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## Original Research Article

# Evaluation of Effective Physical-Spatial Patterns in Creation of the Vernacular Housing Texture of Sufian Neighborhood in Boroujerd, Iran

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## Abstract

**Problem statement:** Absence of identity, lack of attachment to a place, and ignorance of history, nature, and climate, have created diverse problems for the architecture of different regions. A practical solution to improve the architectural condition is to study the vernacular architecture and the original architectural patterns in every region. The vernacular architecture reemphasizes the valuable architectural and cultural background of that region. In addition, the recognition and introduction of architectural patterns can resolve many cultural, social, and developmental needs in that region. Some places in the geographical area of Iran, despite their rich architectural background and valuable buildings, are less known and studied. Boroujerd city in Lorestan province is one of these areas.

**Research objective:** This study aims to identify and categorize the physical-spatial factors used in vernacular buildings of the Sufian neighborhood in Boroujerd and to evaluate their impact on vernacular buildings.

**Research method:** A combination of two research methods was used in two steps in this study. In the first step, the descriptive-analytical method was used to understand the physical-spatial patterns. In the second step, the TOPSIS method was used to evaluate the recognized patterns. Moreover, bibliographic research using related documents and resources, field observations, and questionnaires were used as the research tools.

**Conclusion:** This study seeks to identify the spatial-physical patterns used in vernacular housing of the Sufian neighborhood. These patterns include spatial building components, decorations, building materials, and climatic features. Finally, using a questionnaire and TOPSIS method, it is determined that the most significant physical-spatial patterns in vernacular housing of the Sufian neighborhood in Boroujerd are the building materials and construction techniques.

**Keywords:** *Physical-Spatial Patterns, Vernacular Architecture, Boroujerd Sufian Neighborhood, TOPSIS Method.*

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## Introduction

Many regions and cities in the geographical area of Iran are valuable sources of vernacular architecture that demonstrate the historical identity of the people due to their unique historical background, monuments, and architectural and cultural features. Boroujerd is one of these regions. From the urban planning point of view, Boroujerd city with an area of 270 hectares, can be considered as one of the most important cities of the country due to its historical texture and its architectural monuments such as the Grand Mosque, built more than a thousand years ago (Chegni, Didehban, & Hesari, 2021). Sufian neighborhood is located in the northwestern part of Boroujerd. The city was developed during the Qajar period. Problems caused by population growth, improper land use, unorganized urban development, and other public issues caused the vernacular texture of Boroujerd to be neglected and forgotten. These problems necessitate the need to recognize and study the vernacular architecture of this city. Vernacular architecture is based on the knowledge, the accurate cognition of the environment, spatial capabilities, and the technology used by ordinary people in the past to meet the residents' needs in line with respecting nature (Previtali & Zhai, 2016). This architecture follows specific living and economic patterns, lifestyles, cultures, social relations, and natural patterns (Kirbas & Hizli, 2017).

The vernacular architecture of each region is influenced by the climatic, geographical, and cultural conditions of that region. The vernacular buildings of each area represent centuries of experience in optimizing the use of materials, construction methods, climatic considerations, etc., and neglecting these achievements can lead to the destruction of vernacular architecture and its accomplishments (Maqouli & Ahmadzadeh, 2017). Therefore, this study aims to identify the physical-spatial factors affecting the vernacular housing of the Sufian neighborhood in Boroujerd and introduce the most prominent factors. The study

first presents the vernacular physical-spatial factors and patterns used in the residential buildings of the Sufian neighborhood of Boroujerd, which is based on literature review and extensive research. In the next step, the pattern structures were studied. Eventually, the multi-criteria decision-making method (TOPSIS) is used to evaluate and determine the importance of spatial-physical factors and patterns used in vernacular buildings of this neighborhood. Accordingly, the main research questions are:

- What are the physical-spatial patterns and components of vernacular housing of the Sufian neighborhood in Boroujerd?
- What are the most effective patterns that have created the vernacular housing of the Sufian neighborhood in Boroujerd, using the TOPSIS method?

## Research background

There is no research in recognizing the vernacular patterns used in the historical texture of Boroujerd. However, many studies have been conducted in Iran and other countries to understand vernacular architecture. The specific spatial patterns and physical factors have been reviewed in each study to identify vernacular architecture (Table 1). The research on the recognition of vernacular patterns shows that different patterns have been mentioned to recognize and evaluate vernacular architecture. The most important patterns have focused on understanding the structure and local components, regional decorations, materials, construction techniques, climate, and design context. Therefore, four patterns have been identified and consequently evaluated using the TOPSIS method through questionnaires to evaluate and introduce the construction patterns used in the vernacular housing of the Sufian neighborhood in Boroujerd.

