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RESEARCH

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The implication of spatial-dispersion theory in housing genotypes of Boushehri historic and contemporary houses

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Abstract

Home has always been an important topic in research. In each region, houses change over time under different economic, social, cultural, climatic, and other conditions. Although these gradual changes have occurred to improve the spatial conditions of houses, it has led to a decline in the environmental quality and sometimes their technical efficiency. It is possible to redefine contemporary housing by spatially analyzing houses and discovering genotypes in a particular climate. This study uses space syntax algorithms in the syntactic plugin in Grasshopper to conduct various analyses and combine them with visual analysis extracted from Depth Map. House genotypes are discovered by factor analysis in SPSS. The case study is the coastal and historical city of Bushehr in the south of Iran. The sample size is 45 houses from three historical periods selected by non-random purposeful sampling. The results indicate that the houses in Bushehr have four genotypes, each of which has positive characteristics that can be generalized to contemporary housing architecture.

Keywords: Housing genotypes, Syntactic, Spatial-dispersion, Housing architecture

Introduction

The home has a broader meaning than the physical space of living [1]. Housing is not just a structure and shelter, but a multidisciplinary and institutional concept that is created to meet a complex set of goals [2]. In recent decades, the demand for housing in the developing country of Iran has increased. Although the number of houses has been increasing, their quality has been ignored [3, 4]. Alternatively, traditional architecture provided security and comfort of the inhabitants with a humane approach and effective communication with the environment [5, 6]. With the industrial revolution and the advancement of technology in addition to the neglect of traditional housing, the compatibility of architecture with its surrounding nature decreased, and the meaning of living in a home reduced to being under a roof. Researchers believe that the solution to this problem is to study the housing architecture of the past to the present; leading to discover the strengths of houses over time and guide the process of housing design today [7–10]. Accordingly, in this research, historical and contemporary residential spaces in Bushehr are studied, and, by discovering their typology, the characteristics of a house based on the ecosystem of the city and the lifestyle of its inhabitants are explained.

In the study of residential spaces in Iranian research, factors such as integration, entropy, visibility, and access have often been analyzed graphically using Depth Map [11–14]. In international articles, Depth Map is mostly used for urban space analysis [15–21]. In cases where residential spaces are analyzed, either as a subjective analysis or using A Graph and Depth Map, the level of integration, visibility, and hierarchy of spaces' interaction is presented in the form of colored diagrams [22–25]. In these studies, the space

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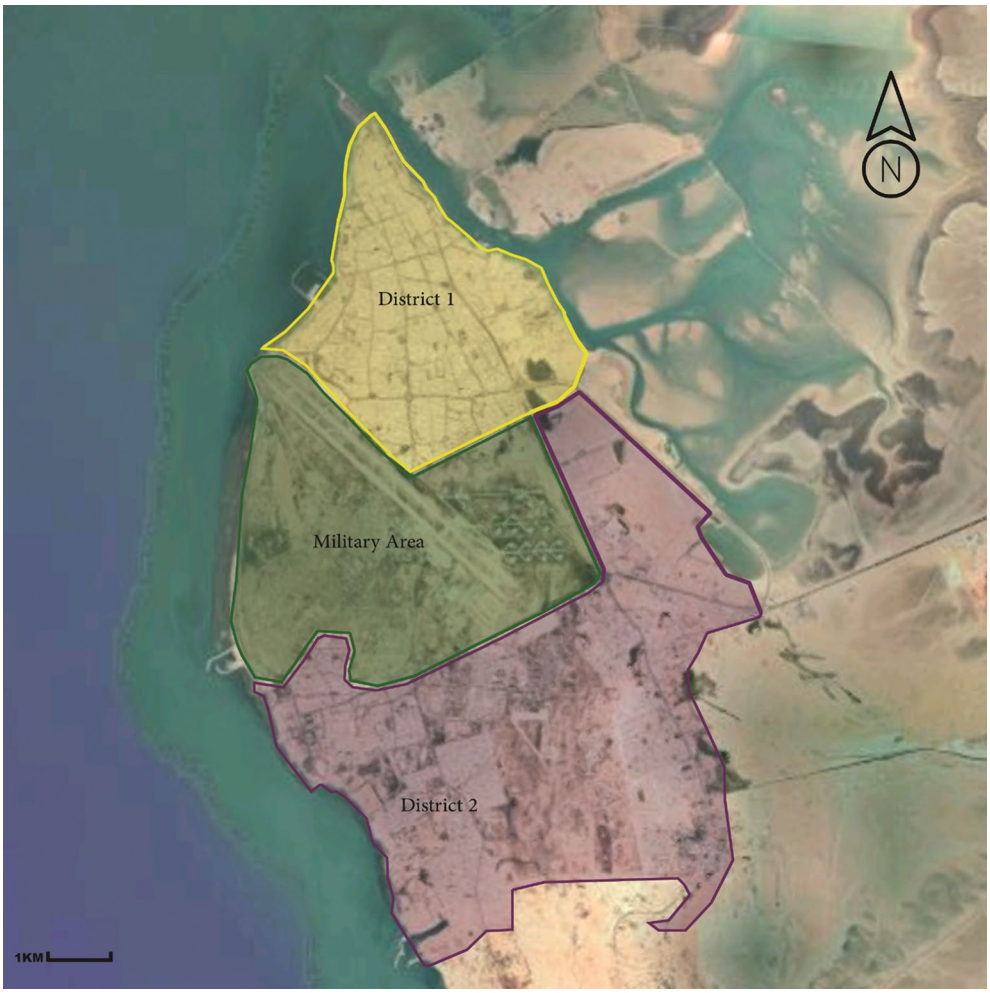


Fig. 1 Urban regions of Bushehr

syntax data and their software output were purely visual, graphical, and based on color ranges. Thus, the results were solely descriptive.

However, another tool called Syntactic can be used to analyze the syntax of architectural spaces, including residential ones. This tool is based on the theory of spatial analysis of Hillier and Hanson [22]. In Rhinoceros software and Grasshopper plugin, based on user input data, various spatial properties are accurately measured through mathematical algorithms and the effect of spatial configuration on the behavioral pattern of individuals is determined [26]. In recent years, studies investigated the syntax of residential spaces using this new method with the help of the Grasshopper plugin, which calculated the level of integration, control, choice, and entropy of spatial features such as privacy, spatial hierarchy, access, and order [27–29]. In this study, the typology of houses in the coastal city of Bushehr was discovered by combining the output of spatial analysis in Rhino and Depth Map, analysis of house structure, and factor analysis of the obtained data.

With a history of 5000 years, Bushehr Peninsula is located on the north coast of the Persian Gulf [30]. The strategic location of the city has caused its development to be only southward. The expansion of the city at any historical point has formed an area with a specific border. Most of Bushehr has a military use that has played a significant role in the formation of residential areas: it has led to the division of urban housing into two regions (Fig. 1). In the study of Bushehr houses, there are differences in the method of construction, the spatial layout of house spaces, title and number of spaces in the house, materials used, etc. A closer look reveals that the houses in both regions belong to the three periods of Qajar (196–1925) and early Pahlavi (1925–1941), late Pahlavi (1941–1978)

Fig. 2 Urban fabric of three historic eras of district 1

to about 30 years after the Islamic Revolution (2008), and finally the last decade. In this research, these three periods are called old, middle, and contemporary, respectively. In order to discover the patterns governing the houses, some cases from each period were collected and evaluated (Fig. 2). This evaluation is conducted to discover the genotypes of houses to infer the architectural principles of Bushehr houses according to the culture and climate of the region.

Methodology

The methodology of this research is divided into two stages. In the first phase, the pattern of houses in Bushehr is studied in three time periods using the space syntax technique with the help of Grasshopper and visual and qualitative maps of Depth Map (Fig. 3). In this regard, each of the houses is analyzed in Grasshopper environment within three phases of entering the initial data (title of spaces, their area, and total infrastructure), defining data relationships, and implementing various algorithms. The algorithms including integration, choice, entropy, control, and justified graph assign a specific value to each space of the house. These precise calculated numbers make it possible to compare different characteristics of the spaces in the houses with each other. Based on the data extracted from Grasshopper and their combination with Depth Map diagrams, the spatial structure and characteristics of Bushehr houses are analyzed.

In the second step, all the obtained data are analyzed through factor analysis to infer the typology of Bushehr houses regardless of the construction time frame. In this study, the sample population is Bushehr houses. Based on the purpose of the study, non-random purposeful sampling was used so that the selected samples represent the whole community [31]. All the

