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Typology of Hamedan's vernacular residential mass and space with the approach of climate performance analysis

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Abstract

The vernacular architecture of Iran consists of a meaningful combination of mass and spaces, which has found harmony with the environment under the influence of environmental, subsistence and climatic conditions; Currently, due to the energy crisis and the multiple needs of climate change, the depletion of fossil resources, the catastrophic destruction of the environment, and the exposure of valuable works of vernacular architecture to destruction, the need to record its patterns and characteristics is more and more in the center of attention. has taken Therefore, this research is looking for the physical analysis of mass and space in vernacular houses with the aim of investigating its climatic performance. Due to the fact that the cold climate is neglected in the researches, Hamadan vernacular houses as one of the cities with historical value in the Qajar to Pahlavi period were selected as the scope of the research. The research method is descriptive-analytical, which was conducted using the method of field studies and modeling in Design Builder software, and the results were analyzed based on a comparative approach and correlation test. The results show that there is an inverse and strong relationship between the indicators of the ratio of the total area to the volume and the ratio of filled to empty space to the amount of energy consumption, while there is a direct correlation between the criteria of the ratio of the opening to the side surfaces and the area of the yard to the amount of energy consumption.

Keywords: Mass and space; Residential; Vernacular architecture; Climatic performance; Hamedan

1. Introduction

Various studies have shown that indigenous buildings, compared to modern ones, consume less energy and create better comfort conditions (Nematchoua et al. 2014: 690). After 1960, indigenous architecture was considered as a source to address some shortcomings, deficiencies, and problems resulting from modern architecture in different parts of the world (Sadeghi-Pey, 2012). The study and restoration of indigenous architecture took place due to dissatisfaction with modern architecture and its inhumane qualities, with the belief that its restoration could provide solutions to contemporary issues. It is evident that the identification and preservation of indigenous architecture not only help in its conservation but also aid in discovering the hidden secrets and characteristics within it (Oveisi et al. 2020).

Vernacular architecture has created appropriate solutions and ways to adapt the building to the climate, and the climate has been considered as the main factor in the design, orientation, and spatial organization of the building (Zarei, 2018); The principles used in indigenous buildings can be well implemented in new buildings to create less energy efficient buildings (Shanthi Priya et al., 2012). Understanding the vernacular architecture of Iran requires recognizing the patterns and explaining the typology and physical characteristics affecting the climatic performance. Considering the extensive cold climate and that cities in this climate are major consumers of fossil energy, the study and exploration of the hidden aspects of the climatic performance of mass and space in indigenous residences in cold regions of the country have received less attention. Most of the conducted research has focused on warm and dry climates (Hashem Nejad and Molanai, 2008). The role of the environment in the vernacular architecture of the cold climate due to its special form and despite the different and amazing structure that has a special place in the physical and functional shaping of the buildings due to the existence of different sub-climates in different parts. Among the cities of this region, Hamadan city, with its thousands of years of vernacular architecture, was chosen due to the growth of construction in this city in recent decades and the danger of these works being lost in the near future. Therefore, the physical typology of vernacular houses in Hamedan and the evaluation of the climatic performance of different types of vernacular residential architecture and its compatibility with the climate will be pursued as

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the aim of the research, and to achieve this goal, 33 vernacular houses in the Qajar and Pahlavi periods of Hamedan city were selected and The typology was discussed, among them, the energy simulation of 5 houses with Design Builder software and the evaluation of its effect on the climatic performance of different species were compared.

1.1 Research Questions

A) How are Hamedan's vernacular houses classified in terms of the arrangement of mass and space concerning climate, and what are the characteristics of eco-oriented architecture in each type?
B) What effect did the environment have on the shape of mass and space residential space in Iran's vernacular architecture in cold climate?
C) How do the influential physical criteria affect the climatic performance of indigenous houses in Hamedan?