## Theoretical foundations

### • Vernacular architecture

Vernacular architecture is a perfect architectural

Table 1. research background. Source: Authors.

No.	Research approach and the most significant patterns	Research title	Authors
1	In this study, the vernacular housing patterns used in Rasht are identified and categorized. The essential physical components and building materials are identified.	Housing typology in the old texture of Rasht	Khakpour, Ansari & Tahernian (2010)
2	In this study, the functional, physical and constructional evolution has been explored. This study comprehensively deals with the physical changes in buildings, materials, constructions, decorations, geometry, and introversion and extroversion of buildings.	Analysis of physical changes in Gorgan houses during the Qajar period	Ghelichkhan, Etesam & Mokhtabad Amreie (2012)
3	In this research, understanding the housing typology of vernacular patterns is based on the physical-spatial features. Also, the physical properties, including materials, decorations, and physical patterns, have been discussed.	Typology of historic houses in the old texture of Mashhad, from the early Qajar period to the late Pahlavi period	Farahbakhsh, Hanachi & Ghanaie (2017)
4	In this research, the spatial structure of houses has been studied. Also, the structure and constituent components of spaces in buildings have been studied.	Reflections on the spatial structure of the traditional housing typology in Dastgerdan section of Tabas	Zarei, Mousavi Haji & Sharif-Kazemi (2018)
5	After classifying the housing types, their physical and spatial organization has been discussed.	Analysis of morphological features in chahar-sofeh housing and its influence on the morphology of traditional houses in Isfahan	Rahravi, Valibeig, Dehghan & Masoud (2019)
6	The vernacular design criteria have been identified in hot and dry climates with an emphasis on materials.	Design criteria in the structure of the central courtyard and summer hall of Qajar houses in Yazd	Yazdi, Mofidi Shemirani & Etesam (2019)
7	In this research, the physical and spatial components have been mainly studied and introduced. The indicators evaluated in this research include climate, building form and technique, and materials.	Evaluation of factors affecting form in indigenous architecture, in cold and mountainous climates	Silvayeh & Asefi (2019)
8	In this study, people's effort in each region to use local materials in the vernacular architecture of that region to achieve thermal comfort has been studied.	Classification and specification for evaluation of the vernacular architecture	Zhai & Previtali (2010)
9	In this research, the authors have focused more on the used materials and construction techniques regarding the climate to understand the vernacular architecture.	Lessons from the vernacular architecture of Britain	Forster, Heal & Paradise (2014)
10	The impact of local materials on energy savings in vernacular housing has been reviewed.	Assessing the impact of the material transfer on the energy consumption of vernacular housing Energy	Praseeda, Monto & Venkatarama Reddy (2014)
11	The effect of local materials on achieving thermal comfort in vernacular housing has been discussed.	Traditional techniques to improve thermal comfort in Malaysian vernacular housing	Chyee Toe & Kubota (2015)
12	In this research, the constructive factors, the effect of materials, climate, and design context have been studied.	Functional understanding of the vernacular architecture of the Bhopal region of India	Mitra & Bose (2017)

trend that has never been specifically addressed in the history of architecture. It has been widely used since the middle of the twentieth century. Architectural historians, especially until the twentieth century, focused on formal, scientific, and monumental features in architecture. Formal art with a specific artistic style has been

traditionally taught in art and architecture history books. However, the vernacular art or the local art was not studied continuously and regularly before that time. With the development of civilizations, the formation of governments, and the creation of powers, the first models of formal architecture, with custom-made designs and plans, were proposed to

be built by experts. However, few models were built compared to vernacular structures (Naghavi & Kiani, 2019).

The vernacular architecture was developed by people whose design decisions were influenced by their cultural tradition. Also, their knowledge was developed during a long period of trial and error and innovation in their location. It can be said that the house owner was the architect, designer, and builder of vernacular architecture. The owner determined the original shape of the house in which he lived and changed and improved it, using local resources and labor (Agorsah, 1985). The characteristics of vernacular architecture are studied in terms of design, construction, and planning that affect the thermal comfort in the house. These characteristics identify the socio-economic and climatic conditions in different geographical locations, with different designs, planning, and materials (Chandel, Sharma & Marwah, 2016). Vernacular architecture has maintained its unique identity, despite undergoing transformative changes throughout history. Since it is considered a valuable identity in every region, it reflects their customs, spirit, emotions, thoughts, beliefs, style, and art (Salahi Esfahani, Mirza Ali & Sadin, 2017).

