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Study of the Roles of Physical Factors and Variables Affecting the Heating Behavior of the Traditional Houses of Shiraz (Qajar period) with an Emphasis on the Microclimatic Role of the Central Courtyard

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Abstract

There is a large number of traditional houses in the historical texture of Shiraz City that have during their history managed to meet the living needs of regional people from climatic and environmental perspective. The main problem of the present study was to investigate the physical characteristics of Qajar period houses in Shiraz City, Iran, from an environmental perspective and their effects on the thermal behaviors of these houses. The study's methodology was descriptive-analytical and data were collected from library and documentary methods and field surveys. 88 traditional houses from Shiraz's historical texture of the Qajar era were identified, with 48 houses, meeting the information required, selected for investigation and typology. Findings indicated that houses are mainly inclined to the southwest, which further reinforces the effect of the Qiblah that other factors in determining the angles of the houses' orientation. Houses with four-front construction courtyards (around 38%) are assigned the highest frequency. most courtyards cover areas of 50 to 250 m. wide and extended courtyards are not common in Shiraz's traditional houses. Around 52% of the houses have courtyards of length-to-height ratios of 2:2.5, with the most frequent width-to-height proportions (a total of around 71%) pertaining to 1.5, 2 and 2.5 ratios. Garden areas mainly cover areas of 5-30 m2. Meanwhile, pools and fountains account for the highest areas of 5-30 m2. Large areas assigned to pools and fountains not only provide humidity and reduce air dryness but also reduce the ambient temperature through evaporative cooling.

Keywords: Physical factors; Thermal behavior; Shiraz traditional houses; Qajar period;, Central courtyard

1. Introduction

Since long times ago, our land has witnessed smart and reasonable climate-adaptive solutions in designing and constructing buildings. Local architecture has, since the past, met environmental needs, especially in hot and arid regions. Iranian architects have long concerned about dealing with unconducive environmental conditions and thought about constructing houses proportionate to each type of climate. Traditional courtyard houses in Iran's hot and arid climates have represented one of the successful architectural samples. These houses have been designed based on climatic, social and cultural conditions. The city of Shiraz, which experiences a hot and arid climate, has witnessed some solutions employed in the design and construction of traditional houses. These buildings appear to have conformed to climatic conditions, thus contributing to the living stability of historical housing in this city. For this, the present study aimed to study the physical factors and architectural characteristics that affected the climatic and thermal functions of Shiraz's traditional housing and to explore the relationship between these factors as study variables and climate-adaptive principles and the provision of thermal comfort for residents. This can enable designers and planners to employ climatic rules and principles in contemporary construction design and architecture. To this aim, 88 historical Qajar-era houses were selected as the statistical population, and their characteristics were compared and classified to investigate the adaptability of these houses with regional environmental conditions.

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2. Research Background

For so many years, Iran's local and traditional architecture has coped with environmental issues and thus employed smart solutions to adapt to the climate and its surrounding nature, various samples of which can be noted in the traditional houses in various climatic zones across this country. Historical-traditional houses are highly valuable examples that have met various dimensions of social, living and cultural needs of residents. Understanding climatic patterns and components and their functions in interaction with climatic needs is a practice that can help explore the climatic rational and rules governing this type of architecture, which can be used in contemporary architecture. A body of research has examined the relationship between physical characteristics and thermal behaviors, as well as the climate-based responsiveness of traditional houses. Khaksar et al. (2020) also investigated the thermal behavior of earth-shelter residential houses in Meimand of Kerman, Iran, and found that the thermal behavior of all these structures was desirable throughout the hot spell of the year, with the maximum thermal comfort pertaining to buildings with the highest penetration in soil depth, two-room structures, southern and southeastern orientations relative to sunlight and exposure to the middle topographic elevation levels. In another article, Asadi and Fakhari (2016:339) investigated the thermal behavior of Yazd's traditional houses. Here, the thermal behavior of the Rasouliyan House was simulated using Energy Plus software. According to simulation results (which respectively recorded the hottest and coldest days to be on July 21 and December 26), the internal temperature in the summer season experienced less fluctuation than the external temperature, with the main climatic solutions involving the appropriate organization of building forms and the use of appropriate materials. Moradi et al. (2017) also discussed the typology of traditional courtyard houses in Tabriz based on the physical criteria affecting climatic functions. Findings suggested the dominance of the factor of Qiblah in determining the angles that govern house orientations, with the single-front courtyard houses, mostly two-story buildings, holding the highest frequency of courtyards' width-to-length ratios, ranging from 0.8 to 0.9, while covering areas of 100-300 m2. In the article "Recognizing the Design Patterns of Shiraz's Historical Houses in the Qajar era Using a Climatic Approach", Zarei (2018) investigates the role of climate from the perspective of spatial relations and proportions in the Shiraz historical houses. Zare Mehzabieh et al. (2016-2019) investigated the quality of the internal environment of the Qajar houses in Shiraz from the point of view of the thermal comfort and daylight, and the result of their research in the Nemati house as a case study , showed that the various characteristics of architecture in the rooms of this building had given different results. Khashei (2010) studied the role of passive systems in Isfahan's local houses (Case study: The Karimi House). This study investigated such elements as wind-towers, a springhouse, a pool and gardens in the central courtyar, as passive cooling systems for providing humidity and natural ventilation in summers, while the use of solar energy through the central courtyard and good materials for storing heat in winters were studied as passive heating. Mehdizadeh et al. (2014) also investigated the role of ante-entrance on the main spaces of Yazd's old houses, concluding that the presence of ante-entrances could moderate temperature in those spaces across the various seasons of the years. Nazarboland and his colleagues et al. (2021) have investigated the issue of reducing energy consumption through optimal openings in high-rise residential buildings in accordance with skylights of traditional buildings in Shiraz city. In this research, the optimal percentage of openings, the optimal angle of louvres and the optimal glass in a high-rise residential building have been simulated with the help of Design Builder software. Considering that skylights have the necessary efficiency in traditional architecture, the results of their use show that most of the traditional methods of lighting and light control can be replaced with modern methods of designing shells with the same performance and quality, and it is possible to use the methods that were used in the past in the design of skylights in The buildings have been used and modeled for new buildings as well. Masoudi-Nejad et al. (2018) also studied the thermal behavior of Shevadans*, and found that thermal comfort in different seasons in this space and the constant mean radiant temperature were influenced by the effects of walls' thermal capacity, especially in the hot season of summer. In another study, Ghodsi et al. (2018) explained the geometric indices affecting the thermal behavior of residential buildings in hot and arid climates and found that after the building form, the relative compaction index, rather than compaction, followed by the surface ratio of the southern front, were much more important. Farazjou and Zrandi (2020) investigated the components affecting the thermal behavior of prevailing residential architectural patterns in Tabriz City, Iran. In another study, Heidari-Arjalo et al (2022-2023). Regarding the metrics of energy planning in Iranian traditional houses (case example: Shiraz houses), after establishing the Morgan statistics community, collecting studies with questions, then statistics analysis with the Spss software, and finally after examining the statistics on traditional houses, water use, maximized use of the wind, use of light, cooling shade, use of green, adjustments and compositions of architectural elements, materials, sustainable space architecture, construction direction and management of space, and environmental and active energy strategy, a proper orientation and form, a capacity for thermal management of partitions, shades, and lengthening shades, revealed that a climate-friendly housing could be designed accordingly, offering the most adequate climate absorption and energy consumption.

They found that the amount of energy required for heating was nearly three times as much as the amount of energy required for cooling in the residential buildings of this city Uskouei and Dehghan (2020) also investigated the physical typologies of Urmia's historical houses of the Qajar era. They found that many of the characteristics of Urmia's historical houses were in harmony with cultural, religious, economic and social variables; meanwhile, we see some clear physical distinctions between these houses, despite common concepts featuring the formation of the physical patterns of these houses (including, climates, economics and politics). They also concluded that based on physical analyses, the social class of residents played a major role in the typology of house fabrics. In sum, the study aimed to investigate the physical characteristics of the Qajar era houses from an environmental perspective and examine their roles in the thermal behavior of these houses.

In studies related to the background of research, the climate performance of traditional houses in various towns has been examined on such indicators and variables as Space coordinates, Comfort is a heat, natural light, the optimum percentage of openers, and so on. but no studies with a Comprehensive statistical community which would consider the roles of physical factors and variables which influence the heating behavior of the traditional Shiraz houses, emphasizing shallowness Microclimatic role of the central courtyard, have not been observed. The present research has its novelty in being almost entirely a summary exposition of the 48 traditional houses in the historical tissue of Shiraz (houses of the Qajar period) based on criteria and physical characteristics which influence the micro-climatic performance and thermal behavior of houses, courts, and adjacent space, describe, classify, compare and analyse the physical characteristics of classification and typology.