2. Research Background

Some researchers have suggested climate as the main reason for the emergence of open spaces in housing in Iran (Malekzadeh and Loveday, 2008). Soflaei et al. conducted an empirical field study to analyze three important parts in the design of open spaces (courtyards) in twenty notable indigenous houses in seven cities in Iran, including orientation, dimensions, proportions, as well as opaque (walls) and transparent surfaces (windows). As a result, they proposed a physical-environmental design model and introduced the central courtyard as a valuable passive strategy (Soflaei, et al, 2016). Farrokhzadeh and Modiri analyzed and examined the evolution of mass and space in different periods, offering suggestions for improving the design based on the principles of residential spaces in historical Iranian architecture (Farrokhzadeh and Modiri, 2014).
Kazanasmaz et al. conducted a study in Izmir, Turkey, examining the climatic performance of buildings and found that approximately half of the energy consumption differences in structurally similar buildings were attributed to differences in their architectural form (Kazanasmaz et al,2014). Saad et al. conducted a typology of Malay indigenous houses and evaluated their internal climatic performance, concluding that these houses provide easy ventilation for residents (Saad et al. 2019).
A study introducing six types of semi-open spaces in Yokohama, Japan, demonstrates a direct relationship between the area of open space and air temperature and relative humidity (Chun et al. 2004). Cho and Mohammadzadeh conducted a detailed study analyzing the thermal comfort of Iranian courtyard spaces in Kashan using EnergyPlus simulation software, and their results confirmed the significant advantages of Iranian courtyard spaces, particularly in the climatic performance of interior spaces in warm and dry climates, especially in adjacent areas to the courtyard (Cho and Mohammadzadeh, 2013).
Oikonomou and Bougiatiotib conducted a typology study of 40 samples of houses in Florina, Greece, with a cold climate and then analyzed climatic parameters inside and outside the buildings (Oikonomou and Bougiatiotib, 2011).
Soflaei et al. conducted a comparative analysis in a study, examining the concept of courtyard houses in Iran and China as two of the oldest civilizations in the world, with a focus on social and environmental conditions from a sustainable perspective as a holistic approach (Soflaei, et al, 2016). In Mehrabian's research, it was concluded that in the formation of spaces in indigenous architecture in these regions, attention has been paid not only to general climatic characteristics but also to the microclimaic features of each region. The microclimatic and sub-climatic differences in each of the two regions have led to differences in the architectural structure of spaces in each domain (Mehrabian et. al 2016).
A study was conducted in 2005 by Shuji et al. classifying traditional houses of "Kampong" and "Banawi" located in North Jakarta. In this research, the physical characteristics of houses in "Kampong Lotar Batang" in Indonesia were identified, analyzed, and studied (Shuji et al. 2005).
Pfeifer and Brouneck, two German researchers in the book "Typology of Courtyard Houses," categorized houses into groups including houses with central gardens, L-shaped houses, passive houses, and houses with atriums (Pfeifer and Brouneck, 2008). In a study, the selected literature indexed in the Web of Science has been reviewed in the period between 2000 and 2022 and qualitative analysis of different areas in vernacular architecture, in this article with special attention to the study area, vernacular building materials and Construction techniques, conservation problems and solutions, climate adaptation, and reuse of abandoned vernacular buildings are considered to achieve the goal of preserving vernacular architecture in the coming centuries(Pardo, J.M.F. 2023)
In the review, Karahan and Davar Dost have evaluated the vernacular architecture of Ozondere city in its relationship with ecological sustainability.(Davardost, Karahan,2020)
Zarei et al. categorized the architectural forms of houses in Hamedan in the book "Old Houses of Hamedan" (Zarei et al. 2018). Sheikh Ol-Eslami, in a research study, introduced and analyzed the climate of Hamedan and classified the housing of Hamedan from the Qajar period to the present. In this research, housing was divided into three periods, and the characteristics of each period were described solely in terms of their form (Etemad Sheikh Ol-Eslami,2011). Etemad Sheikh Ol-Eslami has attempted to achieve the principles of climatic design by examining the heating needs of the city of Hamedan and examples of indigenous housing (Etemad Sheikh Ol-Eslami, 2011).
Philokipro et al., in the research of the physical typology of vernacular buildings, identified effective factors in improving the thermal comfort conditions in the interior environment of the vernacular architecture of the city of Nicosia in Cyprus, and the results show that houses with a central courtyard and semi-open spaces and vernacular materials perform better. are better (Philokyprou et al, 2020).
Studies show that climatic analyses in indigenous architecture in countries such as Turkey, Spain, Greece,

and Japan, which are countries with rich historical heritage and architectural works, are increasing. It is obvious that studies have been conducted regarding the geometric and proportional principles of houses in different regions from a formal perspective. However, most of these studies have focused on warm and arid climates and are not easily applicable to cold climates. Therefore, considering the above, the innovative aspect of this research is emphasized.

3. Theorectical Framework

3.1.Indigenous architecture

Traditional houses can be seen as a tangible expression of human life (Gokce and Chen, 2018) and these are one of the important components of the fabric of historical cities, whose main documents reflect the characteristics of the communities to which they belong(MozafarMoghaddam etal, 2023).

The most influential early works in this field are the those of Rudofsky. Both Oliver and Rapaport attempted to set fundamental principles for this architecture, which is also referred to as anonymous, self-generated, indigenous, and rural architecture (Rudofsky, 1987), and distinguish it (Zwerger, 2019).

Since the beginning of architecture, based on local knowledge and experiences, indigenous architecture has been striving to achieve harmony between nature and buildings (Kirbas and Neslinur, 2016). Humans have always sought to create suitable living spaces within the constraints and possibilities of the climate. Their efforts have given rise to various housing patterns and created different species, each functioning optimal within its own habitat (Nikghadam, 2013).

As an important part of cultural heritage, indigenous houses preserve tangible and intangible values, shape the local identity of places, and contribute substantially to achieving sustainable development goals. The design of indigenous houses and their characteristics are primarily based on knowledge gained through trial and error rather than conventional scientific methods, offering desirable solutions to environmental constraints (Rakoto-Joseph et al. 2009).

