahmadi House

The mathematical analysis of Bani-Ahmadi house shows that the mean of total depth (TD) is 61.2. And the mean depth (MD) is 3.23; therefore, all spaces whose mean depths are greater than the mean are of spaces that are more isolated in the configuration. The exterior (MD= 3.79), basements (MD= 3.63, MD= 3.79), storage rooms (MD= 4.42), two-door rooms (MD= 3.68) and the kitchen (MD= 3.47) are among them. Conversely, spaces with a mean depth below the mean are more accessible. The most accessible spaces are porch (MD= 2.00), courtyard (MD= 2.11), foyer, five-door hall, porch at the front of the two-door rooms, and storage room (MD= 2.84), spring house (MD= 3) and other spaces are in the next category. By examining the integration value, it can be seen that more accessible spaces are more integrated, and their integration value is significantly higher than the mean value of total integration of house spaces (53.4). For example, in the courtyard and porch, this difference is about twice the mean. Finally, it can be said that porch (CV= 3.25) shows the highest spatial impact, which is almost more than three times the other nodes, except for the courtyard and kitchen (Table 3).

Table 3. Summary of JPG Results for Bani-Ahmadi House

#	Space	TD	MD	RA	i	CV
0	**Carrier**	72	3.79	0.31	3.23	0.50
1	**E**	54	2.84	0.20	4.89	1.13
2	**B**	38	2.00	0.11	9.00	3.25
3	**Y**	40	2.11	0.12	8.14	2.13
4	**R2**	55	2.89	0.21	4.75	0.46
5	**L**	54	2.84	0.20	4.89	0.96
6	**R1**	53	2.79	0.20	5.03	0.79
7	**E1**	53	2.79	0.20	5.03	0.96
8	**R5**	69	3.63	0.29	3.42	0.83
9	**S2**	54	2.84	0.20	4.89	0.63
10	**R3**	54	2.84	0.20	4.89	1.13
11	**C2**	72	3.79	0.31	3.23	0.50
12	**HK**	58	3.05	0.23	4.38	0.25
13	**B1**	54	2.84	0.20	4.89	0.75
14	**R4**	70	3.68	0.30	3.35	1.50
15	**C1**	88	4.63	0.40	2.48	0.50
16	**B2**	52	2.74	0.19	5.18	0.58
17	**K**	66	3.47	0.27	3.64	2.50
18	**S**	84	4.42	0.38	2.63	0.33
19	**S1**	84	4.42	0.38	2.63	0.33
MEAN		61.20	3.22	0.25	4.53	1.00
MIN		38.00	2.00	0.11	2.48	0.25
MAX		88.00	4.63	0.40	9.00	3.25

4.4. Qoreishi House

After the entrance gate and passing the sloping corridor route, we enter into a courtyard that on its four sides, a set of one-floor spaces have been constructed. Except for the eastern façade space, which is located at the same level with the courtyard, the other spaces are a bit higher (Fig. 7). On the eastern side, there are a spring house and a kitchen, a two-door room and a three-door room. On the western side, a cellar is located in the basement whose roof has created a porch and in the middle of it, there is a five-door hall and 2 two-door rooms on both sides. On the southern side, a terrace with two symmetric three-door rooms has been made on both sides. On the fourth side, there is also a small Taromi (porch with woody fence) with two-door rooms on either side of it (Farokhyar, 2013, p. 231).

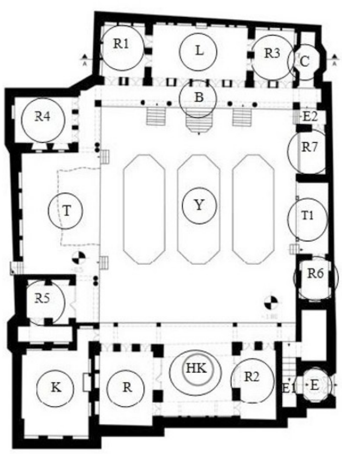

Fig. 7. Qoreishi House's Ground-Floor Plan
(Farokhyar, 2013, p. 231)