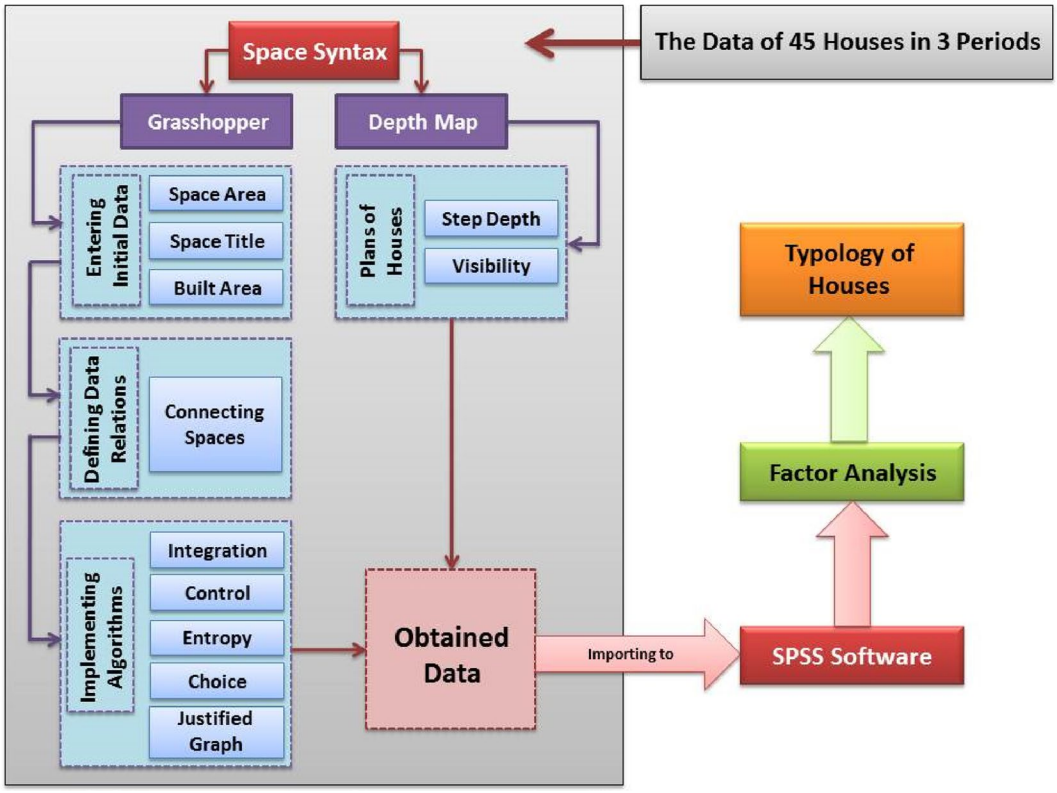


Fig. 3 Process of the methodology

houses belonging to the old and middle periods have courtyards. This was also considered in the selection of contemporary houses so that the samples met the same criteria. Accordingly, all the evaluated houses had courtyards in order to examine the impact of this spatial element on the lives of residents. With the purpose of determining the sample size, the number of houses belonging to each time period was enough to provide common results generalizable to the community. In this research, 45 houses (15 buildings from each period) were selected for analysis (Table 1). The historical part of Bushehr is located in the coast of Persian Gulf, and divided to four neighborhoods of Kooti, Behbahani, Shanbedi, and Dehdashti (Fig. 4). Thus, the samples of the old period were selected purposefully from this part of the city. To obtain reliable results, the selected samples must have the similar conditions. Therefore, all the selected old buildings were original, without any physical change from the time of construction, and also have the same number of floors and type of space. They were solely residential, without storeroom, water storage, and combined trading office. Middle and new period houses have spread in two urban districts. Given the location of historical houses in district one, houses of the other two periods and the total sample size were selected from this district. Also, as the houses from the old period have open space of yard, the middle and contemporary houses with yard were chosen.

Research findings and analysis

Integration and spatial correlations

Over time, the houses in Bushehr have faced changes in the number and type of spaces, layout, and correlations between themes, and variations in the integration of these spaces. In order to study these developments, in the first step, force-directed drawings and the results of the integration algorithm were implemented on all spaces of houses from the old, middle, and new periods. In the study of integration, a number and color are assigned to each space in each house. The higher the number and the warmer the color, the higher the integration of that space with other spaces and vice versa (Fig. 5).

Examining the type and level of relationships between different spaces in the house (Fig. 6), it was observed that

Table 1 Analyzed houses from three old, middle, and contemporary periods

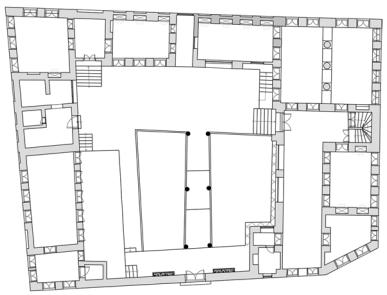
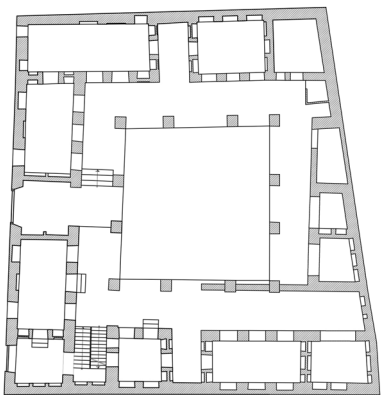
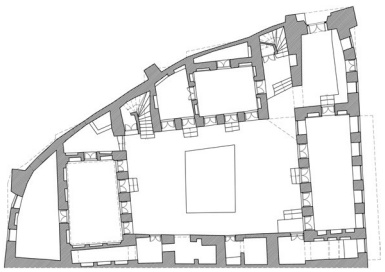
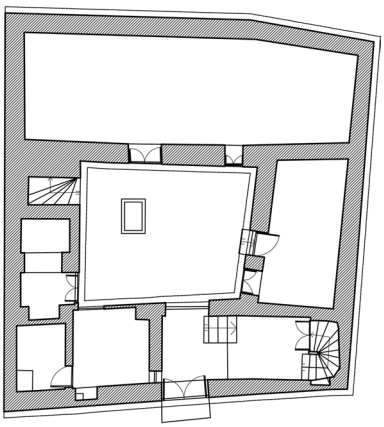
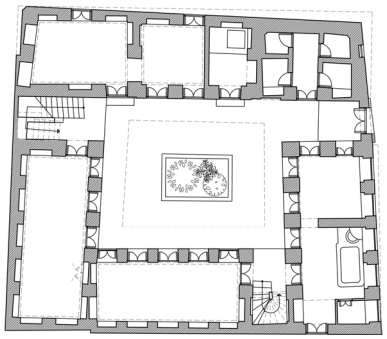
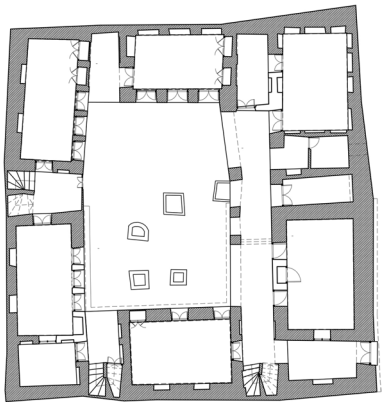
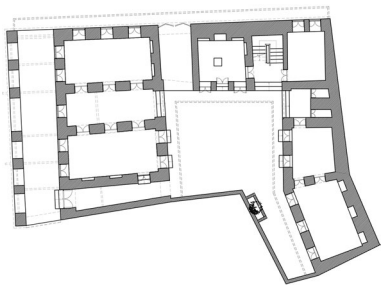
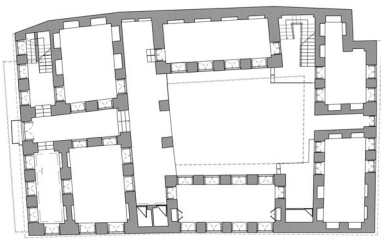
Period	No.- house name	Built area (m^2)	Ground floor plan	Period	No.- house name	Built area (m^2)	Ground floor plan
Old	H1- Asiaei Mansion	697.04		Old	H2- Hafte Mansion	440.09	
Old	H3- Azin Mansion	610.29		Old	H4- Rafiei Mansion	255.94	
Old	H5- Rashidi Mansion	555.56		Old	H6- Eskafi Mansion	508.81	
Old	H7- Taheri Mansion	904.72		Old	H8- Nozari Mansion	890.81	

Table 1 (continued)

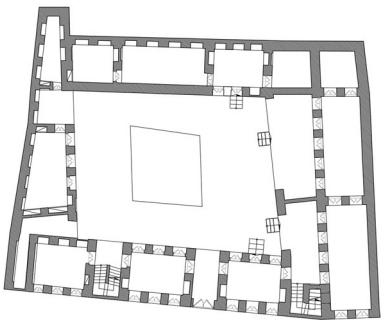
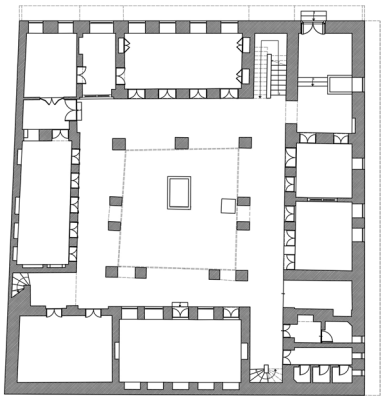
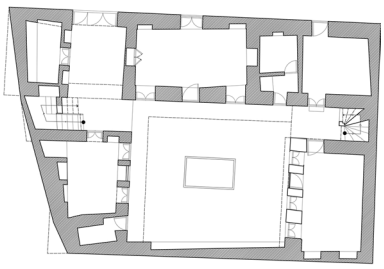
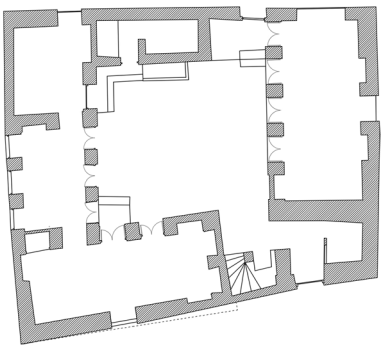
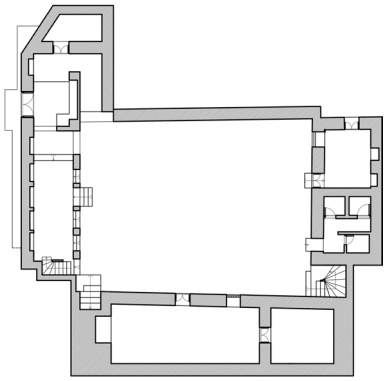
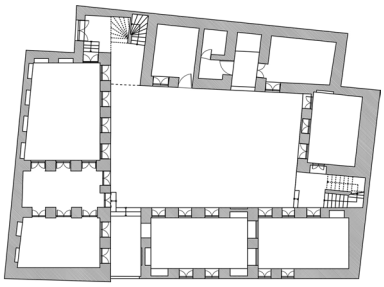
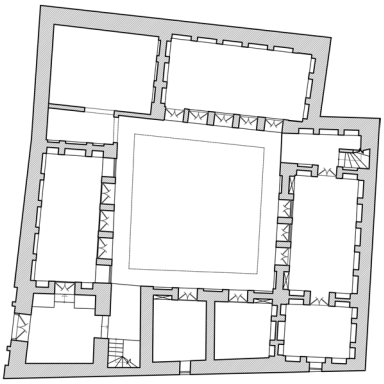
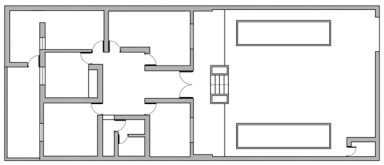
Period	No.-house name	Built area (m^2)	Ground floor plan	Period	No.-house name	Built area (m^2)	Ground floor plan
Old	H9- Jan Nesar Mansion	880.44		Old	H10- Tabib Mansion	1011.28	
Old	H11- Hosseini Mansion	472.10		Old	H12- Khoram Mansion	243.88	
Old	H13- Beladi Mansion	647.75		Old	H14- Sodaei Mansion	589.96	
Old	H15- Moradi Mansion	501.19		Middle	H16- Bakhtiari House	353.30	

Table 1 (continued)