Rapaport considers indigenous architecture to be simpler and more popular, overall an architecture that responds to the needs of the general public. In his opinion, indigenous architecture seeks to create a balance instead of dominating nature (Alpagono, 2005). Roth also believes that in less developed cultures, known as third world countries, a vital renaissance of their own architecture has emerged, a style influenced by traditional culture and indigenous patterns (Roth, 1994).

3.2. Typology

This term is also used in other sciences and originates from the Latin word "typus," meaning form. It was during the transformations after the Industrial Revolution and the scientific and industrial advancements of Europe in the 18th and 19th centuries that scientists, such as Linnaeus, extensively contemplated the scientific classification of living organisms and other natural objects. From the mid-18th century, typology was employed in architecture and archaeology as a tool for recognition and classification. Architects like Durand attempted to scientifically approach architecture based on developments in various sciences, such as biology. Types of typological methods include climatic typology, formal typology, historical-evolutionary typology, semantic typology, and cultural-social typology (Amir et al. 2022), each of which starts with a specific criterion, and the typology is then carried out based on that criterion. In this study, due to the emphasis on the climatic performance of houses, a form-climatic typology has been employed. First, the influential criteria on the climatic performance of traditional houses in Hamedan's empty courtyards were evaluated, and based on that, traditional houses in Hamedan were classified.

Table 1
Effective criteria on the climatic performance of indigenous houses

Criterion	Indicator	Definition
The shape and layout of the mass and space (criterion 1)	CF1	Buildings with courtyards on one front
	CF2	Houses with courtyards with buildings on two adjacent fronts
	CF3	Houses with courtyards with floor mass on two fronts
	CF4	courtyarded houses with three fronts
	CF5	houses with courtyards on four fronts
	CF6	Extroverted houses in the middle of the yard or garden
orientation (criterion 2)	Longitudinal orientation	Layout relative to the proper direction
Courtyard area	proportions	Courtyard area
Floor mass (criterion 3)	Number of floors and location	The first two-story type (ground floor/first)
		The second two-story type (basement/ground floor)
		The third type of three floors (basement/ ground floor/ first floor)
		The fourth type of three floors (ground floor, first floor, second floor)
		The fifth type of four floors (basement / ground floor / first / second)
		The sixth type of one floor (ground floor)
compactness (criterion 4)	Mass to Space ratio	Mass to space ratio 0 to 0.5
		Mass to space ratio 0.5 to 1
		Mass to space ratio 1to 1.5
		The ratio of Mass to space is 1.5 to 2

3.3. Mass and space in architecture

It seems that by studying indigenous architecture, one can understand its ideas and components and explain how to create harmonious relationships(Falahat,Shahidi, 2014). The consequences of the marginalization of spaces have led to issues such as lack of coordination and coherence in architecture, inappropriate appearance of houses, and negative environmental effects (Ahmadi et al. 2020). Spaces are the most significant spaces that shape climatic patterns and, to some extent, organize climatic patterns (Mahdavinejad et al. 2016).
Examining architectural elements such as dimensions and mass and space indicates that indigenous architects, through their understanding of the laws of coexistence of opposing pairs, the dialectic of reciprocal qualities, and the oscillations between them, have been able to provide the conditions for architectural coordination with the climate. With a proper understanding of geometry, scale, and proportions, they have created houses where negative space receives as much attention as positive space (Ahmadi et al. 2020).

3.4. Climatic performance

The foundation for the formation of residential environments in terms of climatic performance is the creation of spaces that can provide suitable environmental conditions for human comfort with minimal energy consumption. Neglecting climatic conditions in the construction process results in excessive energy consumption, improper use of natural energy sources, lack of thermal comfort, and increased environmental pollution. The climatic performance of buildings affects the optimal energy consumption in buildings and can be summarized in three factors: architectural design, climatic specifications, and occupants' behavior. According to studies, these factors can multiply energy consumption up to 10 times. Inappropriate design alone can increase energy consumption by up to 2.5 times the conventional consumption, and when mechanical facilities are added, energy consumption can increase up to 5 times the normal level (Ghobadi, 2002). As one of the biggest energy consumers, buildings can make a significant contribution to environmental protection through correct and principled design (L. Belussi et al. 2019;S. . Naylor et al.2018). The influential formal criteria on the climatic performance of houses, which are also the main factors in their architectural design, are classified in Table 1.

4. Research Method

Generally, the research process on a small scale does not adhere to a predetermined model of analyzing theoretical and analytical ideological content in applied research, especially when the analysis methods involve field strategies and operational analysis using simulation software in energy studies.
The current research is of an applied nature and combines qualitative and quantitative methods, involving the determination of indicators, data analysis, and ultimately the evaluation of results. The independent variable is climatic factors, while the dependent variable is the climatic performance of houses and their physical characteristics, serving as a moderating variable. The statistical population consists of 90 indigenous houses in Hamedan, with 33 selected as samples from the Qajar and Pahlavi periods due to their availability of information, documentation, and accessibility for fieldwork, considering the destruction of some houses and the vulnerability of others to destruction. The non-probabilistic and purposive sampling method was employed, and the selected houses are specified in Table 3.
In the next stage, the categorization of houses was performed based on criteria influencing the climatic performance of houses. To analyze the climatic performance of the samples, computer simulation using DesignBuilder software was utilized. Finally, the correlation analysis between the influential criteria on the climatic performance of houses and the energy consumption level was examined, and the results were presented for better comparison through tables and charts.