3. Research Methodology

The present study fell under applied research as it describes, classifies, compares and analyzes physical characteristics and the adaptability of those characteristics in Shiraz's traditional houses to climatic components. Study data were collected through written and library sources, as well as documentary and field surveys. Traditional houses of the Qajar era in Shiraz City comprised the statistical population. These houses were selected based on the outstanding building index and sufficient data related to the study objectives within the historical limits of this city. Findings were presented in descriptive-analytical forms and in writing, together with providing tables and diagrams in Excel software. The study also went through a three-step procedure. In the first step, Shiraz's traditional houses were identified via reference to written and library sources, as well as through documentary studies and field surveys. In the second step, the representative houses were classified based on some physical criteria, which can affect the micro-climatic function and the thermal behavior of the house, their courtyards and neighboring spaces. In the third step, meanwhile, the frequency of each of the components affecting the thermal behavior of the houses was investigated, which could help analyze their thermal functioning, based on the frequency of each of the physical component, as intended by the study. In this connection it is essential to discover the functional implications of physical patterns and characteristics based on the frequency of the components, and to discover the hidden angles and the rules governing the climatic functions of each of those characteristics, which can be used in designing contemporary architecture.

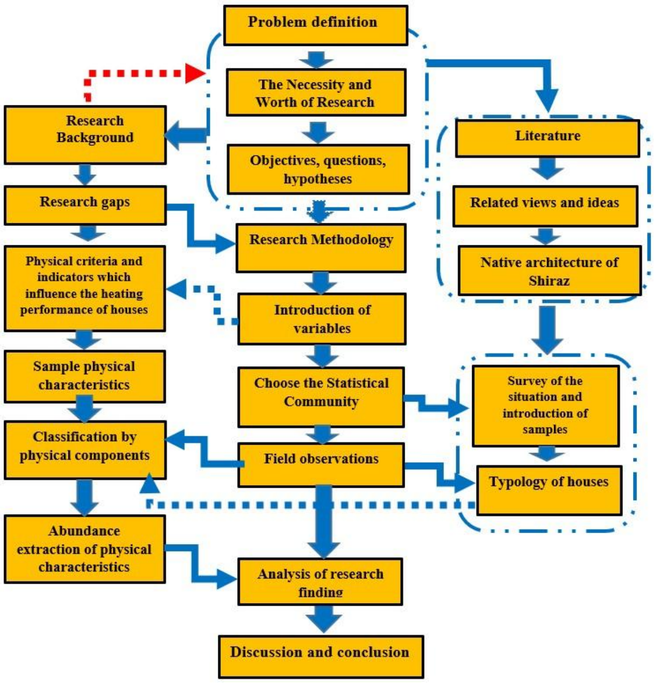


Fig. 1. Diagram of the research process

4. Survey of the Situation and Introduction of Samples

4.1. Geographical location of shiraz

Shiraz is located at latitude 29° and 32' and longitude 52° and 35' in southwestern Iran, with the provincial capital of Fars. This city features almost 40 km long and 15-30 km wide, covering an area of 1268 km^2, surrounded by relatively high mountains. The height of this city from the sea level ranges from 1480 to 1670 m at different points of the city. Dry and salty rivers of the city, which are created seasonally, have resulted in some micro-scale hot-arid and semi-desert climate (Tahbaz, 2018).

* Due to hot and humid weather, architects consider a cellar space in the basement to provide comfortable living conditions.

4.2. The selection of the research population

Searches in libraries and available sources, as well as Internet websites and reference to the Province of Fars Cultural Heritage Office led to the identification of around 88 historical houses that dated back to the Qajar era. Out of this number, the houses that did not meet the information required by the study criteria and goals were excluded from the initial list, and a final 48 houses with courtyards were selected for study. Figure 3 illustrates the spatial location of each of the houses in the historical texture of Shiraz. Table 1 gives the 48 houses and their physical characteristics, typology, entrance vestibules, courtyards, gardens, fountains, pond and waterscape.

5. Physical Criteria and Indicators Which Influence the Heating Performance of Houses

The studied samples were selected based on physical criteria, which affect the thermal and climatic behaviors of the houses. Since a central courtyard as an integral role in traditional houses plays a determining role in the climatic function of hot and arid houses, the physical bodies and characteristics of the central courtyards of the examples were studied as independent variables of the study. To this aim, such components as the angle of the houses rotating southwards, plan massing in various forms of the building, the courtyard's length (L), the courtyard's width (W), the courtyard's height of walls (H), the courtyard's area (S), as well as courtyard proportions including width-to-length (W/L) ratios, the courtyard's length and width ratio to the height of its neighboring walls (L/H) and (W/H) were selected as the criteria of analysis.

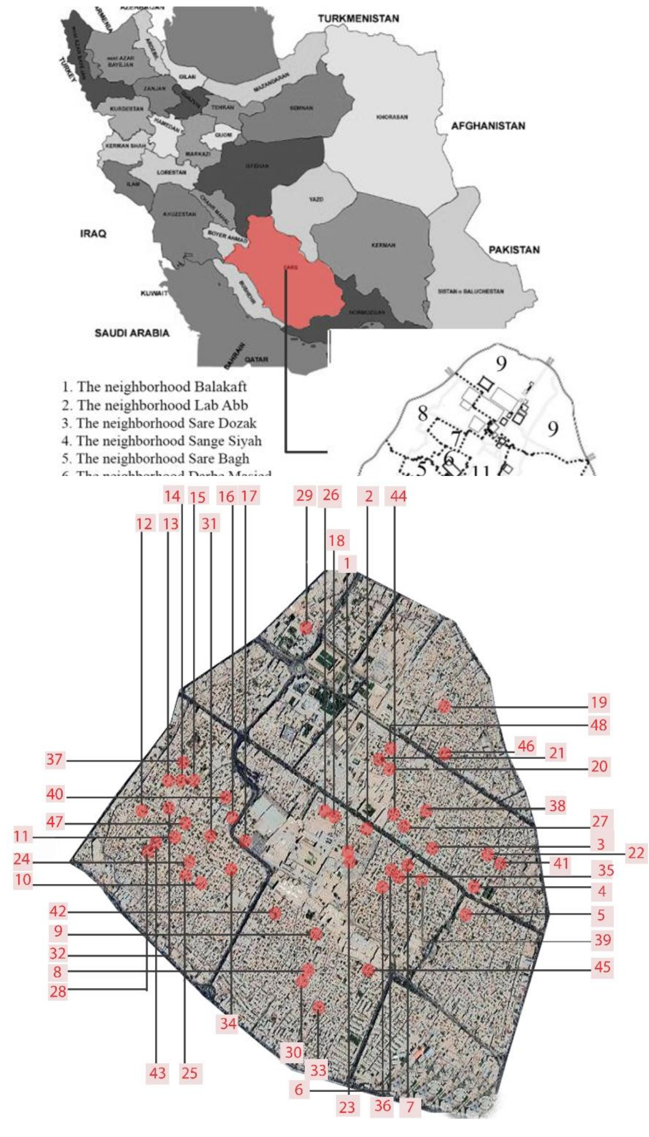
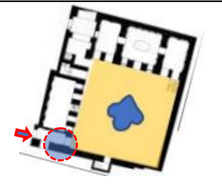
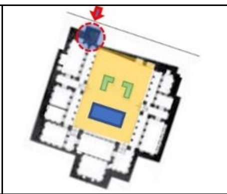
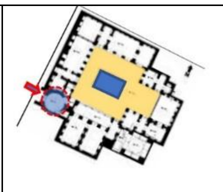
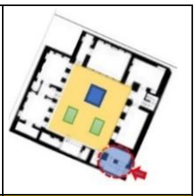
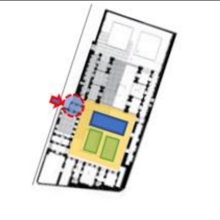
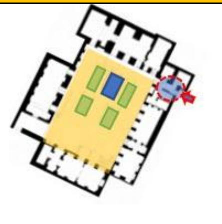
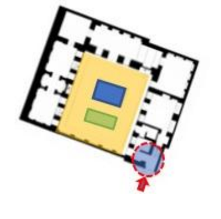
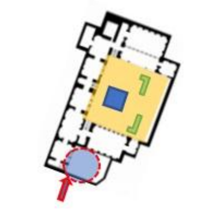
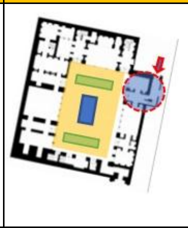
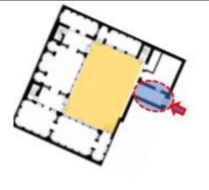
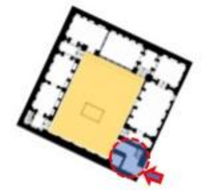
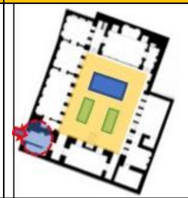
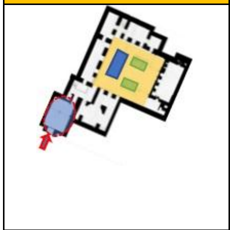
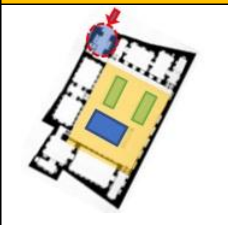
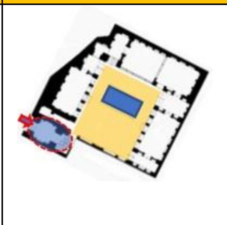
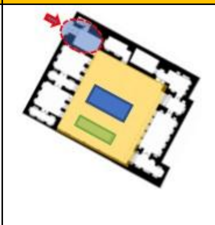
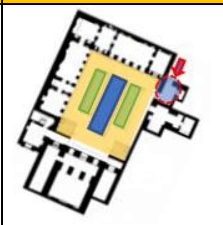
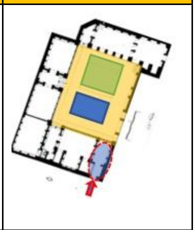
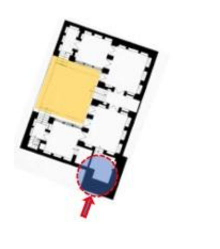
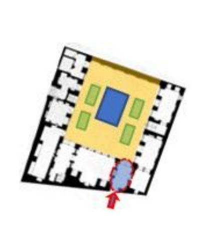
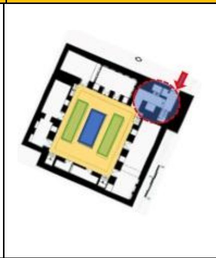
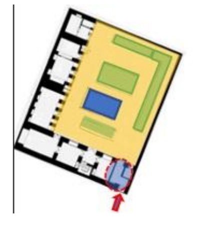
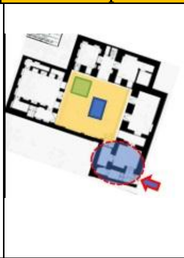