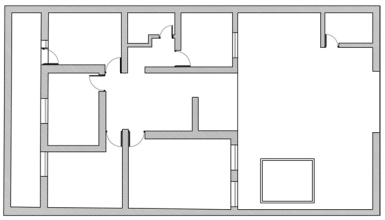
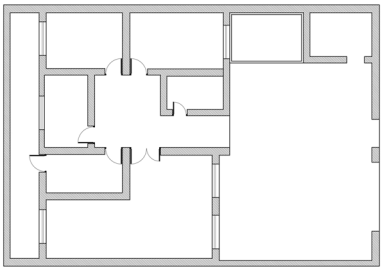
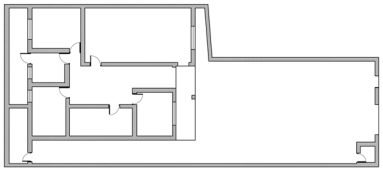
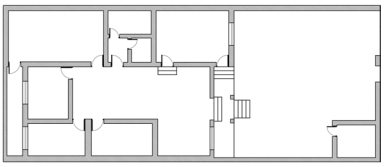
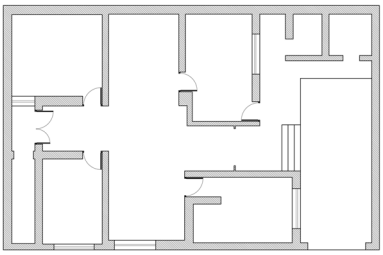
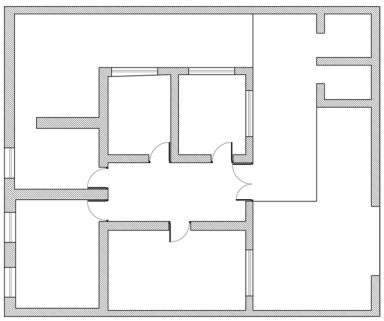
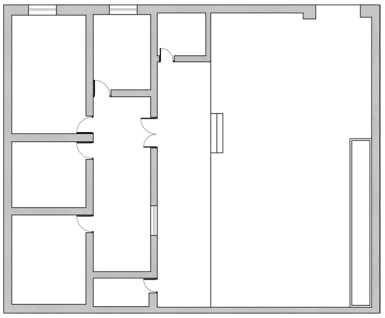
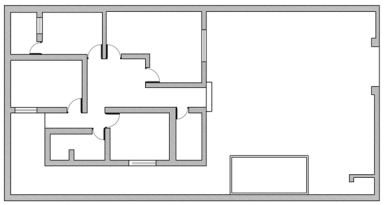
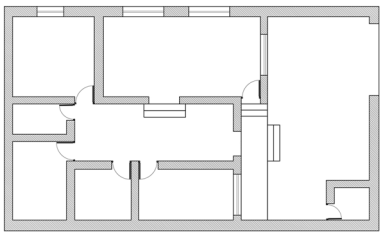
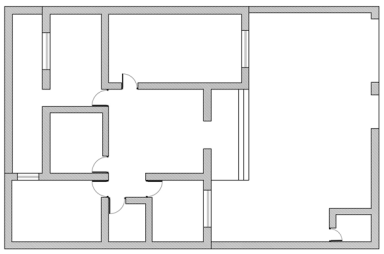
Period	No.-house name	Built area (m^2)	Ground floor plan	Period	No.-house name	Built area (m^2)	Ground floor plan
Middle	H17-Ershad House	260.20		Middle	H18- Pour Gholam House	283.62	
Middle	H19-Alavi Zade House	376.80		Middle	H20-Mohamadi House	338.07	
Middle	H21-Ravian House	215.13		Middle	H22-Mosadegh Zade House	218.06	
Middle	H23-Kontoratchi House	331.57		Middle	H24-Ashkesh House	285.57	
Middle	H25-Bahreini House	119.28		Middle	H26-Mostafavi House	308.29	

Table 1 (continued)

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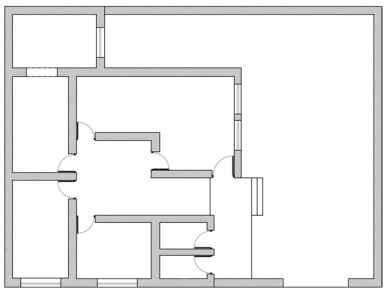
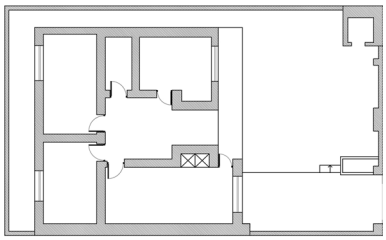
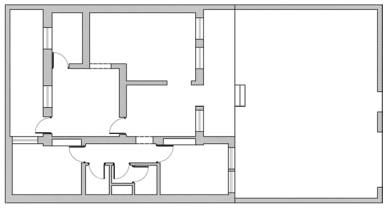
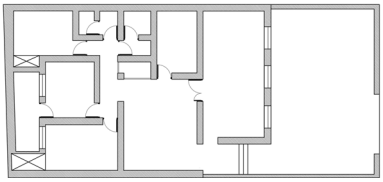
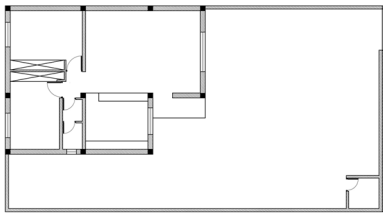
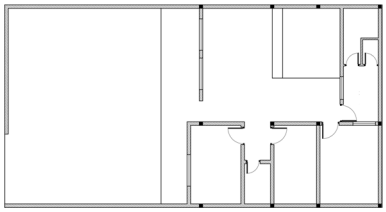
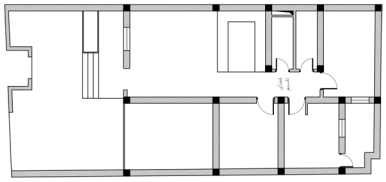
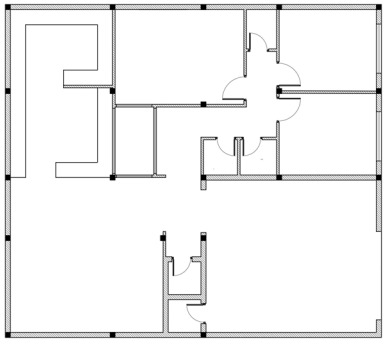
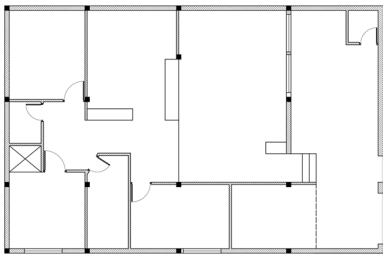
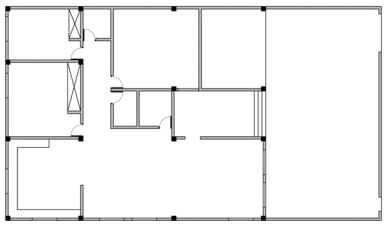
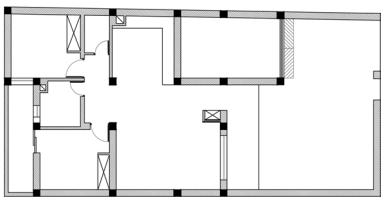
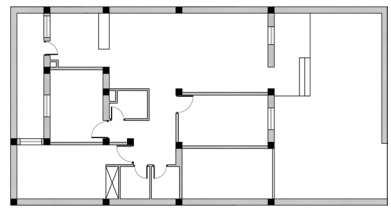
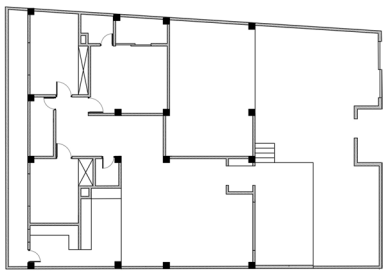
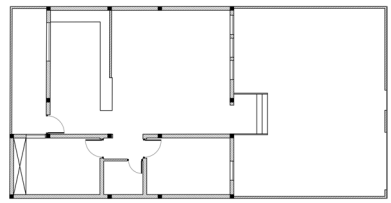
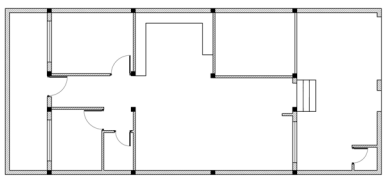
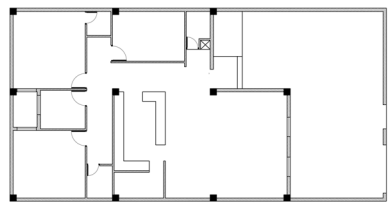
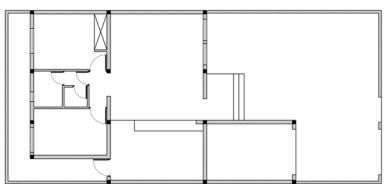
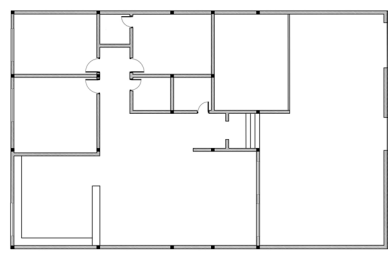
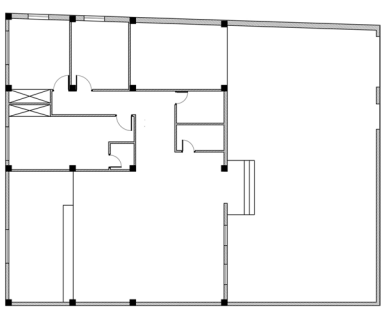
Middle	H27-Alibashi House	303.03		Middle	H28-Farzane House	264.72	
Middle	H29-Esmaeili House	256.18		Middle	H30-Pourbehi House	294.10	
Contemporary	H31-Jalili House	287.50		Contemporary	H32-Ebrahimi House	251.72	
Contemporary	H33-Moharami House	197.40		Contemporary	H34-Moghadam Hlouse	196.68	
Contemporary	H35-Mesri House	178.20		Contemporary	H36-Magham Nia House	502.05	

Table 1 (continued)

Period	No.-house name	Built area (m^2)	Ground floor plan	Period	No.-house name	Built area (m^2)	Ground floor plan
Contemporary	H37-Darya Del House	187.24		Contemporary	H38-Khezri House	231.00	
Contemporary	H39-Maghsoodi House	360.57		Contemporary	H40-Dashti House	197.17	
Contemporary	H41-Sharooni House	141.63		Contemporary	HHossein Pour 42-House	282.00	
Contemporary	H43- Nik Parast House	203.08		Contemporary	H44- Eftekhari House	395.04	
Contemporary	H45-Khaliji House	374.78		*The north direction is up in all the maps.			

a central space that has the most correlation with other spaces can be seen in the houses of all three periods. This space is the connection point between other spaces and therefore has the highest integration in the house. In the houses of the old period, the courtyard is one of the main living spaces that makes the connection between other spaces directly or indirectly through the Revagh,[1] Tarme,[2] and Tarme-Pele.[3] It also allows environmental elements to enter and affect the body of the house. Thus,

[1] A place like a corridor that surrounds a courtyard.