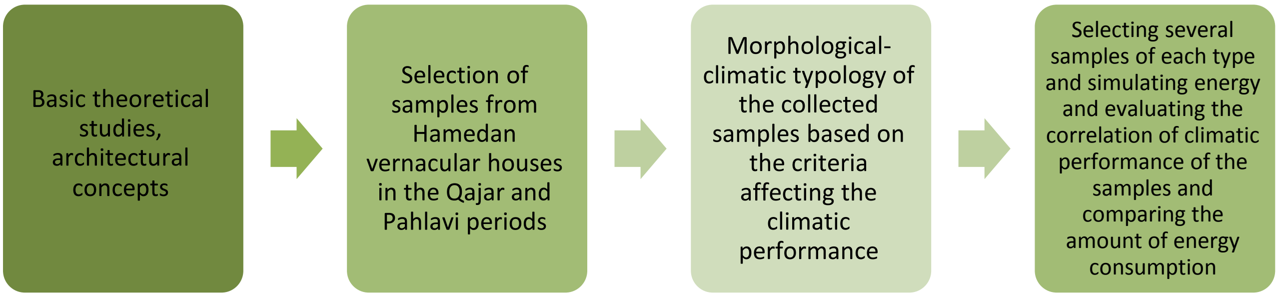


Fig 1. Research process

5. The situation of the samples

Hamedan, a historical city located in north western of Iran, is as the first governmental center of Iran in the mountainous region of Alvand. According to long-term climatic studies Service in 2021, the climatic characteristics of Hamadan are listed below. The average annual temperature is 11.2 °C and the average maximum

temperature is 31.4 °C during the warmest summer days. The average minimum temperature is -1 °C during the coldest winter nights. The temperature fluctuation during a month (difference between the minimum
and maximum temperature) is often more than 4 °C and even reaches 13.2
°C (8.2 °C on average). (US National Weather Service,Iranian typical meteorological year (ITMY) data). The characteristics of this city include mild summers and severe cold in winter. Winters are long, cold, and harsh, with low precipitation in summer and snow in winter. Generally, the spring season is short in this region . The heating requirement accounts for 92% compared to the cooling requirement of 8%. Winter lasts from 4.5 to 6 months, and the temperature drops below 4 degrees. There is also the factor of the cold western wind (Etemad Sheikh oleIslami, 2011). Figure 2 shows the bioclimatic diagram for Hamedan caused by the Climat Consultant software.

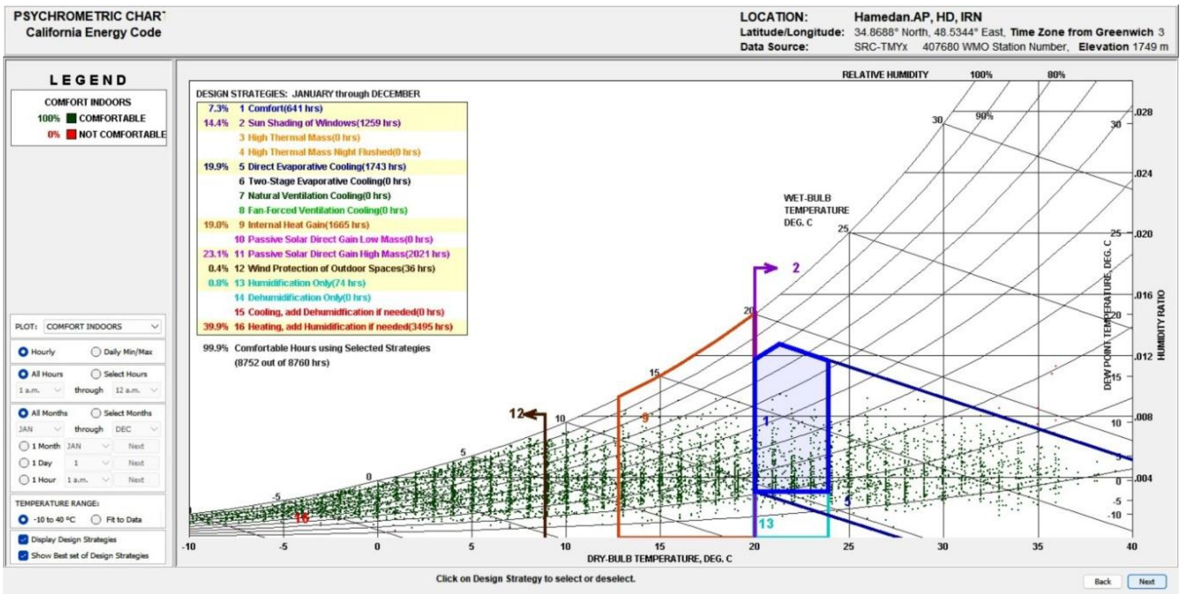


Fig 2.Bioclimatic diagram in Hamedan (Source: Climate Consultant software)