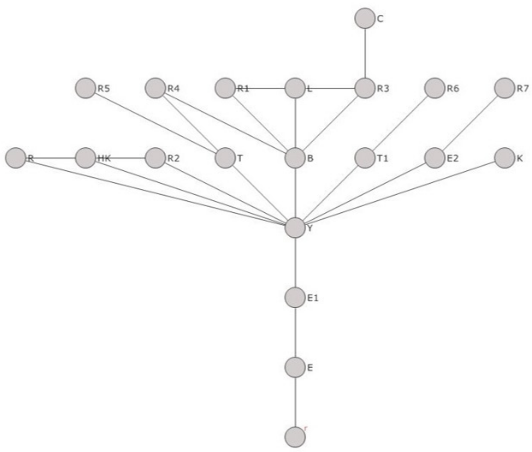

Fig. 8. Justified Plan Graph of Qoreishi House

The visual analysis of this house's JPG indicates that the house graph is generally frutescent, and the courtyard is the space from which the spaces begin to spread. Very deep parts are not visible in this house and they have formed a relatively shallow graph (Fig. 8).

The mathematical analysis of Qoreishi house shows that the mean of total depth (TD) is 53.4 and the mean depth (MD) is 2.81. Therefore, all spaces with the mean depth greater than the mean are of spaces that are more isolated in the configuration. Among these spaces, we can refer to the exterior (MD=4.16), basements (MD =3.79), foyer (MD=3.21), corridor and Taromi (MD =3.42) and hall (Five-door) (MD=2.84). Conversely, spaces with a mean depth less than the mean are more accessible. The most accessible space is the yard (MD=1.63), with a large difference, followed by porch (MD=2.5), hallway and corridor (MD=2.37), spring house and Taromi (MD=2.47) kitchen (MD=2.58) and other spaces are in the next category. The examination of integration value shows that more accessible spaces are more integrated and their integration value is significantly more than the mean integration value of the whole house (5.63). For example, in the courtyard, this difference is about three times the mean. Finally, it can be said that the courtyard (CV= 4.37) shows the highest spatial impact, which is almost three times more than other nodes (Table 4).

Table 4. Summary of JPG Results for Qoreishi House

#	Space	TD	MD	RA	i	CV
0	**Carrier**	79	4.16	0.35	2.85	0.50
1	**E1**	45	2.37	0.15	6.58	0.61
2	**Y**	31	1.63	0.07	14.25	4.37
3	**B**	39	2.05	0.12	8.55	1.78
4	**R3**	54	2.84	0.20	4.89	1.53
5	**R1**	56	2.95	0.22	4.62	0.53
6	**R4**	53	2.79	0.20	5.03	0.53
7	**T**	45	2.37	0.15	6.58	1.61
8	**R2**	48	2.53	0.17	5.90	0.44
9	**HK**	47	2.47	0.16	6.11	1.11
10	**R**	48	2.53	0.17	5.90	0.44
11	**C**	72	3.79	0.31	3.23	0.33
12	**E2**	47	2.47	0.16	6.11	1.11
13	**T1**	47	2.47	0.16	6.11	1.11
14	**R6**	65	3.42	0.27	3.72	0.50
15	**R7**	65	3.42	0.27	3.72	0.50
16	**R5**	63	3.32	0.26	3.89	0.33
17	**K**	49	2.58	0.18	5.70	0.11
18	**L**	54	2.84	0.20	4.89	1.03
19	**E**	61	3.21	0.25	4.07	1.50
MEAN		53.40	2.81	0.20	5.63	1.00
MIN		31.00	1.63	0.07	2.85	0.11
MAX		79.00	4.16	0.35	14.25	4.37

5. DEBATE

One of the most effective comparisons that can be made to identify a spatial pattern is the comparison of the integration values of different spaces in samples. The following graphs show this genotype investigation (Figs. 9-12).