[2] A semi-open space that connects open and closed spaces together.

[3] A combination of Tarme with staircase.

as an open space with the highest integration, the yard is the main living space in the house. In the subsequent period, the open space of the yard simply became a place of transition from the alley into the house and was associated only with Tarme and sometimes service spaces such as toilets. Therefore, the central space of the houses comes to be the Hall[4]: a semi-private enclosed space with the highest integration that connects the public, private, and service spaces of the house. Hall directly influences the privacy and hierarchy of spaces. In contemporary houses, similar to the middle period, the yard functions as a transition area and parking space for the car. As well, the central space has been turned into the living room and the house spaces have been divided into public and private categories. With the removal of the semi-private space, the proper connection between public and private parts of the house has been lost. Thus, on the one hand, the hierarchy and privacy have been disrupted and, on the other hand, the private and service parts of the house, including bedrooms, kitchen, bathroom, and toilet, have been overseen from public space of urban areas.

Comparison of integration diagrams demonstrates that, in the old period, closed spaces of the house have a similar degree of importance and integration with other spaces. DoDari,[5] SeDari,[6] ChaharDari,[7] PanjDari,[8] HaftDari,[9] ShahNeshin,[10] and even Shenashir[11] are equally related to each other and have the possibility of equal choice. This shows the attention of the housebuilder and, consequently, the residents' equal use of all living spaces. However, in later periods, the value of home spaces varies based on their relationship with other spaces and the main central space. Reduced integration of the yard with spaces of the house is a confirmation of the elimination of the function of this space on life and its effect on the comfort and tranquility of inhabitants, which was mentioned in the previous section. The inconsistency of the integration of living spaces indicates that the value of some spaces and the level of their use are different. This has caused some spaces to be used less and sometimes even removed from the process of inhabitants' lives. In other words, these spaces are built but not used as they should be, such as Tarme, Matbakh,[12] yard, backyard, atrium, and even in some examples the bedroom. When life does not flow in these spaces, it consequently enters the most integrated spaces such as the entrance and the hall in the middle period and the living room and kitchen in the new period. Thus, the activity load increases in some spaces, while they do not have the capacity for this amount of activity. In contrast, some spaces in the house remain unused.

Another point that can be seen in this analysis is that despite the reduction of the infrastructure of the semi-open space of Tarme in each period compared to the previous one, it has not been removed from the home space and has maintained its integration with other living sectors. However, despite being integrated, it has lost its function and has become one of the factors of the hierarchy of passage. According to interviews with residents of the houses and papers related to people's lifestyles, Tarme semi-open space has been part of the residents' living space in the past, just like open spaces. In addition to connecting different rooms, Tarme is a place to spend time all day long when the environmental conditions allow the use of open space. On the other hand, considering the height of the houses and the location and introversion of the open space of the courtyard, the residents used Tarme without any restrictions. In the middle and especially the new period, the main reason for not using Tarme is the type of location and extraversion of the yard compared to the home environment. Through these conditions, privacy in the semi-open space has been lost and other residential units in the neighborhood can oversee Tarme and destruct its privacy.

Control and visibility

Privacy is one of the most significant variables that have been examined in various studies in modern and traditional housing. Although the concept of privacy in Western architecture is often related to security and even territory, it has a broader meaning in Iranian houses. It means the allocation of the body of the house to different spaces, in such a way that it has both physical and semantic privacy. Privacy in the spatial body is more focused on the principles that will shape the security of space based on territory. In the semantic realm, it entails features that bring sanctity and value to the architectural space in such a way that inhabitants reach calmness in it [30]. This concept is analyzed in different layers in the houses from old, middle, and new periods in Bushehr by combining the results obtained from the control algorithm in Grasshopper (Fig. 7) and the visibility in Depth Map (Table 2).

Any space that people have more control over is indicated by a bigger number in the Grasshopper and a warmer color in the Depth Map output. According to the above diagrams, it is observed that visibility and control of the space, which express the privacy of that

[4] The central space of middle period houses connects all of the other spaces together.

[5] A room with two doors next to each other.

[6] A room with three doors next to each other.

[7] A room with four doors next to each other.

[8] A room with five doors next to each other.

[9] A room with seven doors next to each other.

[10] A room for entertaining guests.

[11] A wooden balcony which provides privacy with its structure.

[12] A room used as a kitchen which provides a complete privacy.

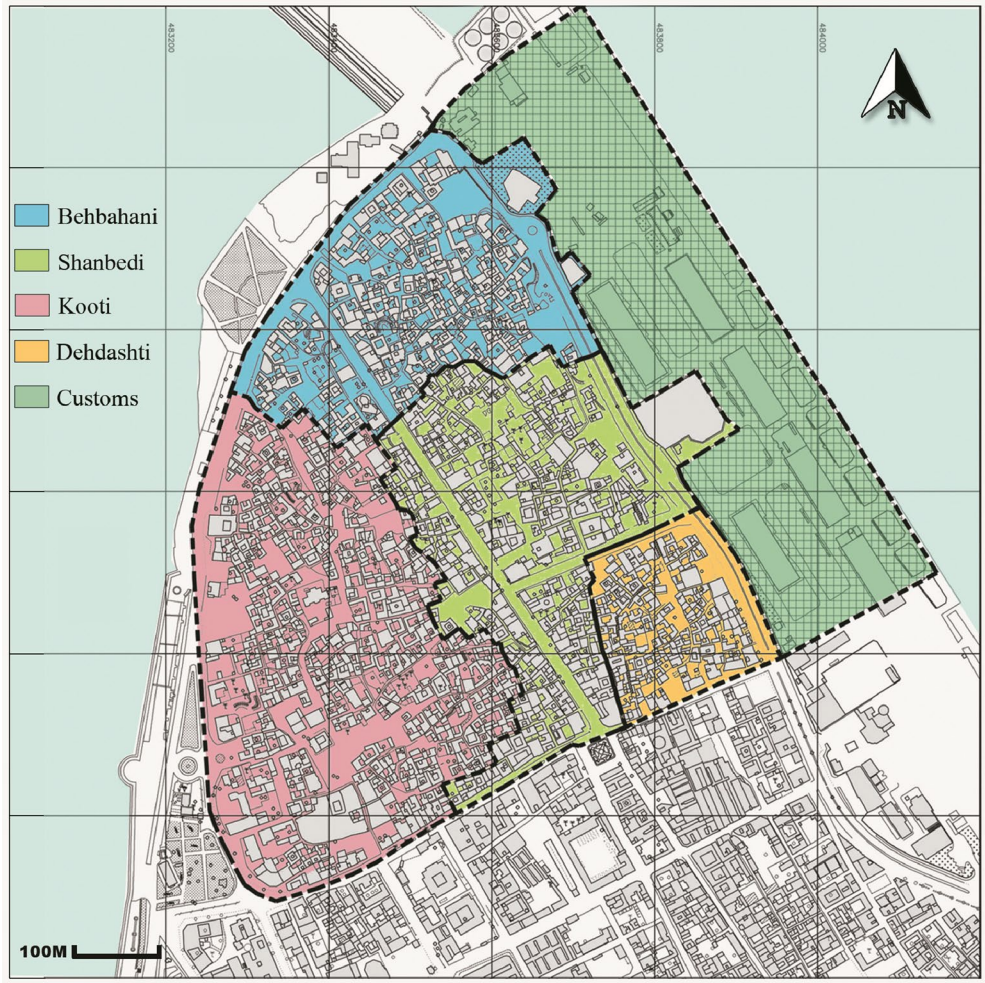


Fig. 4 Neighborhoods in Bushehr's Old Fabric

space, are in a direct relationship. In the old period, the yard was under the most control and visibility. In other spaces such as rooms, the less visibility they have, the more control there is over them, and the more privacy they have. In the middle and new periods, with the separation and relocation of the yard from the center of the house to one side and the placement of other spaces on the other side, the level of visibility with and without the yard has been analyzed. In both periods, the highest visibility is generally for the yard. When the spaces of the house except the yard were analyzed by the field of view, it became clear that the Hall and living room in middle period houses and the living room and division space in the houses from the new period were under the highest level of visibility and had the lowest privacy. Tables and diagrams of control derived from Syntactic also confirm this. Therefore, allowing space entry and visibility (visual privacy), transmitting sound outside or inside the house (audio privacy), controlling and spreading odor in spaces (olfactory privacy), rotation and circulation in any space (movement privacy), and, finally, the feeling of insecurity and the entry of other people into space (psychological/mental privacy) in all three periods are less in private spaces and more in public spaces.

Choice and spatial hierarchy

One criterion for the correlation, role, and position of each space in the house is the method of choice and the hierarchy to achieve it. How deep each space is in the house and how many steps must be taken to enter it, is effective on the type of space, its level of privacy, spatial territory, and dominance. Different spatial territories must be subjected to a range of transitional stages so that there is no instantaneous movement from one spatial territory to another [32]. A combination of choice algorithms and justified graphs (Fig. 8) were used to determine the type of choice of each space and the depth that space has in the whole house. Firstly, by comparing the average choice of house spaces in each of the old,

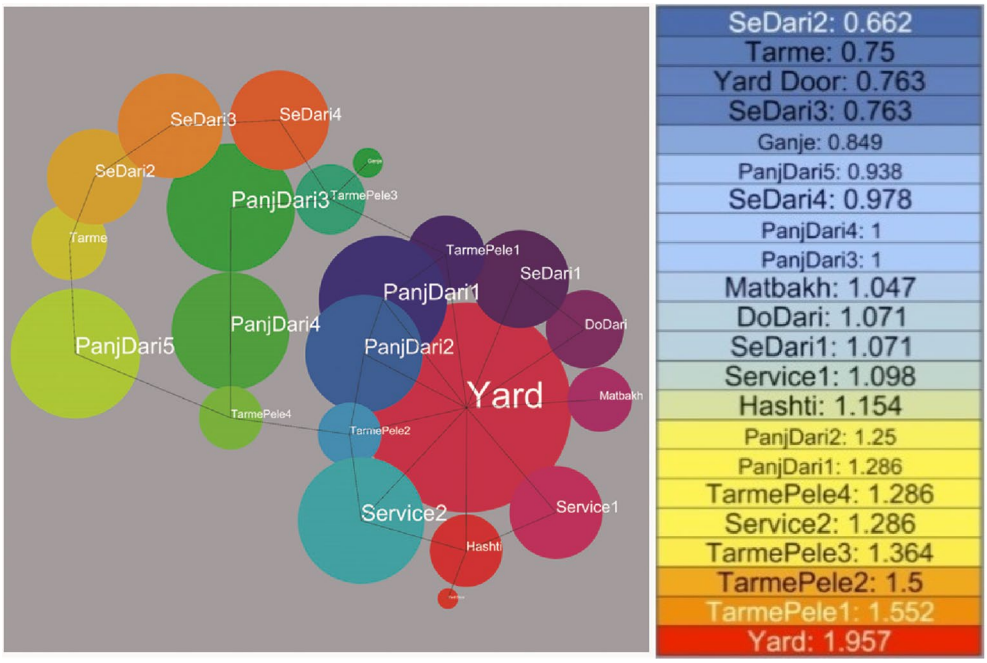


Fig. 5 A sample of integration and force directed drawing algorithm in spaces of a house in Grasshopper

middle, and new periods, it is observed that, in each period, a space that is more chosen is not necessarily in the initial depths of the hierarchy and is not the most used space.