Fig. 3. Where the study samples are placed in the historical tissue of Shiraz

Table 1
Lists of 48 selected houses in the circumference of the study sources: (Persian Heritage Authority) – extraction and compilation of authors.

					
1.Shafei Ardakani	2. Atrvash	3. Pesaran	4. Zinatolmolouk	5. Afshariyan	6. Amouie
					
7. Nasirolmolk	8. Kateb	9. Kazerouni	10. Tohidi	11. Pakyari	12. Moadelo Saltaneh
					
13. Haji Mohaya	14. Forougholmolk	15. Safa Dehghan	16. Saaber	17. Leyaghat Rafiei	18. Nematolahi
					
19. Dokhanchi	20. Sabagh	21. Tajer	22. Shafa	23. Sadr Jahromi	24. Abtahi & Ahmadpour
					
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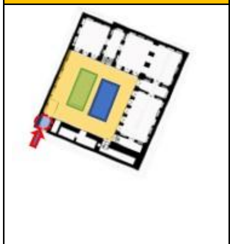
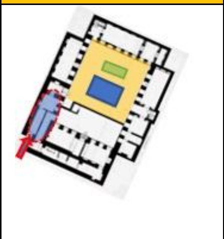
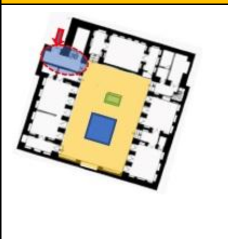
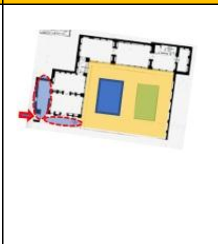
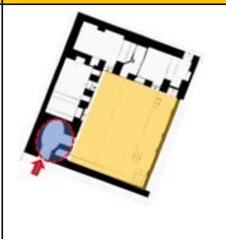
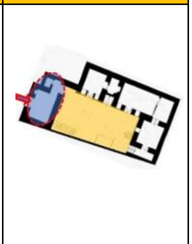
					
31. Hamidi	32. Heydari	33. Doaei	34. Dehghan	35. Dehimi	36. Rafat Afra

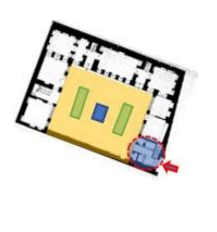
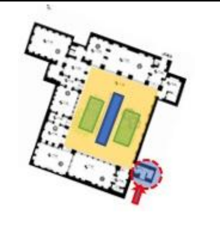
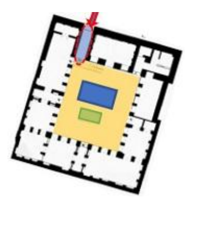
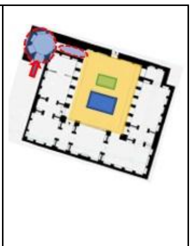
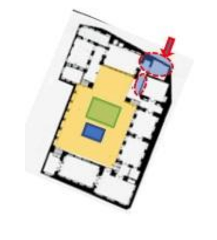
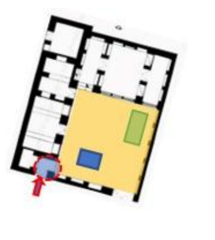
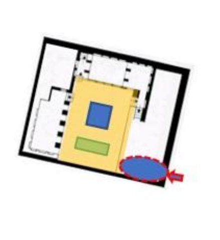
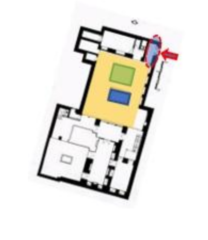
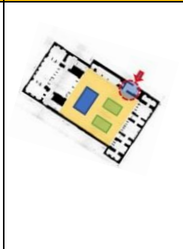
					
37. Zanjirchi	38. Salimi	39. Sabaar	40. Abaspour	41. Gholami	42. Kazerouni
					
43. Kompani	44. Masoumi	45. Nemati	46. Nobandegani	47. Hashemi	48. Hasani Ardakani

Table 2 gives the names and the physical characteristics of each of the examples (based on relevant library sources and maps provided by the Cultural Heritage Office of the province). The tabulation and relevant extraction led to the presentation of the percentage of frequency of each of the components, illustrated by diagrams and analyzed by relevant software. This can facilitate the extraction of physical characteristics and finding analyses.

6. Analysis of Research Results

As stated above, the physical criteria and indicators affecting the thermal performance of the houses led to the following components, including the angle of the houses rotating southwards, courtyard forms (plan massing in various forms of the building), the courtyard's length (L), the courtyard's width (W), the courtyard's height of walls (H), the courtyard's area (S), as well as courtyard proportions including width-to-length (W/L) ratios, the courtyard's length and width ratio to the height of its neighboring walls (L/H) and (W/H), which were selected as independent criteria and variables for analysis and classification.

Figure 3 illustrates the frequency of the orientation angles of the houses, as extracted by Table 1. To better understand the houses' orientation, the rotation of the main axes of the houses from the geographical south direction on the east and west sides served as the basis of comparison direction on the east and west sides served as the basis of comparison The rotation of the main axis of the houses towards the geographical south was considered in a clockwise (SW) direction and in an anti-clockwise (SE) direction, with numerical 5° intervals for the samples under study. Findings from houses' rotation angles and orientation indicated that around 45% of the houses were oriented towards southwestern angles of 20-30°, while around 28% towards angles of 10-20°, as the frequency of houses' orientation outside the angles mentioned saw a significant decrease (Figure 3).