#### • Vernacular housing

Human housing, regardless of its physical

dimensions and natural and climatic criteria, is influenced by socio-cultural factors and beliefs and transcendental requirements of life that give meaning to life. The housing that has such criteria is called vernacular housing. In general, any housing affected by socio-cultural, natural, and economic factors of the environment is called vernacular housing (Khakpor, Ansari, Sheikh Mehdi & Tavoosi, 2015). In Iran, builders have focused on nature-friendly design, beautifying the environment, adapting to the climate, and creating physical and mental peace and comfort. Housing construction is appreciated when it is compatible with the specific natural and climatic characteristics and when the spiritual and divine aspects of residents' lives (religious and divine beliefs) are considered (Arbabzadeh, Etesam, & Mofidi Shemirani, 2020). Vernacular architecture strikes a balance between social, economic, and political powers and flourishes as a result of this balance (Haeri Mazandarani, 2009). The effective phenomena in the formation of Iranian vernacular housing are categorized as internal and external factors and phenomena (Table 2).

#### Understanding the history of residency in Boroujerd

There is no accurate information about the situation of Boroujerd in pre-Islamic times, and there are no

Table 2. Factors and phenomena creating vernacular housing. Source: Authors.

Factors	Definitions	Effective phenomena
Internal factors	General and cultural factors and phenomena, as a whole, stimulate the creation of a kind of national or regional architecture that can eventually lead to the emergence of vernacular architecture.	General and cultural phenomena
	Political conditions have also influenced the construction of vernacular housing. For instance, in cities where people were not socially safe and had to face the threat of strangers, the building entrances were unadorned so as not to attract others' attention of others.	Political and governmental conditions
	Economic factors can also affect the shape and size of a vernacular house. A low population and inexpensive lands are some influential economic factors.	Economic conditions
	There were some special materials and structures in each region that necessitated a unique type of local and vernacular architecture, distinguished from other architectural styles. This indicates that each region had its own vernacular architecture style.	Local conditions
External factors	External factors and phenomena are a group of cultural and architectural factors of other regions that have affected the vernacular architecture of a specific area. It is quite clear that, like today, the adjacent lands had different cultures and often influenced each other in the past. Naturally, the cultural exchanges were unstable in different historical periods, conditions, and requirements.	

valid archeological studies about this city. Opinions about the position of Boroujerd in the pre-Islamic period are different and based on speculations. Moghaddas Jafari, in his book the geography of Boroujerd city, asserts that this city was located near the Grand Mosque before Islam. Still, Hazin, in his book an overview of Boroujerd city, believes that the location of the pre-Islamic city was near the present village of Fial, which was developed around the Grand Mosque after Islam (Piriaei & Aghadavoudi, 2017). According to historical texts, Boroujerd had been of great political and social importance and prosperity until the end of the Seljuk period. According to historical books such as Ibn Athir's book *Al-Kamil*, *Rahat Al-Sadr* Ravandi, *Zobdeh Al-Nasr*, the city was at its prime during the late Seljuk period Emad al-Din, Kateb Isfahani, etc. (Muqaddas Jafari, 2002). During the reign of Fath Ali Shah Qajar, Mohammad Taqi Mirza Hesam Al-Saltanah was the governor of Khuzestan, Lorestan, and Boroujerd and made Boroujerd the center of his government. By his order, the city bazaar was repaired, and the construction of the Soltani (Imam Khomeini) Mosque was completed (Moradi, Pirzadi & Moradi, 2018).

## Study area

The historical texture of Boroujerd city consists of four neighborhoods, including Dodangeh, Sufian, Qadqoon, and Yakhchal neighborhoods. In terms of antiquity, first, the Sufian and Dodangeh neighborhoods have emerged, and then Qadqoon and Yakhchal neighborhoods were formed, respectively. The formation of the Sufian neighborhood dates back to the Qajar period. The Sufian neighborhood is located in the northwestern part of the historical texture. The area of the Sufian neighborhood is 51. 7 hectares, which covers about 20% of the whole historical area (270 hectares). The best historic houses are located in the Sufian neighborhood, both physically and in terms of antiquity. Large gardens were found in this neighborhood during the Qajar period, and

there were large monasteries in these gardens that were in use until the end of the Qajar government. Eventually, the Qajar government destroyed the gardens and monasteries out of fear of the Sufis. This place was then transformed into residential areas with the name of Sufian. As a result, most of the residential houses in the Sufian neighborhood belong to the Qajar period (Ahmadi Tabatabai, 2005).