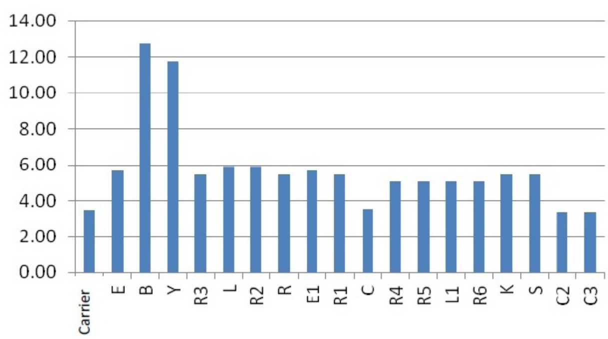

Fig. 9. The Integration Value of Neshastehpour House

As seen in the above graph, the integration value of the courtyard and Taromi in Neshastehpour house, as a sample of the sunken courtyard houses, is considerably higher than other areas in the house (Fig. 9). This result is also seen in the case of another sample of the sunken courtyard. In fact, it can be stated that in these houses, each floor has its own separate courtyard, and the difference between the integration values of both courtyards with other spaces is clearly visible, and it seems that the upper courtyard (Taromi) is somewhat more integrated than the lower yard (Fig. 10). This result is also observable in the other two samples, which are not of sunken courtyard houses, and the integration value of the courtyard is very different from that of the other spaces in the house (Figs. 11-12). It is expected that the spaces providing the circulation are more integrated, but there is a huge difference between the integration value of the yard with, for example, that of the anteroom, which also has a circular role. Therefore, the courtyard in traditional Iranian architecture does not have just the role of providing access to the other parts of house. It is a multi-functional space in which everyday life flows.

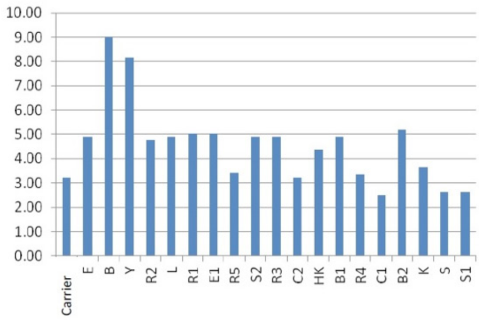

Fig. 10. The Integration Value of Bani-Ahmadi House

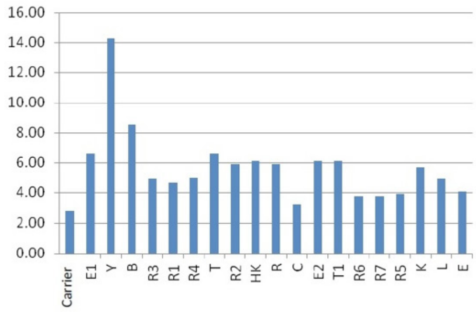

Fig. 11. The Integration Value of Qoreishi House

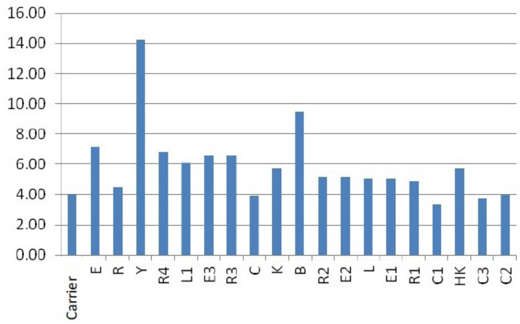

Fig. 12. The Integration Value of Karkhanehchi House

6. CONCLUSION

To investigate the spatial impact of the courtyard and its contribution to the formation of traditional Iranian houses, four cases of single-yard houses in Kashan City, which have been constructed at various periods and by different architects, were analyzed. For each case, a convex map was first prepared and niches, shelves, and breaks imposed on the geometry of the space, due to structural requirements, were ignored. Considering the exterior as the carrier point, the justified graph plan was plotted, and then, based on the total and mean depth and the number of convex spaces, mathematical calculations were done and then reviewed and controlled using the software. Genotype data shows that the courtyard is the main element of all buildings in terms of integration value and completes the configuration of buildings. In fact, in all cases, the courtyard dominates the plan. The apparently simple forms are complex, in other words, the simplicity is the other side of complexity in these houses. With all the contradictions in the space form and syntax, the study of several houses shows that, although houses belong to multiple periods, they have the same syntax. This result is close to the concept of authenticity and identity. The courtyard, as one of the house spaces, has a quite different integration value in comparison to other spaces and shows that the courtyard significantly contributed to the creation of the social logic of these houses. While in today's architectural design, this contribution has significantly reduced and even tends to zero. Therefore, it can be said that the courtyard is one of the most key spaces that should be considered to revive the past identity-based architecture. It seems that future research concerns making a comparison between the genotype of houses in other cities in Iran, for example, the northern or southern cities, and the genotype of the central cities. It also concerns investigating the contribution of the courtyard to the spatial organization in these houses. The answer to this question can somehow confirm the reliability of the present study.

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