6. Findings

6.1.Physical-climatic typology of houses

6.1.1. Criterion 1- The shape and layout of the mass and space of vernacular houses in Hamedan (CF)

By examining the plans of the researched houses in context, regarding the way of floor mass in different fronts of the building, six models (types) can be investigated and classified as described in Table 2:

Table 2
The characteristics of different types of houses in Hamedan based on the placement of mass and space in different fronts of the building .

The shape and layout of mass and space (criterion 1)	**CF1** - one-front courtyarded houses
	CF2- houses with courtyards on two fronts, built with fllor mass on two adjacent fronts (L shape)
	CF3- Houses with courtyards on two fronts, built with a floor mass on two opposite fronts
	CF4- Houses with courtyards on three fronts - (U shaped)
	CF5- built houses with courtyards on four fronts.
	CF6- extroverted houses in the middle of the yard or garden

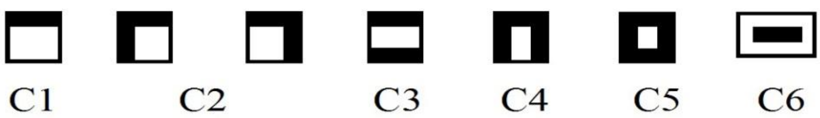
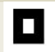
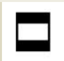
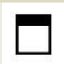
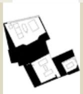
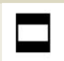
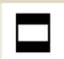
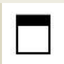
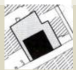


Fig 3. Classification based on the layout of mass and space in different fronts of the building

Table 3
Physical characteristics of selected vernacular houses in Hamedan city

row	house	Plan floor mass	Full to emty ratio	Courtyard area	Foundation area	Exterior courtyard	Interior courtyard	Ivan and semi-open	Opening installation	ratio of opening surface in facade	Lan length to width ratio	direction	plan
1	Entezam		0.72	252	330	252	-	-	vertical - horizontal	45%	1.7	23 SE	
2	Parsivoshan		2.32	2270	1071	270	-	-	vertical	45%	1.3	18 SE	
3	Tajbakhshian		1.14	130	360	130	-	-	vertical - horizontal	30%	1.2	9 SE	
4	Samavat		0.63	296	358	296	-	-	vertical	42%	1.7	28 SE	
5	Shahbazian		0.57	671	770	451	220	-	vertical	40%	1.5	32 SE	
6	Araghchi		0.68	525	1071	525	-	357	vertical - horizontal	42%	2	26 SE	
7	Ghazanfari		0.34	477	426	477	-	102	vertical - horizontal	40%	1.8	42SW	
8	Mazouchi		0.23	1057	534	1057	-	-	vertical	20%	1.45	61SW	
9	Naraghi		0.93	599	1132	352	247	150	vertical	45%	1.4	36 SE	
10	Farhang mansion		-	-	1200	-	-	400	vertical	18%	1.7	5 SW	
11	Naeini		1.8	180.5	750	180	-	-	vertical	33%	1.5	10 SE	
12	Feizi		0.72	98	136.5	98	-	-	vertical	32%	4.4	2 SE	
13	Ebadi		0.3	655	585	655	-	-	vertical	30%	1.1	60 SE	
14	Zarabi		0.92	450	865	450	-	-	vertical	36%	2.35	28 SE	
15	Madani		0.29	257	150	257	-	-	vertical	30%	2.8	12 SE	
16	Samadian		1.54	227	702	227	-	-	vertical	55%	1.85	28 SE	
17	Sarem aslani		0.52	462	825	462	-	-	vertical	23%	1	61SW	

18	Saberioun		0.6	650	743	650	-	-	vertical	25%	1.1	10 EN	
19	Sharifi		0.52	657	680	657	-	-	vertical	45%	2.1	33 SE	
20	Ebrahim Sharafi		0.63	467	582	467	-	-	vertical	30%	1.8	31 SE	
21	Jannat mansion		0.25	970	698	970	-	-	vertical	20%	1.3	2 WN	
22	Seyfi		0.71	407	544	407	-	-	vertical	33%	1.4	55SW	
23	Shiri		0.1	2736	673	2736	-	-	vertical	25%	1.1	21 SE	
24	Khalabani		1.78	153	508	153	-	-	vertical	25%	1.8	33 SE	
25	Nazari garden		0.1	8150	1692	8150	-	-	vertical	18%	1.8	16WN	
26	Pousti zadeh		0.47	670	640	670	-	-	vertical	40%	1.7	17 SE	
27	Bijan		-	-	480	-	-	-	vertical	50%	2	23 SE	
28	Samsam		1	295	486	295	-	-	vertical	27%	1.5	10SW	
29	Etemadieh Garden		0.011	29884	676	29884	-	-	vertical	20%	1.8	14WN	
30	Ghargouzlo		0.18	4481	810	4481	-	-	vertical	20%	3	2 WN	
31	Ahmadi		0.5	322	320	322	-	-	- vertical horizontal	40%	1.7	15 SE	
32	Chitsaz		0.57	635	900	635	-	-	vertical	40%	1.7	43 SE	
33	American mansion		-	-	183	-	-	-	vertical	20%	1.4	12WN	