7. Orientation and Rotation Angle of Houses

In general, various components and factors including environmental factors (sunlight), wind direction, cultural factors (Qiblah direction) and access to water and aqueduct routes were found to affect the determination of angles and the orientation of traditional houses. According to Mohmmad Karim Pirnia, the orientation of the fabric of Shiraz's traditional houses had an Isfahani (northwest-southeast) direction.

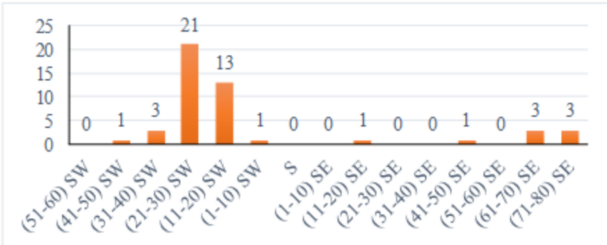
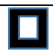
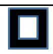
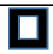
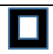
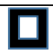
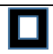


Fig. 4. The rotation angle of the houses relative to the geographical south direction

In total, the highest orientation frequency at 78% with an angle of 25° varied from south towards southwest. This exhibits a significant difference of 25° with the findings obtained from simulation in Ecotect Software (Figure 4) that shows the optimal orientation of the houses in Shiraz to be exactly southwards. Although such factors as pathway orientation and access to water and aqueduct routes can serve as intervening components and variables to determine houses' orientation and angles, the frequency and the prevailing houses' rotation towards the southwest strengthens the dominant effects of the factor of Qiblah than other factors in determining the angles governing the houses'orientation.

Table 2
Names and physical characteristics of 48 selected houses Source: (Cultural Heritage Organization of Fars Province) - (extraction and editing by authors)

Row	Home	Angles and orientation of houses	The shape of the yard (massing the plan)	The length of the yard	The width of the yard	Yard area S (m2)	garden area (m2)	Pond area (m2)	The height of the body of the yard H	Proportions (width to length) W/L	The ratio of the width of the yard to the height of the building W/H	The ratio of the length of the yard to the height of the building L/H
1	Shafie Ardakani	17 SW		14.35	12.73	235.00	30.00	30.00	5.50	0.9	2.66	2.90
2	Atrvash	14 SW		13.83	11.93	165.00	19.00	10.50	6.50	0.8	1.83	2.12
3	Pesaran	20 NE		15.78	10.52	166.00	7.70	13.10	6.00	0.6	1.75	2.63
4	Zinatolmolouk	75 SE		29.54	18.82	556.00	109.00	75.00	7.50	0.6	2.50	3.93
5	Afshariyan	31 SW		14.23	10.47	149.00	8.40	16.10	4.50	0.7	2.32	3.16
6	Amouie	20 SW		8.34	7.31	61.00	4.60	4.40	5.25	0.8	1.39	1.58
7	Nasirolmolk	30 SW		13.07	13.07	171.00	58.20	42.60	7.00	1	1.86	1.86
8	Kateb	28 SW		15.00	10.60	159.00	20.30	6.80	5.50	0.7	1.92	2.72
9	Kazerouni	21 SW		9.50	8.00	76.00	8.40	10.10	6.00	0.8	1.33	1.58
10	Tohidi	32 SW		17.10	12.10	207.00	50.50	25.30	5.75	0.7	2.10	2.97
11	Pakyari	20 SW		12.80	12.50	160.00	15.10	20.40	3.70	0.9	3.37	3.45
12	Moadelo Saltaneh	12 SW		16.80	10.90	183.00	30.10	30.50	7.50	0.6	1.45	2.24
13	Haji Mohaya	29 SW		32.60	19.00	619.00	170.70	55.30	5.16	0.6	3.68	6.31
14	Forougholmolk	48 SW		12.60	8.40	106.00	25.40	20.10	6.50	0.6	1.29	1.93
15	Safa Dehghan	31 SW		8.50	8.30	70.55	5.30	10.90	5.50	0.9	1.50	1.54
16	Saaber	66 SE		12.50	8.80	110.00	10.20	15.20	5.25	0.7	1.67	2.38
17	Liyaghat Rafiei	27 SW		11.30	8.50	96.00	20.30	5.40	5.25	0.7	1.61	2.15
18	Nematolahi	19 SW		11.00	8.40	92.40	10.60	10.80	4.30	0.7	1.95	2.55
19	Dokhanchi	25 SW		14.82	13.97	207.00	20.70	25.20	6.00	0.9	2.32	2.47
20	Sabagh	28 SW		14.20	11.30	160.50	22.10	21.50	4.15	0.8	3.42	2.72
21	Tajer	26 SW		10.00	7.80	78.00	15.00	12.80	4.55	0.7	2.19	1.71
22	Shafa	62 SE		8.50	7.10	60.35	4.30	7.10	4.80	0.8	1.47	1.77
23	Sadr Jahromi	26 SW		15.70	12.10	190.00	42.00	30.30	5.00	0.7	2.42	3.14
24	Abtahi & Ahmadpour	19 SW		13.36	10.41	139.10	26.00	18.90	6.00	0.8	1.80	2.20

Row	Home	Angles and orientation of houses	The shape of the yard (massing the plan)	The length of the yard	The width of the yard	Yard area S (m2)	garden area (m2)	Pond area (m2)	The height of the body of the yard H	Proportions (width to length) W/L	The ratio of the width of the yard to the height of the building W /H	The ratio of the length of the yard to the height of the building L/H
25	Asadolahi	19 SW		9.12	7.22	65.90	0.00	0.00	4.50	0.8	1.60	3.20
26	Amouzegar	20 SW		14.00	12.39	173.50	16.00	16.80	5.50	0.9	2.30	2.60
27	Basiri	16 SW		32.33	22.32	721.60	120.00	120.00	5.40	0.7	4.20	6.00
28	Behnam	24 SW		17.84	16.12	287.60	58.40	35.10	6.50	0.9	2.50	2.80
29	Javanmardi	67 SE		23.95	18.05	432.30	93.90	32.67	4.50	0.8	4.10	5.40
30	Hafiz	18 SW		10.00	8.90	89.00	6.71	6.00	5.40	0.9	1.70	1.90
31	Hamidi	26 SW		14.00	13.50	189.00	21.99	26.95	3.30	1.0	4.10	4.30
32	Heydari	24 SW		17.67	17.25	304.80	19.80	50.00	4.60	1.0	3.80	3.90
33	Doaie	15 SW		18.63	12.57	234.20	21.60	5.30	3.50	0.7	3.60	5.40
34	Dehghan	7 SW		19.65	15.68	308.20	41.68	43.96	5.40	0.8	2.90	3.70
35	Dehimi	22 SW		7.75	6.40	49.60	0.00	0.00	4.50	0.9	1.50	1.80
36	Rafat Afra	22 SW		12.46	6.48	80.00	4.00	0.00	4.00	0.6	1.70	3.20
37	Zanjerchi	20 SW		20.57	16.62	341.90	30.70	7.50	9.00	0.8	1.90	2.30
38	Salimi	77 SE		15.52	9.74	151.20	23.60	4.00	4.50	0.7	2.20	3.50
39	Sabaar	92 SW		15.70	13.06	205.10	24.30	22.90	3.50	0.9	3.80	4.50
40	Abaspour	45 SE		13.18	8.91	117.50	12.50	15.50	5.00	0.7	1.80	2.70
41	Gholami	27 SW		11.42	9.83	112.30	5.00	14.00	4.50	0.9	2.20	2.60
42	Kazerouni	16 NE		14.02	11.85	166.20	7.80	21.80	4.20	0.9	2.90	3.40
43	Kompani	12 SW		13.50	12.05	200.00	24.10	9.80	4.50	0.9	3.00	2.70
44	Masoumi	25 SW		9.80	9.20	90.20	3.00	0.00	5.00	1.00	2.00	1.90
45	Nemati	22 SW		16.90	12.02	203.20	25.00	13.50	5.00	0.8	3.40	2.40
46	Nobandegani	17 SW		13.45	10.60	142.60	17.20	11.10	6.00	0.8	2.30	1.80
47	Hashemi	74 SE		18.26	12.30	224.60	7.00	15.00	4.60	0.7	4.00	2.70
48	Hasani Ardakani	27 SW		16.00	14.68	182.80	20.40	22.40	5.50	0.9	2.60	2.31

Figure 4, obtained from the Ecotect simulation, illustrates the amplitude of the angles and allowable and optimal orientation in the city of Shiraz.