In the old period, if a Revagh was located around the central courtyard of the house, this space was the most chosen. Following that, the physical element of the yard was chosen as a stage of transition to other spaces. This was despite the fact that the courtyard had the highest integration with other spaces of the house under any circumstances. The Revagh and yard were the stages of the spatial hierarchy after the entrance and Hashti,[13] respectively. After these two spaces, Tarme Pele, Hashti and Shenashir were the most chosen spaces. Following them, living spaces including rooms and, in the last stage, service and storage spaces (Ganje[14] and Pastoo[15]) were chosen. The results indicate that, in this period, the amount of space choice and the depth of the transition stages in the spatial hierarchy as well as the degree of importance of using that space are consistent with each other. In other words, the more private the space, the deeper its location in the hierarchy of the house and the less chosen it is. In contrast, any space that was more public was used more often, had a higher choice rate and less spatial depth. Another point is the relationship between space type and its location. Public and semi-public-semi-private spaces, such as Revagh and courtyards, are located at a lower depth of the hierarchy while more private spaces, such as rooms and service spaces, require more spatial stages.

Middle period houses, which had undergone many physical changes compared to the previous period, also had different hierarchies and spatial choices. In this period, the most selected spaces are the semi-private space of the Hall and the private space of division. These two spaces also have the highest level of integration with other spaces. However, the usage rate of other spaces, their type, and their choice rate do not correspond to the hierarchy of transition from public to private space. Tarme, yard, and living room, which are public and semi-private and are at different depths of space, were the most selected spaces. But this does not necessarily mean the constant use of these spaces. In the houses of this period, passing or stopping in any of these three spaces was mandatory and the residents had no role in choosing it. For example, to enter the bedroom, a person had to go through the yard, Tarme, entrance, and Hall while they did not have to use any of these spaces. The bedrooms, bathrooms, toilets, and backyard are equally able to be chosen, while their usage rates have been quite different. The hierarchy and the level of space choice do not match the usage and space type. Public spaces of the house are located at a lower depth but are not used. Private spaces

[13] A waiting space adjacent to the main entrance of the house.

[14] storage space for essentials.

[15] storage space for objects which are not necessary for daily use.

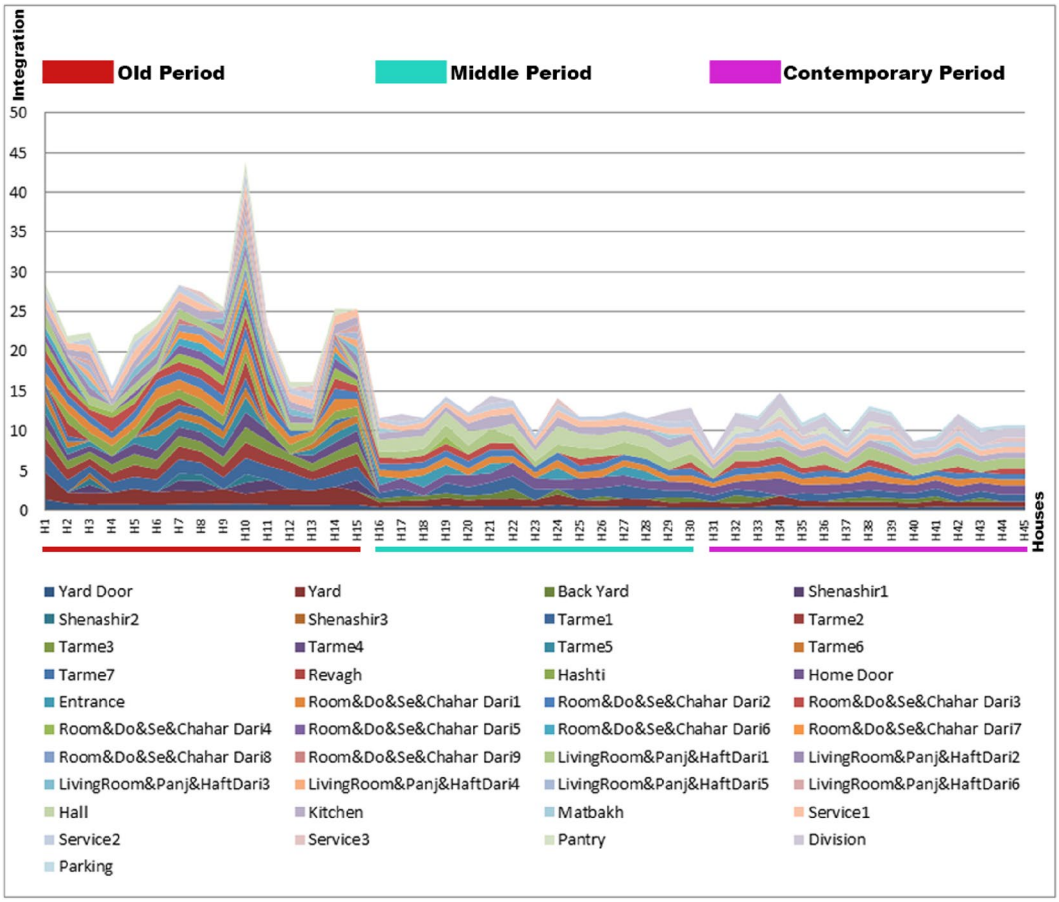


Fig. 6 Integration of spaces in Bushehr's houses

are deeper in the hierarchy of passage but are not chosen due to their usage.

In the houses of the new period, as the body of the house has changed due to the presence of cars and parking spaces at the first ranks of the spatial hierarchy of the house, it is the least chosen space. The division and living room, which should be the private and public spaces of the house, have both become semi-private-semi-public spaces that are the most chosen. The courtyard in this period, like the middle period, is located in the primary spatial depth and its choice rate is higher than indoor living spaces, but it is not used and has only become a necessary transit point to reach other spaces. Other home spaces, including bedrooms, kitchens, Matbakh, bathrooms, toilets, and storage, can be equally chosen, but their usage rate is quite different.

Finally, the number of spatial depths and transition stages in each of the three periods varies between five and seven stages and has no role in the level of space use and choice. In the houses of the old period, private spaces were arranged in the house at more depth with less choice and public spaces at lower depth with more choice. This provided the existing territories in the house along with privacy. In the houses of the middle and new periods, this process has been disturbed in a way that public spaces, although at a lower depth, have less choice factor and are not used. In the middle and new periods, the yard is located at a depth of 1 in front of the alley, while in the old period, it has a depth of 2, 3, or 4, and this does not allow a direct connection, visibility, and dominance over the house's open space from urban passages. The semi-open space was in the second depth in the middle and new periods, but in the old period, it was combined with other open and closed spaces in different depths of the house, and it was not only a transitional stage for the closed space but also it was used permanently. As well, the Revagh in the old period and the Hall in the middle period are both semi-private spaces in which the most choices were made, but in the new period, the highest choice rate is for the living room, which is a public space. This directly and negatively affects the level of privacy that people feel at home.