(Source: Hamedan Cultural Heritage Organization)

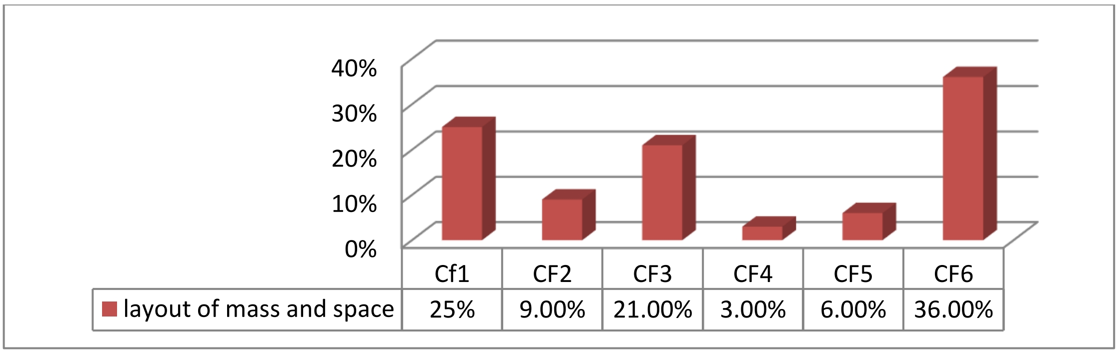


Fig 4. Frequency of different types of houses in Hamedan based on layout of mass and space (CF) -(Source: Research findings, 2024)

According to picture 4, 36% of the samples have a house in the middle of the yard, after that 25% of the samples have a building mass only on one northern front of the yard, 21% of the samples have a building mass on two fronts (facing each other), 9% of the samples have building mass on two adjacent L-shaped fronts (north and east), 3% of samples on three fronts (U-shaped) and 6% of samples also have building mass on all four fronts around the yard. Therefore, the increase in the ratio of houses to the building mass in the north face is due to the need to use the sun's radiation in the cold seasons. Houses with a central courtyard provide conditions for seasonal use and create a full and dense space, which reduces the heat exchange with the outside, and by reducing the external surfaces, it gets a relatively dense texture. In some studies, Hamedan houses are divided into 5 types: one-sided, two-sided, L-shaped, U-shaped and central (Shams Azad, Fooladi, 2022).

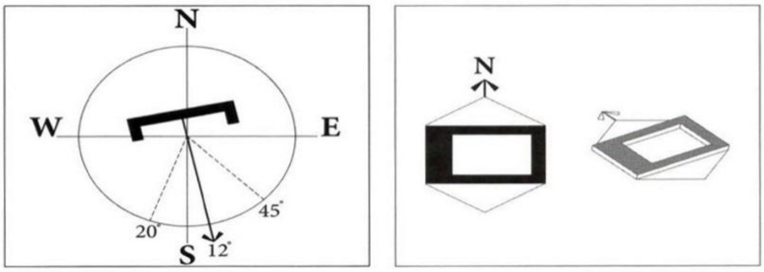


Fig 5. The orientation of the building in Hamedan according to Pirnia's opinion (Source: Pirnia and Memarian, 2016) (left side)

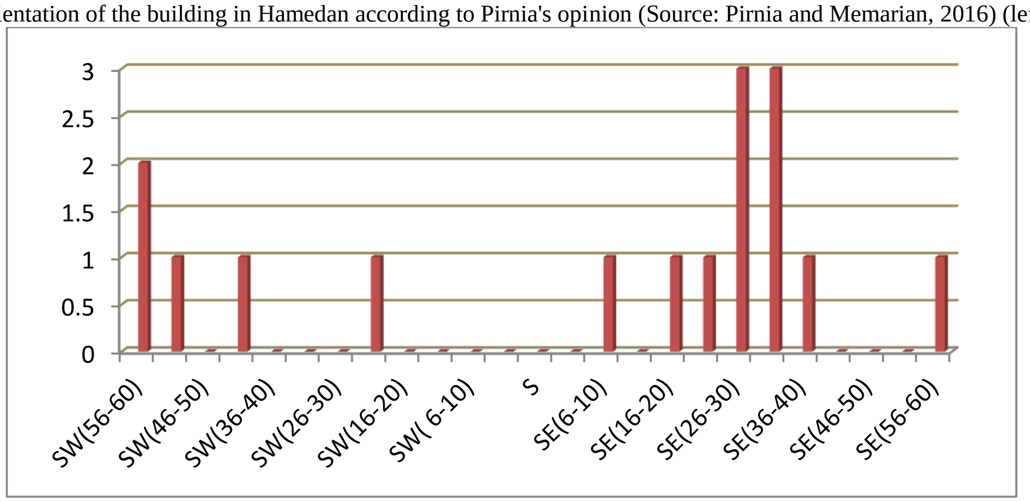


Fig 6. The angle of rotation of Hamedan house courtyards in relation to the geographic south direction(An-C)