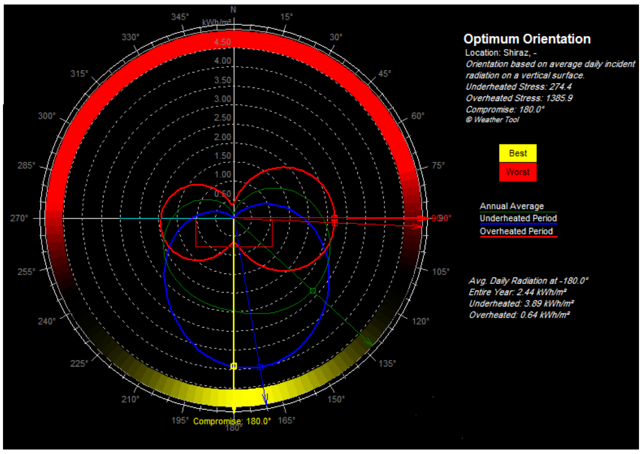


Fig. 5. (Findings from the simulation of Ecotect software for the optimal orientation of buildings in Shiraz from a climatic point of view) Source: the authors

8. The Shape of the Courtyard and the Massing of the Plan in Different Fronts of the Building

By examining the plans of the researched houses and the texture map, regarding the way of stacking the plan and the shape of the yards, five modes (types) can be investigated and classified as follows;

1- Building houses with courtyards on four fronts.

2-Houses with courtyards on three fronts, built with a building mass in the directions (north, east and west) of the building.

3- Houses with courtyards on three fronts, built with a building mass in the directions (south, east and west) of the building.

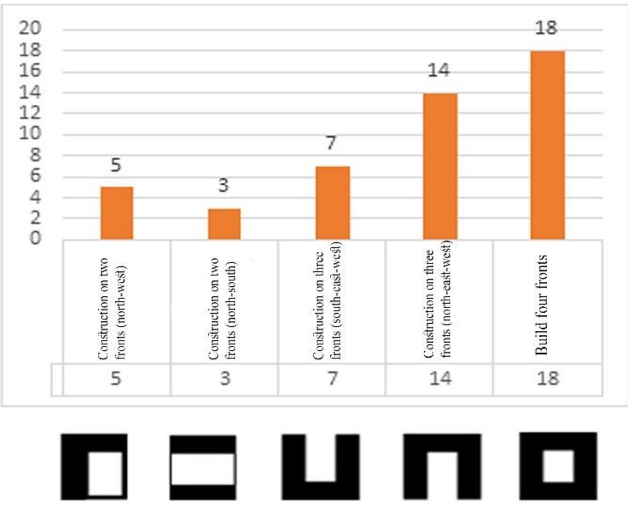


Fig. 6. The frequency of classification based on the shape of the yard (massing the plan in different fronts of the building)

4-Houses with courtyards on two fronts built with a building mass in the directions (north and south) of the building.

5- Houses with courtyards on two fronts built with a building mass in the directions (north and east) of the building.

Findings from various courtyard forms and plan massing indicated that 6% of the samples had a building mass on the northern and southern fronts of the courtyards, 11% on the northern and western fronts of the courtyards, 15% on southern, eastern and western fronts, 30% on northern, eastern and western fronts, and a further 38% had a building mass on all fronts around the courtyard.

Houses with four-front construction courtyards accounted for the highest frequency (38%) and houses with two-front construction (north and south of the courtyards) held the lowest frequency (around 6%), compared to other samples. The large number of courtyard houses with four-front building masses correspond to the common patterns seen in all-season houses in hot and arid areas of Shiraz. The all-season house patterns were dominant massing patterns in hot and arid areas, with central courtyards and summer and winter sections most corresponding to climatic conditions. This pattern can also desirably meet the introvert beliefs of regional people in terms of introversion, privacy and enclosure. According to this pattern, the summer section, which sits on the southern angle, accounts for a considerable area, with northward windows not exposed to southern direct sunlight. The winter section (northern front) is less used because of the longer days of the hot seasons, while accounting for a lesser area than the summer section. The spaces situated on eastern and western fronts are mainly dedicated to less important and service spaces such as bathes, warehouses and WCs.

9. The Area of the Yards (S)

Courtyard areas can be considered as components or criteria significantly influenced by climatic conditions, while influencing the thermal comfort and function of the courtyards and adjacent building masses.

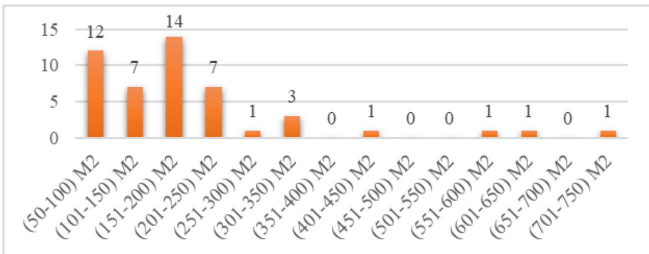


Fig. 7. The frequency of classification based on the area of yards

Courtyards with areas of 151-200 m (around 30%) held the highest frequency among other studied samples, and courtyards with areas of 50-100 m (around 26%) ranked second. In general, most courtyards were within 50-250 m, with courtyards with areas of more than 250 m being small in numbers. This indicates wide and extended courtyards were not common in Shiraz's traditional house architecture, as the courtyards mainly enjoyed smaller areas with maximum enclosure. Small and enclosed courtyards limit direct sunlight in hot seasons of the year and increase depth and shading to reduce heat stored on the bodies and surfaces neighboring the courtyards. Creating wide shading on the surfaces and bodies of buildings and their outdoor spaces is an essential issue in the design of central Iran's regions. On the other hand, a decrease in courtyard areas and an increase in their enclosure help prevent the settlement of undesirable winds in the courtyards and adjacent walls.

9.1. Classification based on the height of the walls adjacent to the courtyard (H)

Typology findings based on the criterion of the height of building walls neighboring the courtyards indicate that the height of the masses and walls varied from 3 to 7 m.Walls of 4-6 m high accounted for the highest frequency at 74%.

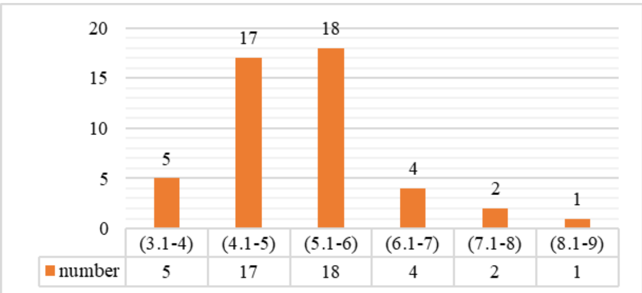


Fig. 8. The frequency of classification based on the height of the walls adjacent to the courtyards (H)

From a climatic perspective, high walls help form wider shades across surfaces and walls facing the courtyards. This serves as an effective factor in moderating micro-climates in courtyards in hot and arid areas. Increasing the height of walls, especially on the southern front of the courtyards, creates wide and deep shades across surfaces neighboring the courtyard. Given the longer hot seasons and higher angles of sun height at geographical latitudes, as in Shiraz City, the height of building masses is suggested to be deployed on the southern front to reduce direct sunlight on peak hot days (July and August) directed at the horizontal and perpendicular surfaces neighboring the mentioned courtyards. The coldness resulting from creating building mass shading, as integrated with tree shades and humidity from water (pool) levels, can help increase the quality of thermal comfort in the courtyards and internal spaces around the courtyards.

9.2. Classification based on the ratio of width to length of yards (W/L)

Debates surrounding space geometries and proportions in architecture have always been critical, as observing systematic proportions in living space dimensions can help promote the architectural quality of spaces, from various aesthetic, structural and geometric rationale perspectives. From climatic and environmental perspectives, the geometry and proportions of building forms and fabric are influenced by environmental conditions, the geometry of courtyard dimensions and relevant proportions. Meanwhile, width-length scales are criteria that have significant effects on the thermal behavior of the courtyards and their adjacent spaces. Different length-width proportions in courtyards play determining roles in terms of sunlight received, shading on horizontal and perpendicular surfaces and walls neighboring the courtyards, and also wind turns and twists in the courtyards.

Investigating the W/L ratio can help measure the extension of the courtyards. According to this scale, courtyards extend from 0.1 to 1. The closer the W/L ratio to 1, the closer the courtyard dimensions to a square, and the more this ratio inclines towards 0.1, the more the courtyard will be a rectangular. According to Figure 8, W/L proportions with ratios of 0.7, 0.8 and 0.9 held the highest frequency at 81% among other samples, suggesting that the courtyards are mainly inclined towards square shapes.