## Case studies

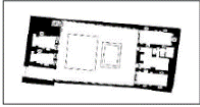
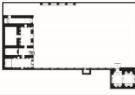

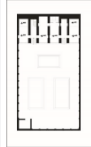


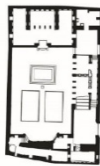
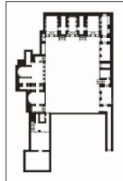
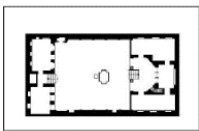
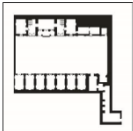
In this section, ten houses in the Sufian neighborhood of Boroujerd have been selected. Their selection was based on their location in the Sufian neighborhood, their historical antiquity, and registration in the cultural heritage organization of Iran (Table 3).

## Research methodology

The research method is combined of different methods conducted in two stages. In the first stage, the physical-spatial patterns used in the vernacular housing of the Sufian neighborhood of Boroujerd were identified by the analytical-descriptive research method and field studies. The literature on vernacular housing architecture was reviewed in a bibliographic study and field observations to scrutinize the physical-spatial patterns. After recognizing the physical-spatial patterns, the most important patterns in buildings were evaluated and weighed in the next stage. TOPSIS method was used to evaluate the physical-spatial patterns in the research. TOPSIS model is known as one of the best multi-criteria decision-making methods used in many studies due to the accurate mathematical analysis and the slightest defects in ranking the alternatives (Makvandi, Astani & Lorestani, 2015). The TOPSIS method is based on an evaluation matrix consisting of m alternatives and n criteria. According to this method, the alternatives are prioritized based on the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution (Saeedi & Dashti,



Table 3. Case studies' specifications. Source: Authors.

	Hariri House	Hatami House	Birjandi House	Bozorgmehr House	Efttekhar House
Plan					
Period	Qajar	Qajar	First Pahlavi	Qajar	Qajar
Area	546 m <sup>2</sup>	1140 m <sup>2</sup>	540 m <sup>2</sup>	1200 m <sup>2</sup>	1150 m <sup>2</sup>
Number of Entrances	1	2	1	1	3
Stories	2	3	2	3	2
Orientation	Rasteh	Rasteh	Rasteh	Rasteh	Rasteh
	Moghisi House	Mesri House	Moradi House	Ronasi House	Setayeshi House
Plan					
Period	Qajar	Qajar	Qajar	Qajar	Qajar
Area	1620 m <sup>2</sup>	830 m <sup>2</sup>	780 m <sup>2</sup>	330 m <sup>2</sup>	1050 m <sup>2</sup>
Number of Entrances	3	2	2	1	1
Stories	3	2	2	2	2
Orientation	Rasteh	Rasteh	Rasteh	Rasteh	Rasteh

2017). To score the alternatives, a questionnaire was completed by 25 experts and people who practiced architecture in Boroujerd, including architecture professors with experience in the historical texture of Boroujerd, and experimental architects in the field of traditional architecture. Since the selected people all had a history of being present in the vernacular texture of Boroujerd and were practically familiar with the texture, this statistical community was valid to achieve the correct results. In the last stage, the most effective factors in the formation of physical-spatial patterns in the residential texture of the Sufian neighborhood were identified and evaluated.

## Data analysis

### • Assessing the structure and vernacular components shaping the space

In vernacular architecture, the physical and

incorporating components are designed in harmony with the architectural structure of the building. In fact, the entire components and elements of the building are organized in an integrated whole. Whether individually or as a part of a complex, the buildings in Iranian architecture are created based on the three patterns of open space, closed and semi-open space (Table 4), (Haeri Mazandarani, 2009).

### • Building decorations

The decorations and architectural ornaments in the vernacular housing of Boroujerd have undergone significant changes during different eras, especially the Qajar and Pahlavi periods. The materials used in the decorations of the vernacular housing of Boroujerd can majorly distinguish the buildings of this region. The unique decorations used in the Sufian neighborhood of Boroujerd are described in Table 5 based on their materials.

Table 4. Assessing the vernacular structure and components of vernacular housing in the Sufian neighborhood of Boroujerd. Source: Authors.