6.1.2. Criterion 2- courtyard rotation angle (An-C)

The orientation or alignment of a courtyard, which is measured relative to geographical directions, has a direct correlation with the amount of sunlight received and determines the quality and quantity of received solar energy. Among various patterns in this city, according to conducted studies, the NW-SE orientation has the highest frequency with 61%, which determines the frequency of adaptation to the climate. The rotation angle and orientation of the house relative to the north-south axis play a role in the relationships because they affect the amount of sunlight and shading. The elongation and extension of courtyards in some examples are aligned with the main axis of the courtyard, while in others, they are aligned with the secondary axis. Previous research on this topic indicates a lack of comprehensive and systematic studies (Zarei et al. 2018), with only the opinions of Pirnia and Kesmaee available. According to Pirnia's opinion, the alignment of courtyards in Hamedan follows the Kermani trend, which is in the east-west direction (Pirnia, 2016) (Figure 5). The term "orientation" refers to the main axis of the main spaces of the house, generally the reception hall, and most of Hamedan's house orientations during the Qajar period, as shown in Figure 6, are toward the southeast. The elongation and extension of courtyards in some examples are aligned with the main axis of the courtyard, while in others, they are aligned with the secondary axis. In general, the north-south extension of courtyards predominates. In general, the more elongated the north-south extension of the courtyards, the higher the amount of radiation, and consequently, the average solar temperature and heat reflection from the horizontal surfaces of the courtyard floor and building masses increase, contributing to improved thermal comfort in the courtyards during the cold seasons.

6.1.3. Criterion 3 - Floor mass

Regarding the compactness of building floors, according to the chart in Figure 7, there are six classification categories: the first category includes two floors (ground floor / first floor), the second category includes three floors (basement / ground floor / first floor), the third category includes three floors (ground floor / first floor / second floor), the fourth category includes two floors (basement / ground floor), the fifth category includes four floors (basement / ground floor / first floor / second floor), and the sixth category includes one floor (ground floor). The second category, with two floors (ground floor / first floor), has the highest frequency with 54%, while the fourth, fifth, and sixth categories each have the lowest frequency with 3%. Therefore, most of the houses in Hamedan are built on two or three floors, which causes more density of the building and reduction of heat losses from the roof.

Typically, in traditional Hamedan homes, living spaces such as the main hall and sitting area are located above service areas such as storage rooms, water reservoirs, and kitchens to utilize their heat.

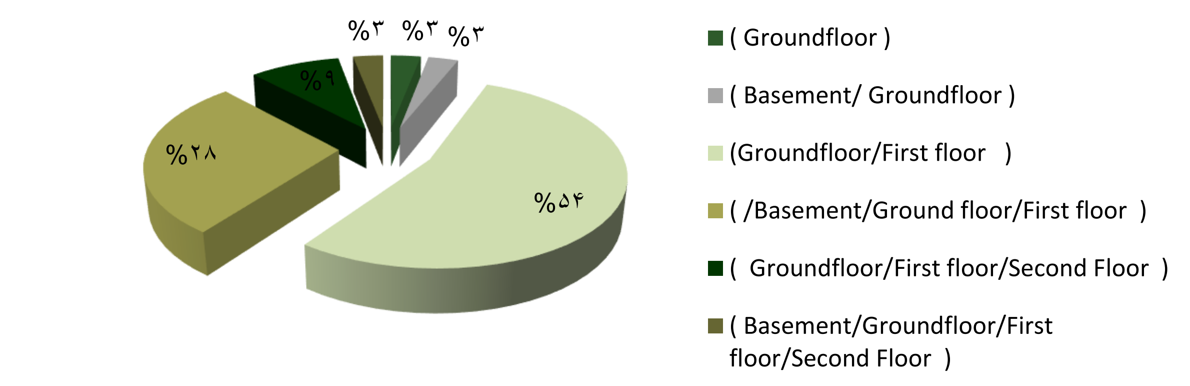


Fig 7. Frequency based on the floor mass of Hamedan houses.

6.1.4. Criterion 4 - The ratio of building area and courtyard area (CA:BA)

This criterion, which indicates the ratio of mass to space, is one of the most important characteristics of courtyards in cold regions and determines their climatic performance. The significance of this criterion lies in its significant impact on the climatic performance of the building. The ratio of mass to spaces in homes ranges from 0.5 to 2; The greater the number of facades, the larger this ratio is, and the smaller the number of building facades, the smaller this ratio is. In open-air homes, this ratio is less than 0.5 due to their location in the middle of a garden or courtyard.