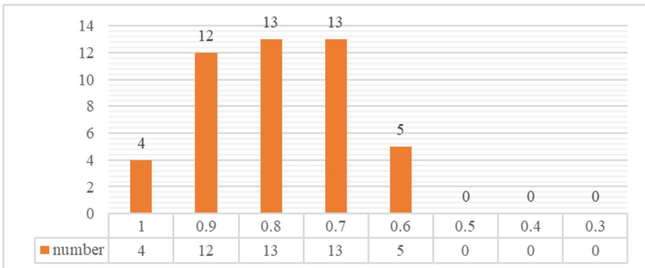


Fig. 9. Abundance based on the ratio of width to length of yards (W/L)

9.3. Classification based on the ratio of the length and width of the yards to the height of the walls adjacent to the yard (L/H) and (W/H)

Physical proportions between length, width and height serve as especially important indicators in the thermal comfort of the courtyards and neighboring closed spaces whose prevailing thermal conditions are determined by sunlight. In general, in the northern hemisphere and in hot regions, the length, width and height proportions of the courtyards and their neighboring walls should be so designed to reduce sunlight over the horizontal surfaces of the courtyards and the perpendicular walls facing them. Due to the higher angle of the sun and its almost perpendicular radiation in the hot seasons, it is essential that perpendicular bodies, especially on the southern front of the courtyards, enjoy a higher height to prevent undesirable summer radiation. It is clear that in addition to perpendicular walls, green surfaces and masses, as well as trees, have a major role in providing shades for the courtyards and the perpendicular bodies facing the courtyards. Also, increasing the height-to-length-width ratio of the courtyards helps control the undesirable sunlight and prevents undesirable wind settlement and desert dusts within courtyard limits.

Fig. 10. The frequency of the ratio of the length of the yards to the height of the walls adjacent to the yard (L/H)

Figure 9 illustrates that the highest L/H frequency pertains to a group of courtyards whose lengths measure 2.5 times their heights. Courtyards with lengths of 2 times those of their neighboring facades are ranked second. The L/H proportions of the courtyards at 2 and 2.5 ratios account for the highest L/H frequency at around 52%.

A review of the frequency percentage of the W/H ratio, as illustrated by Figure 11, indicates that courtyards featuring widths of 2 times the height of the bodies held the highest frequency at around 31%. In general, the W/H proportion typology suggested that the highest W/H proportion frequency (a total of around 71%) pertained to 1.5, 2 and 2.5 ratios. The height of the walls and the extension of the courtyards affecting their functions against gusts of wind requires further reflection. Increasing the height of the courtyard walls not only increases the surface and depth of shading but also adds to the shading area of the wind, thus reducing the settlement of undesirable winds in cold and hot seasons.

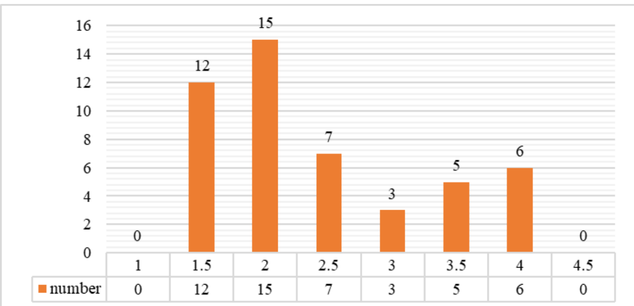


Fig. 11. The frequency of the ratio of the width of the yards to the height of the walls adjacent to the yard (W/H)

Increasing the height of the walls in proportion to the width, length and extension of the courtyards in arid and hot regions such as Shiraz should not extend shade over the southern openings of winter sections in cold seasons, given the oblique sunlight. Although the length of cold spells in hot and arid regions is short, passive heating in winter-section spaces should not be neglected.

9.4. Analysis based on the area of the garden and green space

Planted surfaces have a major role in moderating microclimates in Iran's traditional house courtyards. Pavilions surrounded by types of trees and green masses are the integral parts of traditional Persian Gardens, especially Shiraz's gardens. Green spaces in gardens surround houses, while being surrounded by houses in urban texture, and for this, they play major climatic roles. A survey of the 48 samples indicated that only 3 houses lacked green gardens and spaces, with most of the studied houses featuring various forms and plans in the middle of the houses, and thus providing thermal comfort for the residents by being next to water pools.

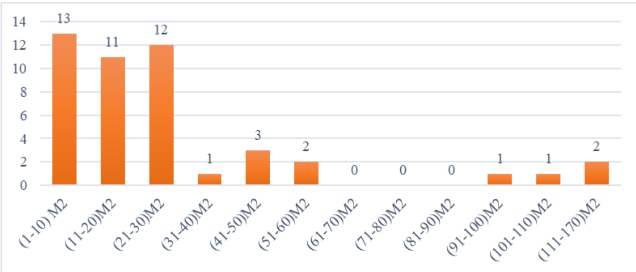


Fig. 12. The abundance of ponds and water levels in the yard

A review of the frequency of the gardens, as illustrated by the diagram, indicates that garden areas account for the highest frequency at around 5-30 m2. Planted surfaces and trees create shade on building walls to reduce heat absorption in hot seasons of the year, while significantly reducing the temperature and dryness of the environment surrounded by trees by increasing evaporative cooling.

9.5. Analysis based on pond area and water levels

Water and pool levels, as in planted surfaces, are considered microclimate-moderating components. A review of the frequency of the areas of water levels indicates that some 75% of the houses have pools and fountains with areas of 5-30 m2. Water levels not only provide humidity and reduce air dryness but also reduce the ambient temperature through evaporative cooling.

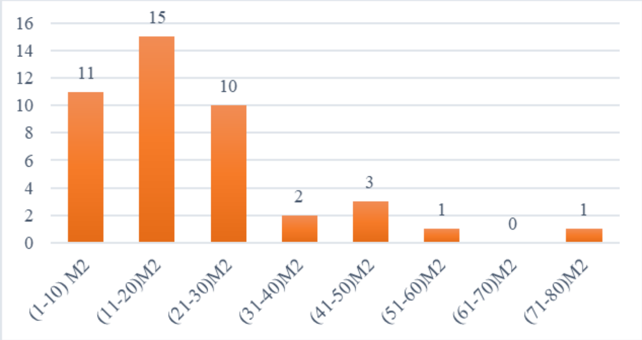


Fig. 13. Frequency of ponds and water levels in the yard

10. Discussion and Conclusion

Iran's local and traditional architecture has over the years employed smart solutions to adapt to different climates and the surrounding nature. Examples of these architectural structures can be seen in traditional houses in various climates across Iran. There is a large number of traditional houses in the historical texture of Shiraz City that have during their history managed to meet the living needs of regional people from a climatic and environmental perspective. Research into the physical factors and architectural features affecting the climatic and thermal function of traditional houses and exploring the relationship between these factors and the principle of adaptability with the climate and providing residents' thermal comfort can help provide planners and designers with effective rules and principles from a climatic perspective. The main problem of the present study was to investigate the physical characteristics of Qajar era houses in Shiraz City, Iran, from an environmental perspective and their effects on the thermal behaviors of these houses. The study's methodology was descriptive-analytical and data were collected from library and documentary methods and field surveys. As for the study's procedure, 88 traditional houses from Shiraz's historical texture of the Qajar era were identified, with 48 houses, meeting the information required, selected for investigation and typology.

Typology findings based on rotation angles and building orientations indicated that the highest frequency of orientation at 78% with an angle of around 25° pertained to the southwestern direction. Although this exhibits a 25° difference with the finding obtained from Ecotect software simulation that precisely shows the optimal orientation of the buildings in Shiraz City to be southwards, such factors as pathway orientation and access to water and aqueduct routes can be considered as components or variables intervening with the angles and orientation of the houses.

Findings indicated that houses are mainly inclined to the southwest, which further reinforces the prevailing effect of the Qiblah that other factors in determining the angles of the houses' orientation. However, plan massing results demonstrated that houses with four-front construction courtyards (around 38%) had the highest frequency. The large number of courtyard houses with four-front building masses represent samples that best conform to four-season houses in hot and arid regions. Courtyard areas can be regarded as a component that is significantly influenced by climatic conditions and thus affects the thermal function of the courtyards and their neighboring building masses.