Type of space	Physical elements	Used elements	Image
Open space	yard	The buildings are divided into two general categories: multi-yard buildings and single-yard buildings. Single-yard buildings are divided into one-sided, two-sided, L-shaped, and U-shaped buildings.	
	Roof	Mostly flat roofs due to weather conditions of cold and dry climate	
	Stairs	Stair tread and riser is usually made of brick, rarely of clay	
Closed space	Panjdari (a chamber with five doors)	A square and rectangular space-door-vertical windows-wooden decorated ceiling-niche-wooden decorated windows- often used as the guest room	
	Seh-dari (a chamber with three doors)	A square or rectangular space - smaller than the Panjdari room - niche - door- for private use	
	Shabestan (a hall with multiple columns)	Located on the first floor, and used in winter, an arcade space	
	Main living room (Shah-neshin)	It can be seen in some houses, especially multi-yard houses – it is smaller than other spaces.	
	Kitchen	Located in the private part of the building - its main components are the oven, stove, window, and niche.	
	Store	It is close to the kitchen area - it is used to store grains.	
Semi-open spaces	Entrance	The entrance border of the building - its main components are the entrance door arcade, which is used in almost all buildings	
	Hashti (vestibule)	It is not seen in all buildings – a conversation space	
	Corridor	It is not seen in all buildings - it is usually seen in houses with several yards – it has a niche	

### • Materials and structures used in vernacular buildings and their construction techniques

The vernacular buildings of Boroujerd were made of brick, clay, and wood. The structural systems of these buildings were founded on load-bearing walls (Table 6). A chain of wooden structures was used to make the buildings stronger and more resistant to earthquakes. The thick and load-bearing walls

of vernacular buildings also served as thermal insulation. Limestone and mortar were used to build vernacular houses. The main facade of the building was made of brick. The thick walls of the building were made of clay and brick. Due to the cold and dry climate of Boroujerd, the roofs had a flat surface and were covered with multiple layers of thatch (made with clay and straw). The ceiling

Table 5. Classification of decorations in vernacular buildings of Boroujerd based on the used materials. Source: Authors.







Decorating materials	Technique	Location	Image
Brick	Rag-chin	The yard walls-facades- meshed windows	
	Dandan-Mushi	The upper part of the facade	
	Khofte-Rasteh	In the yard for decoration	
	Gol-andazi	Interior wall and external facade	
Tile	Moaragh	Entrance space of the building	
	Moagheli	External and internal spaces	
	Haft-rang	Used more in external spaces	
Wood	Structure	Used for columns	
	Decoration	Wooden decoration of the ceiling, doors, and windows	
Stucco	Heshteh-Rfteh with simple patterns	Only in the interior spaces and in the guest rooms	
Painting	Emotional	In rare cases and only in the interior space	
			

Table 6. Recognition of materials used in vernacular buildings of Boroujerd.

The materials used in vernacular buildings of Boroujerd	Descriptions	Materials	Building components
	The walls were thickly plastered with a combination of brick and stone	Brick and clay	Wall
	Brick can also be seen in some buildings	Variable- but mostly stone	Flooring
	Using thatch with wooden ceiling structure, and sometimes ceiling decoration	thatch and wooden structure	Ceiling
	-	Lime and stone mortar	Foundation



structure was made of wood and covered with mud and soil.

### • Climate and orientation in vernacular buildings of Boroujerd

Climate has been one of the most important factors in the formation of architecture. Since it is a determining factor, the architect and the building users should be able to control the building components related to the climate, and many aspects of climatic design should be taken into consideration. One of the most important climatic factors has been solar absorption and building orientation. For a long time, the traditional houses of Boroujerd had Roon Rasteh, meaning that the buildings were oriented toward the northeast-southwest direction. The effects of climate on Boroujerd buildings are described in Table 7.

### • Evaluation of the most effective physical-spatial factors

To determine the most influential factors in the

formation of spatial, physical patterns in this part of the research, the multi-criteria decision method or TOPSIS method has been used. This multi-criteria decision method has the slightest defects in ranking the alternatives. Huang and Yun first introduced this method. In evaluating and ranking the alternatives, the first choice is assigned to the alternative with the shortest distance from the positive ideal answer and the longest distance from the ideal negative answer (Saeedi & Dashti, 2017). The TOPSIS method consists of three stages.