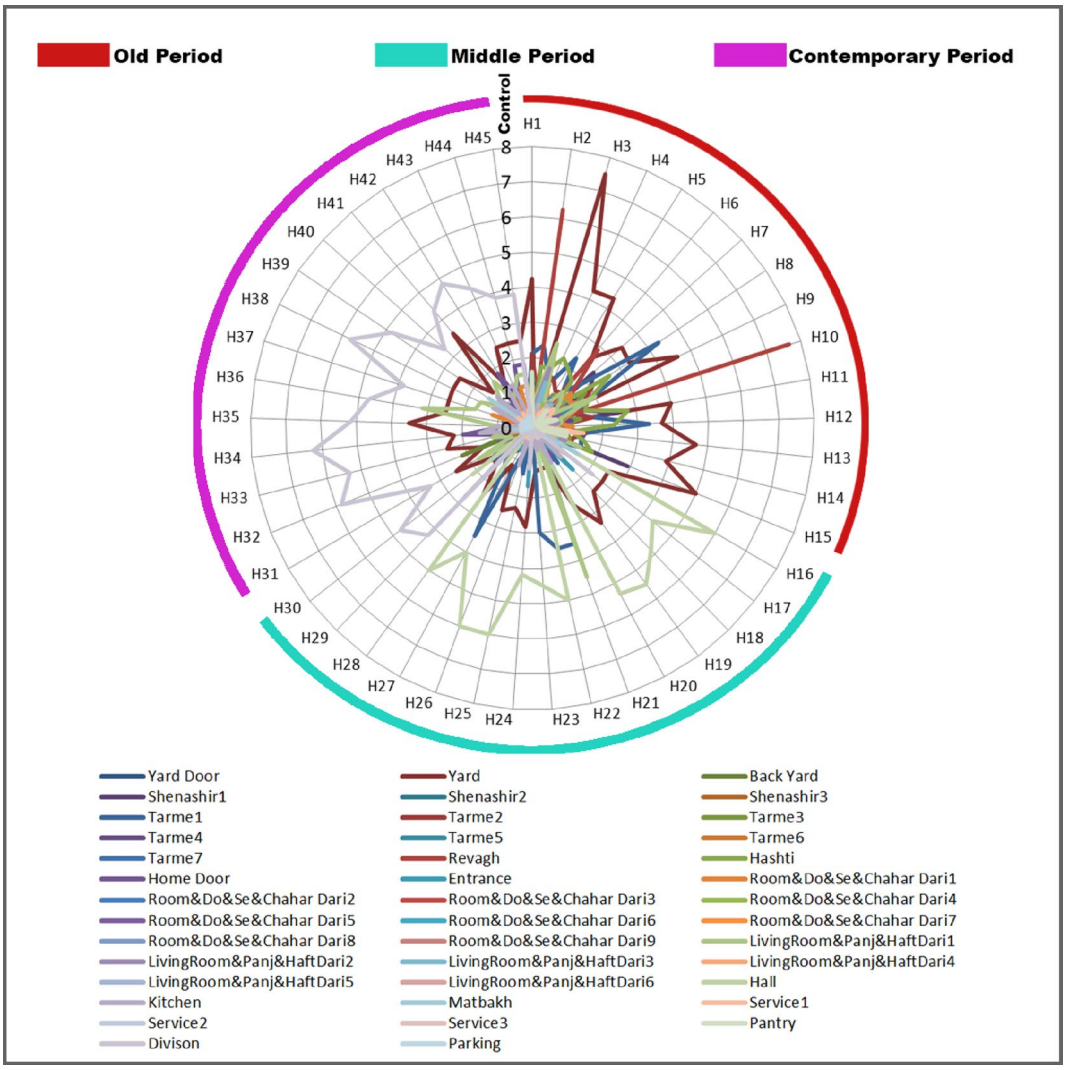
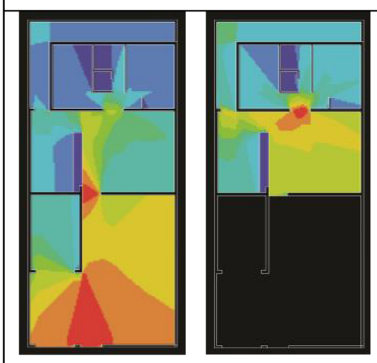
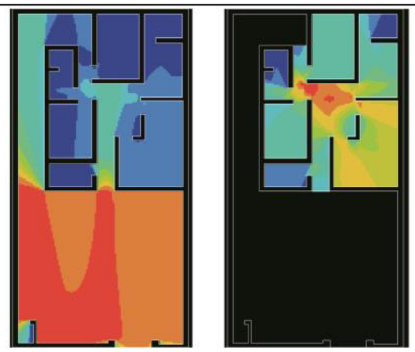
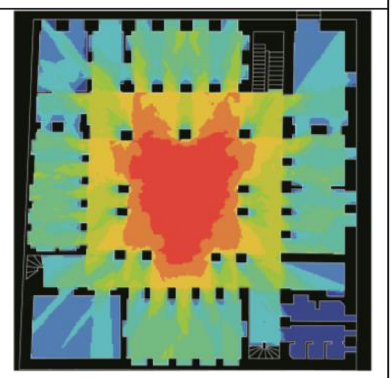


Fig. 7 Control of spaces in Bushehr's houses

Discussion

The analyses conducted on the studied samples were divided into three groups based on the time of construction. Before concluding, the obtained data were evaluated through factor analysis to check the accuracy of this basis. In this regard, in the first step, the data on integration, control, choice, entropy, and the level of open, semi-open, and closed spaces in all surveyed houses were inserted into SPSS. The KMO and Bartlett's tests were performed on the data to evaluate the adequacy of the number of studied houses. According to Table 3, a KMO value of 0.881 indicates the adequacy of the sample size and the scree plot cattle diagram demonstrates there are four components (Fig. 9). Subsequently, the cumulative percent of the rotation sums of squared loadings have been investigated in the general variance table. This value (82.231%) indicates that more than 50% and almost 82% of the data from the analysis are common and it is possible to continue the analysis to discover the categories. In the next step, using the rotated component matrix table, the number of extracted categories and the concepts that define each of these factors could be discovered (Table 4). Consequently, the boundary commonalities in houses number 38, 33, 35, 39, 43, 42, 34, 32, 44, 45, 37, 31, 40, 30, 29, 17 and 41 define the first category. Houses number 28, 26, 22, 27, 20, 18, 19, 16, 23, 25, 24, and 21 are the second category, houses number 9, 5, 11, 15, 14, 1, 13, 3, 8, 7, 4 and 12 form the third category and houses 10 and 2 form the fourth category. Houses

Table 2 Samples of visibility in Bushehr's houses from each historic era

New- H43	Middle- H24	Old- H10
		
		

number 6 and 36 were removed from the review process as they had nothing in common with other houses.

As a result, the houses of Bushehr are divided into four categories. Each of these categories has specific characteristics that distinguish it from other ones. The first type is defined by the high rate of parking integration, parking choice, yard door entropy, yard entropy, backyard entropy, home door entropy, room entropy, bathroom entropy, toilet entropy, division entropy, and parking entropy. Based on these characteristics, the parking space of this type of house is considered the most public space of the house, and its spatial structure is such that it is connected to other spaces with the shortest path. This shows the importance of parking space compared to other spaces in the house, even living spaces. On the other hand, the high entropy of other spaces of the house indicates a high degree of difficulty that residents face in moving from each of these spaces to others. These spaces and features are seen in contemporary houses. Accordingly, the first type of Bushehr houses is contemporary or new houses in the time category. This type of house has a yard door, yard, parking space, backyard, Tarme, home door, reception room, kitchen, Matbakh, division/partition space, room, bathroom, and toilet which are connected according to Fig. 10.

The direction of houses in this category is north–south and environmental and climatic factors do not affect this direction. In this type, when the yard door opens, the yard, Tarme, home door, living room, and sometimes some bedrooms can be seen from the public passage. Therefore, the hierarchy from the public urban to the private space of the house is deficient and visual dominance is one of the problems of this category of houses. Among the mentioned spaces, the highest visibility is for the yard. However, with omitting natural features and vegetation, the open space of the yard is not a living functional space; it is merely a place of crossing from the urban passage to the house as well as the parking space of the car. After that, the living room and the division space have the highest visibility and the lowest privacy. With the most integration and connection with other closed spaces of the house, the living room is a public space that is connected with other private spaces. In this category, there is no semi-private space in the house, and the public parts are dominant to the private and service sectors of the house, including bedrooms, kitchens, bathrooms, and toilets, and thus the hierarchy of space and privacy is disrupted. In this type of house, rooms, bathrooms, and toilets have little connection with other spaces, which leads to more privacy. Also, in the houses of this group, semi-open space has formed a very small part of about 3% of the house and has been even removed in some of the houses. This has led to the connection between open and closed spaces without joints and hierarchies and has affected the life qualities resulting from the existence of semi-open space among the spaces of the house. Semi-open space plays an important role in controlling climatic factors in the house and creating thermal comfort in different seasons by controlling the amount of natural light and local breeze, but it has been disturbed in the houses of this group.

The second type of Bushehr houses is defined by the high rate of control of Hall, yard door entropy, yard entropy, backyard entropy, home door entropy, entrance entropy, and hall entropy. The space that distinguishes

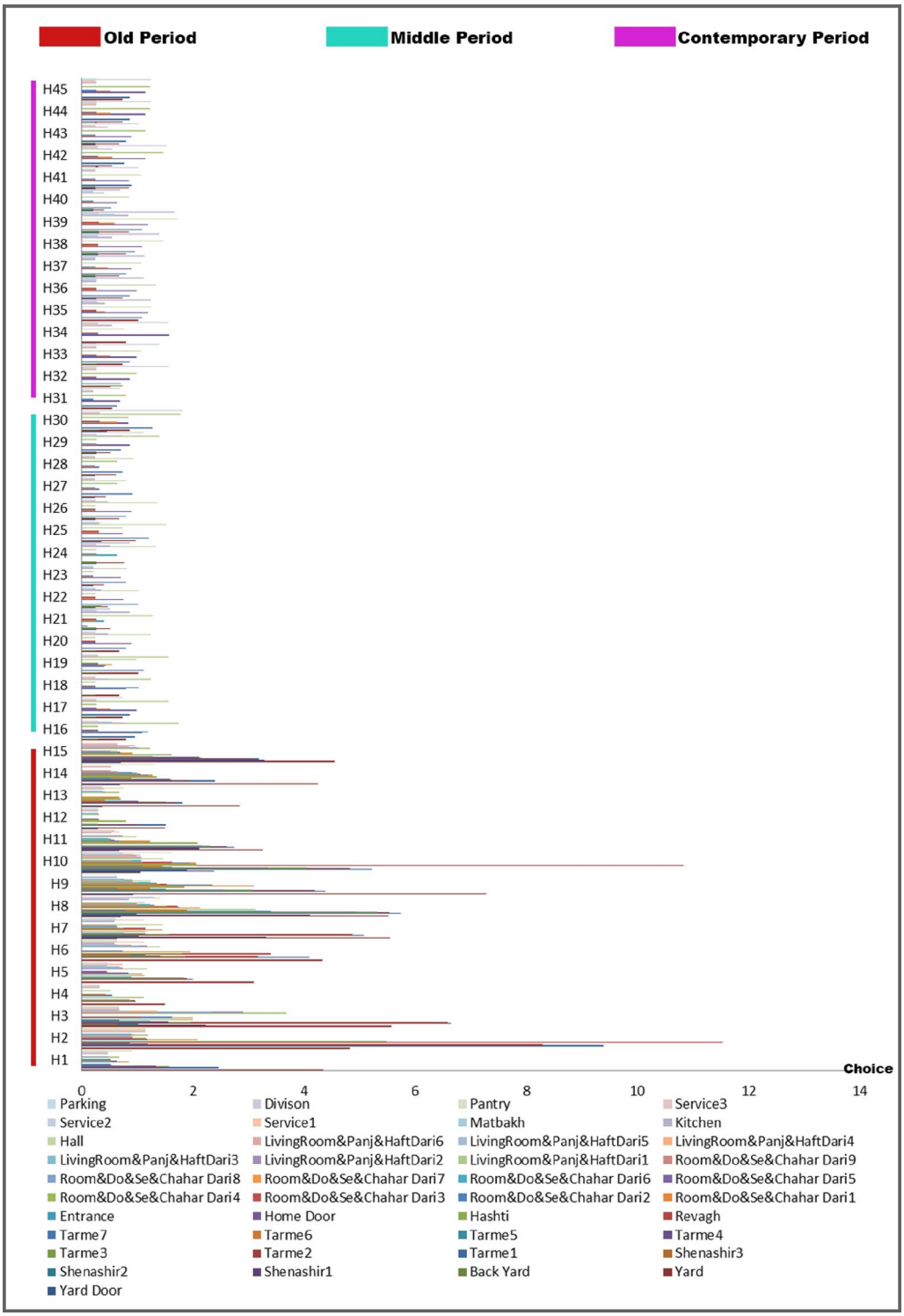


Fig. 8 Choice of spaces in Bushehr's houses

Table 3 KMO and Bartlett

Kaiser–Meyer–Olkin measure of sampling adequacy		.881
Bartlett's test of sphericity	Approx. Chi-square	15,227.002
	df	990
	Sig	.000

this category from other houses is Hall which has a high degree of control and entropy. It also is connected to other spaces with dominance while maintaining its privacy. These features indicate the semi-private semi-public nature of the Hall. The open and semi-open spaces have a high level of entropy and residents have to go through a spatial hierarchy to go from them to closed spaces. All these features can be seen in the houses of the middle period, and thus the second type of houses in Bushehr is the houses of the middle period in the time categorization. This type of house has a yard door, yard, parking space, backyard, Tarme, home door, Hall, living room, kitchen, Matbakh, division space, bedroom, bathroom, and toilet which are connected according to Fig. 11.