In general, most courtyards were within 50-250 m, with courtyards with areas of more than 250 m being small in numbers. This indicates wide and extended courtyards were not common in Shiraz's traditional house architecture, as the courtyards mainly enjoyed smaller areas with maximum enclosure. Small and enclosed courtyards limit direct sunlight in hot seasons of the year and increase depth and shading to reduce heat stored on the bodies and surfaces neighboring the courtyards. The highest frequency of the walls neighboring the courtyards (H) ranged from 4-6 m. Concerning the frequency of W/L proportions in the courtyards, 0.7, 0.8 and 0.9 ratios held the highest frequency at 81% in samples under study. In general, most courtyards were within 50-250 m, with courtyards with areas of more than 250 m being small in numbers. This indicates wide and extended courtyards were not common in Shiraz's traditional house architecture, as the courtyards mainly enjoyed smaller areas with maximum enclosure. Small and enclosed courtyards limit direct sunlight in hot seasons of the year and increase depth and shading to reduce heat stored on the bodies and surfaces neighboring the courtyards.

Physical proportions between length, width and height serve as major indicators of the thermal function of the courtyards and their adjacent enclosed spaces whose thermal conditions are determined by sunlight. In general, in the northern hemisphere and in hot regions, the length, width and height proportions of the courtyards and their neighboring walls should be so designed to reduce sunlight over the horizontal surfaces of the courtyards and the perpendicular walls facing them. Due to the higher angle of the sun and its almost perpendicular radiation in hot seasons, it is essential that perpendicular bodies, especially on the southern front of the courtyards, enjoy a higher height to prevent undesirable summer radiation. It is clear that in addition to perpendicular walls, green surfaces and masses, as well as trees, have a major role in providing shades for the courtyards and the perpendicular bodies facing the courtyards. Also, increasing the height-to-length-width ratio of the courtyards helps control the undesirable sunlight and prevents undesirable wind settlement and desert dusts within courtyard limits. The length-to-height (L/H) ratios of the courtyards at 2 and 2.5 held the highest frequency (around 52%) than other examples. The highest W/H ratio frequency of around 71% pertained to 1.5, 2 and 2.5 ratios. From a climatic perspective, increasing high walls, especially on southern fronts, help form create wider shades across surfaces and thus reduce heat absorption in the hot seasons of the year. Increasing the height of the walls in proportion to the width, length and extension of the courtyards in arid and hot regions such as Shiraz should not extend shade over the southern openings of the winter sections in cold seasons, given the oblique sunlight. Although the length of cold spells in hot and arid regions is short, passive heating in winter-section spaces should not be neglected.

A review of the frequency of the gardens, as illustrated by the diagram, indicates that garden areas account for the highest frequency at around 5-30 m^2. The planted surfaces and trees create shade on building walls to reduce heat absorption in hot seasons of the year, while significantly reducing the temperature and dryness of the environment surrounded by trees by increasing evaporative cooling. Water and pool levels, as in planted surfaces, are considered microclimate-moderating components. A review of the frequency of the areas of water levels indicates that some 75% of the houses have pools and fountains covering areas of 5-30 m^2. Water levels not only provide humidity and reduce air dryness but also reduce the ambient trematurid through evaporative cooling.

One of the limitations of the present investigation was the lack of access to documents and maps of the identified houses. About 88 traditional houses have been identified in the historical context of Shiraz from the Qajar period, and the gathering of documents and maps was done by referring to related books, articles, and references to cultural heritage. but about 48 houses had documents, Plans, and references; and some of the plans obtained were not completely equipped with references (for instance elevations, sections and measurements), so that for certain specimens the measurements were taken a Field observations. Another limitation of the research is the selection of the sample heads from the 48 examined samples for arithmetical calculations with a computer simulation tools. Since the simulation of all 48 samples categorized in this research is not possible, it is necessary to select a certain and limited number of samples (as heads of samples) to measure and test the numerical calculations with the simulation software, in such a way that it has been possible to generalize the results to all samples. Therefore, as a suggestion for future research, it is necessary to select the heads of samples from the 48 classified samples so that it is possible to generalize the results to all samples. Another limitations of research is the selection of suitable simulation software is suitable for calculations of the thermal comfort indices in the open spaces (in the central courtyard).Envi-met energy simulation software can be used for quantitative calculations of thermal comfort indicators in open spaces, but some of the thermal comfort indicators can be used for open spaces (outdoors) through the free version available on the website.

Table 3
General characteristics of selected samples (source: authors, 2023)

No	Name of the house	The manufacturing period	Registration number	Date of entry	Address
1	Hasani Ardakani	Qajar	1601	1357/02/26	Shiraz, Lotfo Ali Khan Zand Street, 12th Imam Street
2	Atrvash	Qajar	1067	1354/02/30	Shiraz, Haji Bazaar, Zanjekhaneh Alley
3	Pesaran	Qajar	4518	1380/10/11	Shiraz, Lotf Ali Zand Street, Ishaq Bey neighborhood
4	Zinatolmolouk	Qajar	8710	1382/03/10	Shiraz, Lotfo Ali Khan Zand
5	Afshariyan	Qajar	8994	1382/03/10	Shiraz, Kh Lotf Ali Khan Zand, Darb Sheikh
6	Amouie	Qajar	6063	1381/05/08	Shiraz, Lotfo Ali Khan Zand Street, Atar Ajam Alley
7	Nasirolmolk	Qajar	1068	1354/02/30	Shiraz, Lotfo Ali Khan Zand
8	Kateb	Qajar	8978	1382/03/10	Shiraz, Lab Ab neighborhood, Bazarche Naib, Alamdar alley, 36
9	Kazerouni	Qajar	5028	1380/12/25	Shiraz, Darb Shazdeh neighborhood
10	Tohidi	Qajar	4522	1380/10/11	Shiraz, Sang Siah neighborhood,

					behind Haj Zainel market
11	Pakyari	Qajar	1497	1356/07/18	Kadkhoda Alley, Khaqani, Shiraz ,65
12	Moadelo Saltaneh	Qajar	1562	1356/07/18	Shiraz, Qaani street, 12th floor
13	Haji Mohaya	Qajar	1602	1357/02/26	Shiraz, Lotfo Ali Khan Zand, Bibi Girls neighborhood
14	Forougholmolk	Qajar	2040	1377/03/30	Shiraz, Sang Siah neighborhood, behind Imamzadeh Bibi Girls
15	Safa Dehghan	Qajar	6055	1381/05/08	Shiraz, Maidan Shah neighborhood, behind Bagh Ilkhani
16	Saaber	Qajar	16056	1385/06/20	Shiraz, Ahmadi Square, behind Shahada Mosque
17	Leyaghat Rafiei	Qajar	8703	1382/03/10	Shiraz, Sarbagh neighborhood, Attaran alley, floor 27
18	Nematolahi	Qajar	6049	1381/05/08	Shiraz, Lotfali Khan Zand Street, 49 Street, Floor 6
19	Dokhanchi	Qajar	1947	1376/09/16	Shiraz, behind Vakil Bazaar, Totunchi Alley
20	Sabagh	Qajar	3276	1379/12/25	Shiraz, Ishaq Bey neighborhood, Mola mosque alley
21	Tajer	Qajar	4519	1380/10/11	Shiraz, Ishaq Bey neighborhood, behind Khan school
22	Shafa	Qajar	2191	1377/10/27	Shiraz, Ishaq Bey neighborhood, Masjid alley
23	Sadr Jahromi	Qajar	2277	1377/12/08	Shiraz, Gudaraban neighborhood, adjacent to Haji Bazaar
24	Abtahi & Ahmadpour	Qajar	8655	1382/03/10	No. 15, Parvin Etsami Alley, Sarbagh neighborhood, Shiraz
25	Asadolahi	Qajar	9003	1382/03/10	Shiraz, Gud Araban neighborhood, Bait al-Abbas alley
26	Amouzegar	Qajar	4678	1380/10/11	Shiraz, Ishaq Bey neighborhood, Nasir Nizam alley, behind Ali Khan Mosque
27	Basiri	Qajar	1224	1354/09/10	Shiraz, Sang Siah neighborhood, Haj Zainel Bazaar, next to the historical house of Tawhidi and Owji
28	behnam	Qajar	8648	1380/03/10	Shiraz, No. 17, Sarbagh Taq Alley, Masjid Shahada Alley
30	Hfiz	Qajar	8992	1382/03/10	Shiraz, No. 8, Taq Beizai, Khanqah Ahmadi Alley, Sarbagh District
31	Hamidi	Qajar	8650	1382/03/10	Shiraz, Sarbagh neighborhood, behind Shahada Mosque
32	Heydari	Qajar	8969	1382/03/10	Shiraz, Lab Ab District, Haj Rahim Khormandar Alley, No6
33	Doaei	Qajar	8718	1382/03/10	Shiraz, Sarbagh first neighborhood,