- Stage 1: Recognition of the variables and criteria: The required variables and criteria of the study can be found in the literature review. In this study, the dependent variables are the four factors that make up the physical-spatial patterns of the vernacular buildings of Boroujerd, and the independent variables are the sub-criteria of the physical and spatial patterns. The independent and dependent variables are represented in Fig. 1.

Table 7. Boroujerd climate model and its effect on vernacular buildings of this city. Source: Authors.

Climatic features	Boroujerd has a cold climate with cold winters and mild summers
Weather data Maximum and minimum temperature Prevailing wind	In winters, the temperature drops to minus 18 degrees, and the maximum temperature of this city in summer is 38 degrees - more than 70 days are frosty in this city.  The prevailing wind of this city blows to the west.
The effect of climate on vernacular buildings	- Boroujerd city has a compact texture, and the buildings are built densely. - Most structures are low-rise buildings and rarely are three-story buildings. Large windows are not used, and the window area in buildings are small. Openings are vertical - Materials with high thermal capacity are used building have an introverted pattern, and they are divided into two parts, summer and winter parts

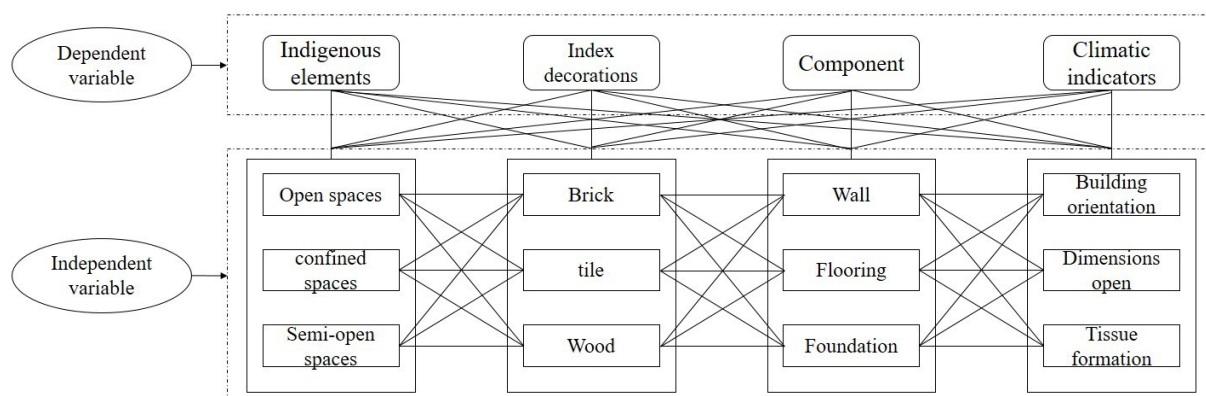


Fig. 1. Recognition of the independent and dependent variables of research to introduce the most effective physical-spatial factors. Source: Authors.

- Stage 2: Scoring the criteria: At this stage, 25 experts in this field scored the criteria in the questionnaires. The selected people are university professors, architects who have practiced architecture in this texture, and practical architects familiar with the vernacular texture of the Sufian neighborhood of Boroujerd. Since the criteria and sub-criteria are qualitative, the right tools should be used to quantify the qualitative data. In this study, a five-point scale has been used to score the physical-spatial factors in the residential context of Boroujerd in the Sufian neighborhood (research alternatives). The criteria can be scored from 1 to 5 based on their importance. The number 5 represents a very strong criterion, and the number 1 represents a very weak one. The alternative scores are shown in Table 8.

- Stage 3: Choosing the best alternative: TOPSIS method has been used to select the most suitable and most effective incorporating physical components. This method is used due to the ability to generate valid results, based on calculating the numerical value of the best and worst alternatives, with a relatively simple computational process and a multifaceted performance of criteria (at least two aspects) (Moghim-Kandolousi, Mohebbi Tafreshi & Mohebbi Tafreshi, 2018). In this step, the calculation is performed, and the effective components in the physical-spatial patterns of vernacular housing (alternatives) are weighed, and the best solution is selected.

After collecting the data obtained from the questionnaires (Table 9), the components of

the physical-spatial patterns are scored. Table 9 consists of four rows (A: the structure of vernacular components, B: significant decorations, C: components, D: climatic factors) and twelve columns (criteria) (1: open space, 2: closed space, 3: semi-open space, 4: brick decorations, 5: very strong decorations, 6: wood decorations, 7: wall construction, 8: flooring, 9: foundation, 10: building orientation, 11: opening dimension 12: texture formation). The numbers in the table represent the average scores on physical-spatial patterns or the alternatives in the decision matrix in the TOPSIS method.