In this category, when the yard door opens, the yard, Tarme, home door, and Hall are visible from the public passage, and the semi-public-semi-private space of the house, i.e. the Hall, is overlooked from the public urban space. The vegetation in the open space of the yard, including trees such as palm, mango, Terminalia Catappa, Ziziphus, Syzygium Cumini, citrus, etc. in combination with Bougainvillea, Matthiola, jasmine, the caper bush, Teucrium Polium, etc. is effective in creating thermal comfort as well as peace of mind of the residents. Despite the high temperature in three quarters of the year, the residents of these houses consider the yard as a living part of the house and have maintained their connection with it. On the other hand, this type of house has the semi-open space of Tarme in the spatial depth of just before the home door with approximately 4% of the house space. Tarme is just a transitional stage in the hierarchy of entering the closed spaces of the house, which is dominated by the public passage and has negatively affected the level of privacy, desirable view, connecting with nature, and as a final point functional and visual use of open space without oversight and loss of residents' privacy. In the closed space of this category, a semi-private semi-public space, i.e. Hall, has the highest integration and connection with other spaces. Hall acts as a joint between the private and public spaces of the house and creates privacy and hierarchy. On the other

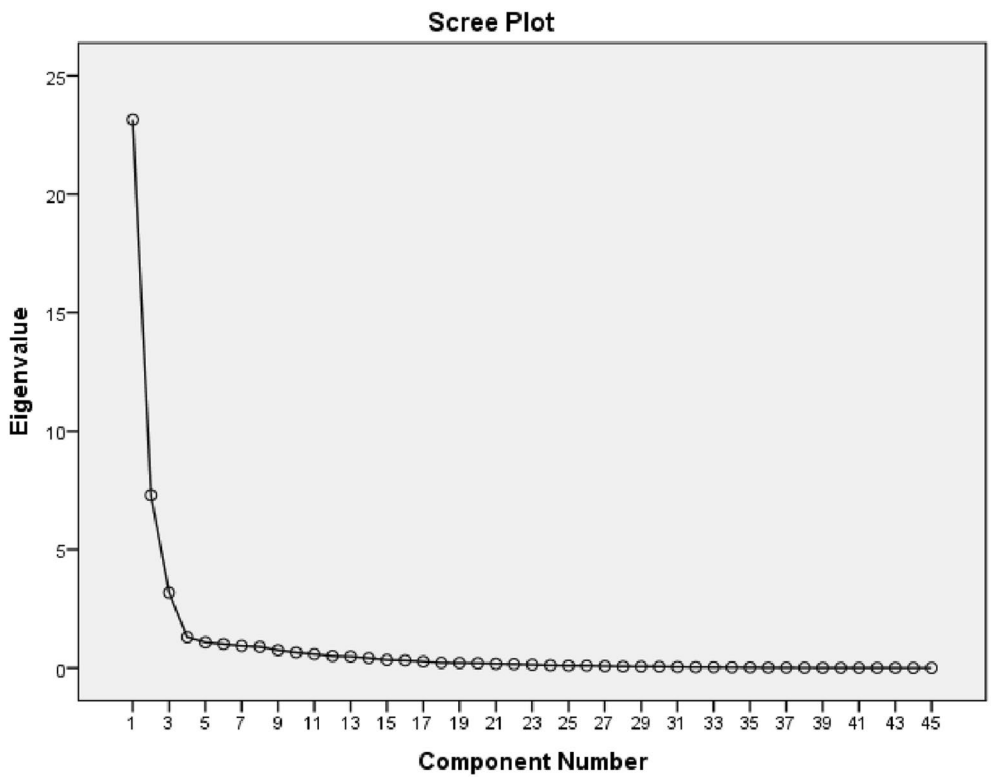


Fig. 9 Scree plot cattle of extracted components

Table 4 Rotated component matrix[a] table and factors extracted

	Component					
	1	2	3	4	5	6
var038	*.923*	.243	.129	.012	.003	.004
var033	*.919*	.298	.124	.010	− .005	− .002
var035	*.901*	.243	.226	− .065	− .030	.008
var039	*.900*	.282	.108	− .046	− .022	− .017
var043	*.893*	.332	.116	− .009	− .003	.022
var042	*.886*	.282	.113	− .009	− .031	.001
var034	*.881*	.137	.054	− .081	.004	− .030
var032	*.879*	.272	.076	.053	.013	.002
var044	*.875*	.306	.198	− .043	− .044	.018
var045	*.875*	.307	.198	− .043	− .044	.019
var037	*.867*	.358	.141	− .005	− .010	.031
var031	*.816*	.402	.234	.001	− .024	.057
var040	*.815*	.403	.108	.046	.013	.021
var030	*.790*	.492	.068	.085	.016	− .021
var029	*.757*	.500	− .009	.023	.028	− .017
var017	*.666*	.660	.153	.021	.015	− .031
var041	*.342*	.121	.034	.002	.003	− .037
var028	.345	*.843*	.245	− .032	− .024	.036
var026	.417	*.837*	.219	.008	.010	− .037
var022	.347	*.833*	.201	.090	− .027	.039
var027	.289	*.831*	.200	.041	− .045	.082
var020	.433	*.829*	.210	.005	.009	− .036
var018	.341	*.827*	.095	− .089	.026	− .093
var019	.349	*.826*	.275	− .029	− .010	− .042
var016	.378	*.826*	.132	− .024	.010	− .056
var023	.345	*.807*	.248	.069	− .039	.103
var025	.390	*.805*	.319	.031	− .022	.010
var024	.458	*.712*	.044	− .171	.025	− .072
var021	.481	*.593*	.148	.018	− .057	.065
var009	.034	.014	*.866*	.162	.139	− .047
var005	.163	.238	*.859*	.014	− .114	.028
var011	.150	.191	*.850*	.069	− .154	− .015
var015	.070	.107	*.846*	.073	− .004	− .010
var014	.051	.104	*.819*	.068	.154	− .073
var001	.129	.222	*.818*	.004	.107	.000
var013	.196	.200	*.797*	− .085	.088	.066
var003	.133	.099	*.795*	.136	.020	.013
var008	.023	.058	*.793*	.241	.027	− .054
var007	.083	.106	*.780*	.304	− .096	− .054
var004	.280	.351	*.755*	− .094	− .119	.011
var012	.223	.378	*.700*	− .019	− .110	.127
var010	− .064	− .037	.366	*.844*	− .036	− .012
var002	− .010	− .003	.489	*.788*	.053	.001
var006	− .030	− .035	.056	.001	*.962*	.017
var036	− .018	− .010	− .049	− .012	.017	*.958*

Extraction method: Principal component analysis

Rotation method: Varimax with Kaiser normalization[a]

[a] Rotation converged in 6 iterations

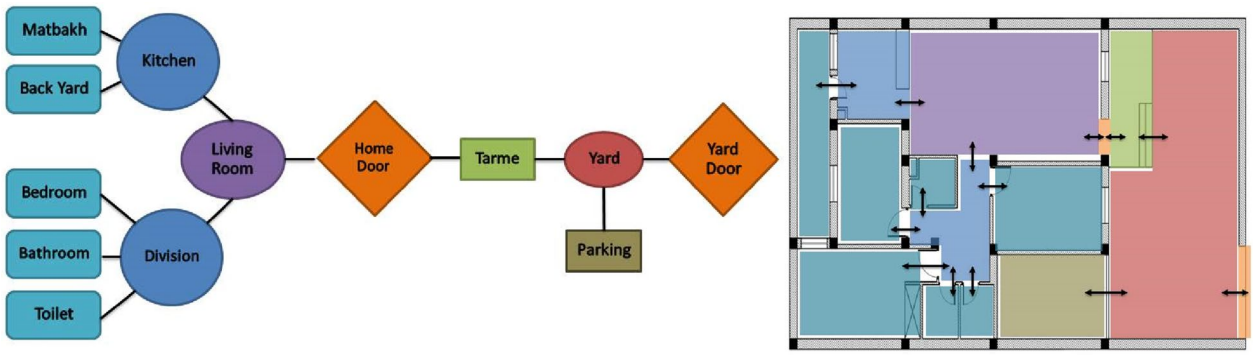


Fig. 10 Type one of Bushehr's houses

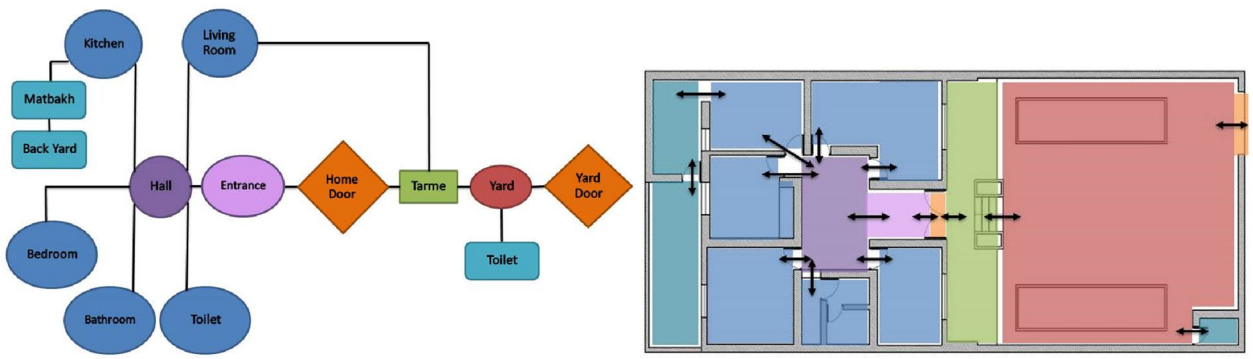


Fig. 11 Type two of Bushehr's houses

hand, however, it has given equal importance to other closed spaces by dominating them. Thus, in this category, living room, kitchens, bedrooms, bathrooms, and toilets are accessible in a certain depth of hierarchy and have the same amount of choice, even though their usage rate is completely different.