					Haft Pitch alley, No13
34	Dehghan	Qajar	8669	1382/03/10	Shiraz, North Ahmadi Street, 19 Tawanger Alley, No16
35	Dehimi	Qajar	8699	1382/03/10	Shiraz, Bin Haramein St., Hammam on25,Mohtasab Alley
36	Rafat Afra	Qajar	8991	1382/03/10	Shiraz, Bibi Girls neighborhood, Engineering Alley, No45
37	Zanjirchi	Qajar	4674	1380/10/11	Shiraz, Ishaq Bey neighborhood, Nasir Nizam alley, behind Ali Khan Mosque
38	Salimi	Qajar	8998	1382/03/10	Shiraz, Lotfali Khan Zand St., Muntaserian Alley, No35
39	Sabaar	Qajar	16053	1385/06/20	Shiraz, Darb Mosque neighborhood, behind the new mosque, no59
40	Abaspour	Qajar	8700	1382/03/10	Shiraz, Bazarche Fil, Koi Moqtadari, No57
41	Gholami	Qajar	8695	1382/03/10	Shiraz, North Ahmadi Street, Tawanger Alley
42	Kazerouni	Qajar	5028	1380/12/25	Shiraz, Darb Shahzad neighborhood, Malek Al-Tajjar dead end
43	Kompani	Qajar	6074	1381/05/08	Shiraz, Gud Araban neighborhood, Lotfoali Khan Zand St., behind Khan School
44	Masoumi	Qajar	8647	1382/03/10	Shiraz, Bin Haramein St., Municipality, No15
45	Nemati	Qajar	4520	1380/10/11	Shiraz, Zand Barik Street, not reaching Baharestan Bath
46	Nobandegani	Qajar	8664	1382/03/10	Shiraz, Guzersang Siah, Islamlo Alley, No15
47	Hashemi	Qajar	8652	13982/03/10	Shiraz, Zand St., behind Mola Mosque, No20
48	Shafie Ardakani	Qajar	8694	1382/03/10	Shiraz, Haj Zainel Bazaar, Golestan Alley

References

Asadi, S., Fakhari, M., & Sendi, M. (2016). 'A study on the thermal behavior of traditional residential buildings: Rasoulian house case study'. Journal of Building Engineering, 7, 334-342.

Asghari moghdam, M.R., & rajabi, A. (2004). The natural geography of the city, Cities in dry areas. Tehran, Sara publication.

Ayali, H., & Movahed K.h. (2016). Determine the Optimal Direction of Central Yard of Houses at Qajar Period in Shiraz Based on the Rate of Solar Energy Radiation. Geography and development. 14(42), 161-182.

Balali Oskoyia, A., & Dehghan, S. (2020). Physical Typology of Qajar Houses in Urmia. Armanshahr, 14(37), 1-14.

Bently, I., Alcock, A., Murrain, P., McGlynn, S., & Smith, G. (1985). Responsive Environments: A Manual for Designers. United Kingdom: Architectural Pres. 152 p.

Dieulafoy, J. (1983). Diolafova's travelogue. Shiraz: Saadi, 449 p.

Farazjou, F., & Mahmoody Zarandi, M. (2020). Investigating the Influence of Architectural Features on Thermal Behavior of Dominant Residential Structure Patterns in Tabriz Housing. Journal of Environmental Studies. 46(2), 413-450.

Ghodsi M., Daneshjoo K., & Mofidi Shemirani S. (2018). Impact of Geometric Indicators on Residential

Thermal Behavior in Hot Arid Climate (Case Study: Yazd). Naqshejahan. 8(3), 143-148.

Hashmi-Zorajabad, H., Sadeghi, S., & Zarei, A. (2015). Investigating the role of climate on the type of architecture and decorations of Nawab Birjand Hosseini. Iranian Archaeological Research, 11(6), 151-162.

Heidari orojloo T, ghorbani param A, hasanpour F., (2023). Studying indicators of traditional architecture of Shiraz houses in order to provide a suitable model for contemporary housing design in order to use clean energy. Jgs. 23 (69), 23.

Heidari orojloo T, ghorbani param A, hasanpour F.,(2022). A study of design indicators on energy consumption in traditional Iranian homes (Case study: Shiraz houses. 4(2),48-24.

Karamirad, S., aliabadi, M., & Habibi, A. (2018). Assessing the Impact of Urban Geometry on Outdoor Thermal Comfort in Microclimate Scale: A Case Study of the Open Space of Goldasht Residential Complex in Shiraz. Journal of Regional Planning 8(29), 161-172.

Khaksar, A.R. Mofidi-Shemirani, S.M, & Nikkhah Shahmirzadi, M. (2020). Journal of Climate Research. 11(43), 171-189.

Khashei, Z. (2010). The role of passive systems in providing comfort in traditional houses in Isfahan: a case study of the Karimi house. WIT Transactions on Ecology and the Environment. 128, 271-280.

Masoudinejad, M. Tahbaz, M., & Mofidi Shemirani, S.M. (2017). The Study of the Thermal Performance of Shavadoons, Case Study: The Souzangar House in Dezful, Iran. Journal of Iranian Architectural Studies, 7(13), 49-70.

Mehdizadeh Siraj, F., Japaqli, G.h.R. & Sanhiyyan, H. (2013). Effect of pre-entry on the thermal behavior of the main space in the hot and dry climate of Iran, investigation of old houses in Yazd. Journal of Architecture and Urbanism of Iran, 8: 97-89.

Memarian, G.h.H. (2017). Introduction to Iranian residential architecture: introverted typology. Tehran: Soroush Danesh, 245-350.

Monshizade, A. (1381). The Review of Sustainable Development in Iran, Yazd.

Moradi, S., Metin, M., & Dehbashi Sharif, M. (2017). Typology of Tabriz traditional courtyard houses based on physical criteria related to the climatic performance of the central courtyard. Urban management. 51: 87-105

Olgyay, V. (1963). Design with climate: Bioclimatic Approach to Architectural Regionalism, Princeton University Press, Princeton.

Qabadian, V. (2015). Climatic survey of Iran's traditional buildings. Tehran: University of Tehran. 264 p.

Razjoyan, M. (2009). Comfort under the shelter of architecture compatible with the climate, Shahid Beheshti University Publications. 230 p.

Sanhiyian, H., Mofidishemirani, S.M., Mehdizadeh Siraj, F., & Nasrallahi, F. (2013). The effect of the juxtaposition of mass and space in building blocks on the thermal behavior inside the building (a case study of common housing in Tehran). Safeh, 63, 46-35.

Tahbaz, M., (2017). Climatic knowledge: architectural design. Tehran: Shahid Beheshti University Press. 45-56

Yaran, A., & Jafari, P. (1401). Analyzing the role of passive energy in the evaluation of Kashan houses. Manzar, 14(59): 57-40.

Zare Mohazzabieh A, , Shahcheraghi A, Heydari Sh., (2016). Indoor Environmental Quality with an Emphasis on Thermal Comfort in Traditional Houses, Case studies: Two Qajar Houses in Shiraz. JIAS. 5(9), 85-100.

Nazarboland N, Ghiyaei MM, Mafi M., (2021). Reduction of Energy Consumption Through Optimal Shutters in High-Rise Residential Buildings in Accordance with the Skylights of Traditional Buildings in Shiraz. Eslamic Art. 18(42), 394-408

Zare Mohazzabieh A, Heydari Sh, Shahcheraghi A., (2019). Indoor Environmental Quality in Qajar Houses of Shiraz with an emphasis on Thermal Comfort and Daylighting (case study: Nemati House). Yazd University- Faculty of Art & Architecture Fall & Winter, 7(10), 269-290.

Zarei, H., razani, M., & ghezelbash, E. (2017). Reconstructing the Design Pattern of Shiraz Historical Houses Approaching Climate in the Qajar Period. Pazhohesh- ha-ye Bastanshenasi Iran. 7(13), 225-242.

https://farschto.ir/., Ministry of Culture, Tourism and Crafts, Fars Provincial Administration.