#### • Computation steps using TOPSIS method

-Firstly, the decision matrix should be normalized according to Formula (1):

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^m r_{ij}} \quad (1)$$

(alternatives = i, elements = j and matrix elements = r)

-(Preparation of criteria weights): This step of the TOPSIS method consists of three parts. During these three steps, the  $E_j$  values for each criterion are calculated in Formula (2), the standard deviation of each criterion is calculated in Formula (3). Finally, the weight of each criterion is calculated using Formula (4):

$$E_j = -k \sum_{i=1}^m [P_{ij} \cdot \ln P_{ij}] \quad (2)$$

$$K = \frac{1}{\ln m}$$

$$d_j = 1 - E_j \quad (3)$$

$$W_j = \frac{d_j}{\sum_{i=1}^n d_j} \quad (4)$$

Table 8. The score ranking of the qualitative indicators in research. Source: Authors.

Very Weak	Weak	Average	Strong	Very Strong
1	2	3	4	5

Table 9. Decision matrix, according to the criteria scores. Source: Authors.

	1	2	3	4	5	6	7	8	9	10	11	12
A	471	4.68	4.68	3.75	4.35	4.01	3.12	3.35	3.19	2.05	2.65	3.06
B	3.12	3.01	2.11	4.69	4.28	4.15	2.45	3.13	1.96	1.19	1.98	1.46
C	3.95	3.16	3.36	3.33	3.11	3.6	4.12	4.24	3.41	2.49	3.75	3.96
D	3.25	2.81	2.25	2.58	3.85	3.32	2.05	2.08	3.19	4.08	3.76	3.42

The following, six steps are used to calculate the decision matrix algorithm.

Step 1: Converting the decision-making matrix to a normalized matrix using Formula (5):

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^m r_{ij}^2}} \quad (5)$$

These formulas are used since different quantitative and qualitative indicators can be calculated together (AhmadiAsl, Momeni & Attarian, 2019). To avoid intensive calculations, other tables and steps have been avoided, and only the normalized matrix (Table 10) is presented. The calculations in the TOPSIS method are very extensive, and in this research, Excel software has been used to perform the calculations.

Step 2: Create a weightless normalized matrix, for this purpose, Formula (6) is used:

$$V = N_D \cdot W_{nn} \quad (6)$$

Step 3: In this step, the ideal positive and negative options are determined using Formula (7):

$$A^+ = \{MAX(V_{ij}/\in J)\} (i = 1,2 \dots m). (j = 1,2 \dots n) \quad (7)$$

$$A^- = \{MIN(V_{ij}/\in J)\} (i = 1,2 \dots m). (j = 1,2 \dots n) \quad (7)$$

Step 4: Calculating the separation steps using equation (8):

$$d_{i+} = \sqrt{\sum_{i=1}^n (V_{ij} - V_j^+)^2} \quad i=1,2,\dots,m \quad (8)$$

$$d_{i-} = \sqrt{\sum_{i=1}^n (V_{ij} - V_j^-)^2} \quad i=1,2,\dots,m \quad (8)$$

Table 10. Normalized matrix. Source: Authors.

	1	2	3	4	5	6	7	8	9	10	11	12
<b>A</b>	0.607	0.689	0.738	0.521	0.514	0.521	0.495	0.512	0.523	0.401	0.398	0.516
<b>B</b>	0.425	0.425	0.325	0.635	0.521	0.565	0.423	0.504	0.311	0.201	0.348	0.263
<b>C</b>	0.536	0.462	0.475	0.425	0.423	0.501	0.698	0.635	0.541	0.476	0.654	0.600
<b>D</b>	0.401	0.411	0.336	0.421	0.525	0.432	0.394	0.325	0.536	0.825	0.635	0.598

Table 11. Prioritization of effective physical-spatial factors in the residential context of Sufian neighborhood in Boroujerd. Source: Authors.

Alternatives	TOPSIS score	Rank
Spatial incorporating elements	0.572	2
Used decorations	0.241	4
Vernacular building materials and construction techniques	0.609	1
Climatic effects	0.516	3

Step 5: In this step, the relative proximity is calculated using Formula (9):

$$cL_{i+} = \frac{d_{i-}}{d_{i+} + d_{i-}} \quad 0 \leq d_{i+} \leq 1 : i = 1,2, \dots m \quad (9)$$

Step 6: In the last step, the alternatives are prioritized based on  $cL_{i+}$ . An alternative is considered good when it is relatively closer to the standard alternative. (Sheikhi, Gharibi & Manavi, 2016). Finally, the studied alternatives, which influence physical-spatial factors, were evaluated according to Table 11.