The third category of houses in Bushehr is characterized by a high rate of closed space, yard door entropy, yard entropy, Tarme entropy, Hashti entropy, the entropy of DoDari, SeDari, ChaharDari, PanjDari and HaftDari, Matbakh entropy, and entropy of bathroom and toilet. Accordingly, in these houses, the closed space is more than the open and semi-open space. The yard door, yard, Tarme, Hashti, and all living spaces have a high level of privacy and it is not easy to go to them from other spaces. These features and spaces in a number of houses of the old period form the third category of houses in Bushehr. This type of house has a yard door, Hashti, yard, Tarme, DoDari, SeDari, ChaharDari, PanjDari, HaftDari, Shenashir, Matbakh, Ganje, Pastoo and service spaces including bathroom and toilet, which are connected according to Fig. 12.

These houses are placed adjacent to each other organically in accordance with the climate. Their direction is based on the position relative to the sea in the direction of wind suction for air drafts and thermal comfort. The height of houses in this category and their distance from each other vary according to the need for shade. The central space, which has the highest integration with other spaces, is the "yard", which is considered a semi-public space due to its location in relation to the public passage, home door, and Hashti, and considering the height of the house. It has the most control over other spaces and dominates their relationships. Numerous semi-open and closed spaces are connected to the yard. The semi-open space of Tarme with an equal degree of importance to the open space of the yard is sporadically combined with other living areas and considered a living space. Tarme has the ability to control the amount of light entering indoor spaces, allowing residents to use the open space of the yard without direct contact with sunlight. In the houses of this category, the level of space choice and the depth of the transition stages in the spatial hierarchy as well as the degree of importance of using that space are

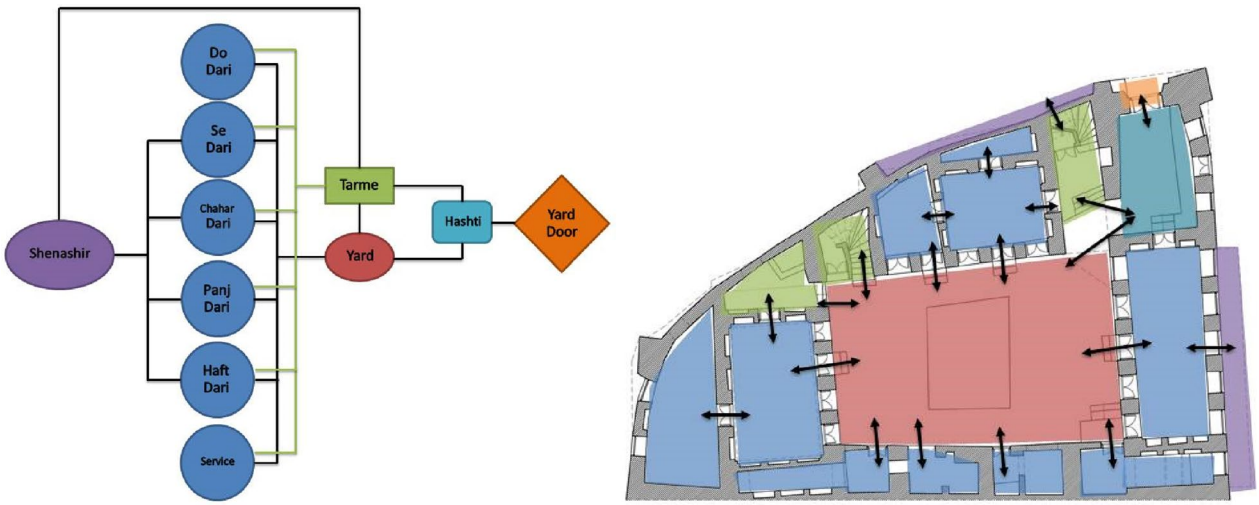


Fig. 12 Type three of Bushehr's houses

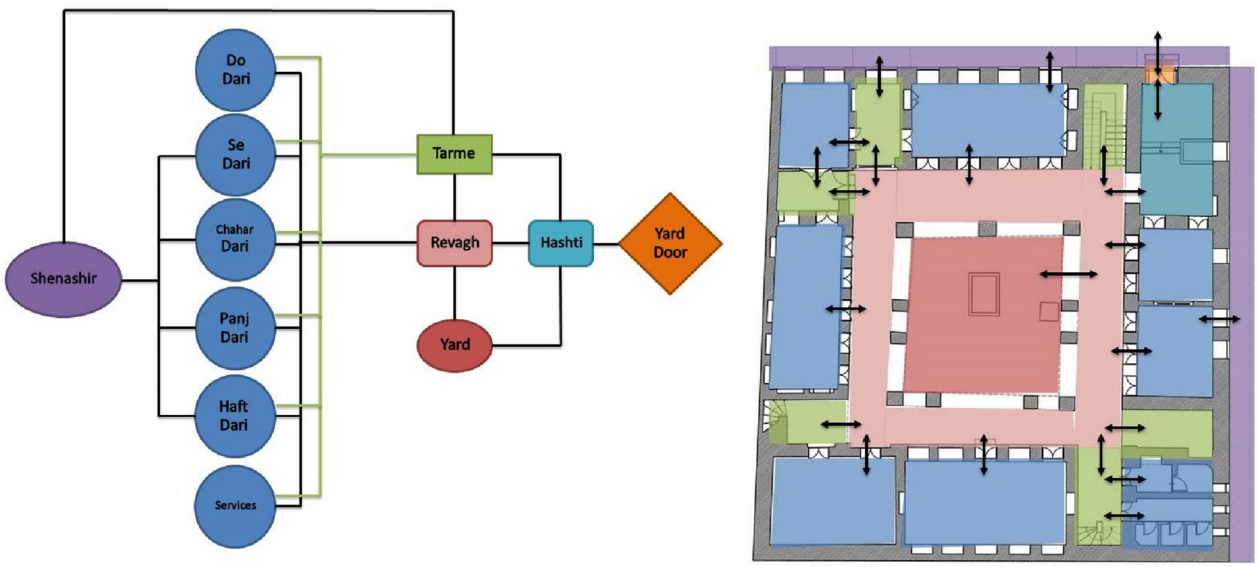


Fig. 13 Type four of Bushehr's houses

consistent with each other. In other words, the more private the space, the deeper its location in the hierarchy of the house and the less chosen it is. In contrast, any space that was more public was used more often, had a higher choice rate and less spatial depth. An additional point is a relationship between the space type and its location; public and semi-public-semi-private spaces, such as Revagh and courtyards, are located at a lower depth of the hierarchy while more private spaces, such as rooms and service spaces, require more spatial stages.

The last and fourth category of the houses in Bushehr is defined by a high rate of integration of Hashti, Revagh control, Tarme choice, Revagh choice, the choice of DoDari, SeDari and ChaharDari, Matbakh choice, semi-open space, yard door entropy, yard entropy, Tarme entropy, Hashti entropy, DoDari, SeDari, ChaharDari, PanjDari and HaftDari entropy, storeroom, Ganje, and Pastoo entropy. In this type, Hashti is the most public space and Revagh is considered to dominate other spaces of the house. Going to Tarme, Revagh, DoDari, SeDari, ChaharDari, and Matbakh

is possible in the shortest distances with the highest privacy. These features and spaces in a number of houses of the old period form the fourth category of houses in Bushehr. These houses have yard door, Hashti, Revagh, yard, Tarme, DoDari, SeDari, ChaharDari, PanjDari, HaftDari, Shenashir, Matbakh, Ganje, Pastoo and service spaces including bathroom and toilet, which are connected according to Fig. 13. All the features affected by the climate in these houses are similar to the third category, with the difference that, in the fourth category, Revagh, as a semi-open space, affects the spatial relations of the house and the amount of light and wind entering the house.

Conclusion

The houses of Bushehr in the past were built according to the climate of the region and the culture of the people. As time went on and the lifestyle changed with modernity, the shape of the houses also altered. The effect of the climate on the lives of the people faded and the houses lost their role as the comfort space of the inhabitants. However, the advent of technology has led to the creation of physical comfort without relying on the climate. This has had both positive and negative effects on the bodies of the houses. Based on this, four different types of houses have been created in Bushehr, each of which can add useful principles to contemporary housing architecture. The first type is new houses in which the parking has a space completely separate from the living spaces of the house and is connected to the house with a short pathway. Given the importance of cars in the daily lives of the contemporary generation, this feature can be used in the target houses of the research. The geographical orientation of the houses is always in the north–south direction in this type, which has reduced the connection between the body of the house and the climate. However, in the other three types, the relationship between house direction and climatic conditions has been emphasized. Using this feature in contemporary houses will reduce the consumption of non-renewable energies.

Hierarchy of access from urban public space to the private areas of the house in the first and second types of houses leads to visual dominance over the interior of the house and the loss of privacy. In the case of the third and fourth types, which are historic houses, this connection is created step by step and increases the privacy of the residents. Accordingly, contemporary houses should strive to increase privacy and reduce visual dominance. Another significant issue is the semi-open spaces of Tarme and Shenashir in the third and fourth categories. These spaces created a quality so that people could communicate more with the outside environment without being seen. Although this space becomes a terrace in contemporary houses, its unreasonable proportions, lack of visibility control, absence of privacy, and deficiency of control over climatic factors have prevented its daily use. As a result, it has become a space for the storage of additional equipment. Consequently, the qualitative characteristics of semi-open spaces in the third and fourth types can be used in contemporary houses. In all types of houses, a central semi-private–semi-public space separates the public, semi-public and private spaces of the house. This space does not exist in the first type and its usage can improve the quality of contemporary residential spaces. Also, outdoor plants have been used in all four types of houses. The presence of natural elements and native plants has a great effect on the thermal comfort and peace of mind of the residents. Bringing this element to the closed and semi-open space of contemporary houses will increase their sensual quality.

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We have submitted an original research article entitled "The implication of spatial-dispersion theory in housing genotypes of Boushehri historic and contemporary houses" for consideration by the Heritage Science Journal. Also, this paper is a critical case study, as Bushehr is a historical city in which its people have lived in different types of houses for centuries and one of the main reasons was the space syntax of the historic houses. Thus, in this paper, the adequate number of houses was spatially analyzed to find the positive criteria in each house genotypes to be used in contemporary housing. We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere and we have no conflicts of interest to disclose.
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All authors designed the study. RN conducted the experiments, analysed the data and wrote the paper. All authors contributed to the manuscript. All authors read and approved the final manuscript.

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