## Conclusion

Recognition of vernacular architecture requires deep scrutiny in the existing case studies to understand the different aspects of Iranian vernacular architecture in the present time according to its definitions and examples. The vernacular architecture of each region reflects the valuable art, culture, and historical background of that region and city. Identifying and introducing the vernacular architecture of different areas and its significant patterns to others can realize many cultural, social, economic aspects of architecture. This study aims to identify and evaluate the vernacular architecture of Boroujerd and its unique physical-spatial patterns. Boroujerd city is a valuable source due to its historical and vernacular texture, but it is less known in architectural fields due to insufficient

research. Therefore, this research tries to explain its vernacular architecture and evaluate the housing patterns using four important indicators (evaluating spatial components, decorations, materials, and climatic factors that have affected the building formation). The vernacular housing of Boroujerd city is unique in terms of local structure and components. The buildings are categorized into several groups, including multi-yard buildings and single-yard buildings with different shapes. The physical components vary according to the housing patterns i.e., open space, semi-open space, and closed space. The architectural decorations in the vernacular housing of Boroujerd city and Sufian neighborhood are made with brick, mosaic, wood, stucco, and paintings. Also, unique techniques have been used in their decorations. Vernacular housing in the Sufian neighborhood of Boroujerd is had also prominent construction techniques and used materials. Due to the seismicity of Boroujerd for a long time, materials and techniques are used with

great care. To strengthen the building foundation, local materials, mostly stone, are used and combined with limestone mortar. Perhaps the unique feature of the vernacular buildings of Boroujerd city and the Sufian neighborhood is their adaptation to the climate and perfect orientation to benefit from solar energy. All the buildings are oriented toward the northeast-southwest (Roon Rasteh). All patterns and components used in the vernacular buildings of Boroujerd are described in Table 12. After recognizing the physical-spatial patterns used in the housing of the Sufian neighborhood, their influences are evaluated by the TOPSIS method. According to this method, the most important factors influencing the physical-spatial patterns of the vernacular buildings in this region are the used building materials and the construction techniques. The constituent physical-spatial components are the third influencing factor. Finally, the climatic factors and the decorations used in vernacular buildings are the other significant factors.

Table 12. Recognition of physical-spatial components used in vernacular buildings of Boroujerd. Source: Authors, 2020.

Physical-spatial elements used in vernacular buildings		Features and structures
Spatial building components used in the buildings	Classification of incorporating spatial structures	<p>In terms of physical-spatial patterns, buildings are categorized into open, semi-open, and closed spaces.</p> <p>The buildings are categorized into two general groups: multi-yard buildings and single-yard buildings. Single-yard buildings are classified as one-sided, two-sided, L-shaped, and U-shaped buildings.</p> <p>The porch, which is one of the semi-open spaces, has been used in some buildings</p> <p>The windows are vertical, and their width to length ratio is 1: 3. All of them are made of wood, and in some cases, the windows are simply decorated with wood.</p>
Decorations used in the buildings	Decorations material	<p>Brick decorations have been used in rag-chin, dadan-mushi, and gol-andazi styles in different yard parts and the exterior and interior facades.</p> <p>Mosaic decorations are used with moaqeli and haft-rang techniques in the exterior and the interior. The combination of brick and mosaic has rarely been used in the exterior.</p> <p>Wood has been used for two purposes in the vernacular buildings of Boroujerd: structural and decorative purposes. The structural use of wood in the form of cladding, beams, and columns, and the decorative use of wood in windows and ceiling decorations, mostly seen in an aristocratic house</p> <p>Stucco is used very rarely in interiors, embellished with simple patterns and plant motifs</p>
Materials used in building construction and construction techniques		<p>Brick and clay were used to build thick load-bearing that effectively reduces thermal conductivity in cold seasons. Stone is mostly used for the floors. The roof has a flat surface, and the thatch material is used to cover the wooden structures. Lime and stone mortar was used to build the buildings</p>
The effects of climate on the formation of buildings		<p>The most important physical factor in building formation in terms of orientation and building components was dividing the building into two parts, summer and winter. All the buildings are oriented toward the northeast-southwest direction to benefit from solar radiation.</p>

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