The area of the courtyard is a significant factor that is influenced by weather and affects the climatic performance of the courtyard and its near spaces. Based on Figure 9, in enclosed homes, houses with courtyards ranging from 100 to 300 square meters have the highest frequency with approximately 33% among the studied samples. Although small and enclosed courtyards prevent direct wind penetration and increase wind shade in cold seasons, they also limit the amount of sunlight radiation during cold seasons and reduce heat storage in the building's structure and near surfaces. On the other hand, reducing the area of courtyards and increasing their confinement limits ventilation in the summer. In general, courtyards in Hamedan houses are small, except for open-air homes located in spacious gardens. The level of courtyards in single-façade houses (CF1) is rectangular and oriented north-south, covering one to three times the area of enclosed spaces. In such buildings, the lower floor level is usually the same as the courtyard floor level. In double-façade parallel houses (CF2), the courtyard area ranges from half to twice the area of the building footprint. In L-shaped houses (CF3), which have square proportions, the courtyard area is also square and varies from half to twice the building footprint.

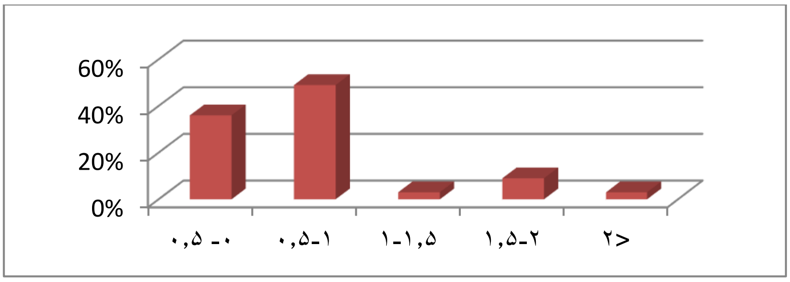


Fig 8.Frequency of types based on the ratio of mass to space .

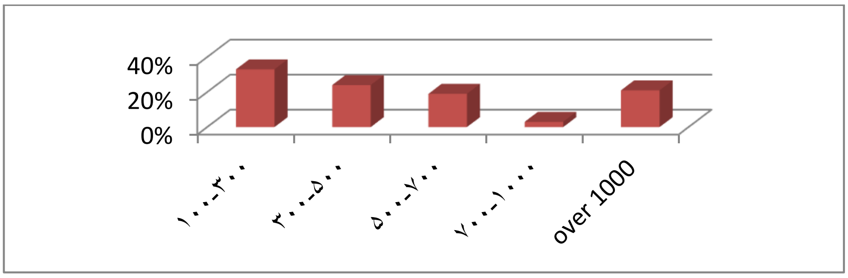


Fig 9. Frequency of types based on courtyard area .

Table 4
The results of the typology of vernacular houses in Hamedan based on the physical characteristics affecting the climatic performance in each type

(S/V)	(H/W)	(H/L) Height ratio according to yard length (H/L)	The ratio of opening levels in the south facade	The ratio of full to space	area	Placement direction	period	**Houses**	**type**
0.3 – 0.45	0.6 – 0.8	45- 65%	40- 45%	0.5- 1	250-500	SE	Qajar	Gazanfatri,Naraghi, Etezam, SHahbazian, ParSiavoshian	**Type-A Qajar**
0.3 – 0.6	0.3 – 0.55	0.3- 0.5	30-40%	0.5 – 1 1- 1.5	100-700	SW)19%, (SE) 81%	late Qajar and early Pahlavi periods	Sharifi, Sharafi, Siefi, Samavat, TajBakhshian. KHalabani, PoostiZadeh, Samadian, Zarabi, Araghchi, Naeini, Feizi, Madani, Bijan, Samsam, Ahmadi	**Type B- Eclectic**
0.1 – 1.2	0.1 – 1.2	0.1 – 0.6	20-30%	0-0.5 1-1.5	Over 700	(SE) 25% ،(SW) 25% (EN)8% ، (WN)42%	Pahlavi	Saberion, Ebadi, Mazouchi, SaremASlani, CHitsaz, Nazari Garden, Farhang, Shiri, Etemadieh Garden, GHaregozlo, American Garden	**Type C- Pahlavi**

6.2. Typology of Hamadan houses

According to the results, the houses in Hamedan were formed in harmony with the climate and the main factor was the use of the maximum solar radiation, and the houses in Hamedan were divided into three types based on the physical criteria affecting the thermal performance of the houses in the period from Qajar to Pahlavi. The main can be classified:

- **Type 1** (Qajar): houses of the Qajar period, which were introverted with a central courtyard and had an interior and exterior space.
- **Type 2** (combined type): houses related to the late Qajar and early Pahlavi periods, which are a combination of introvert and extrovert.
- **Type 3** (Pahlavi): extroverted Pahlavi houses inspired by western architecture.

6.2.1 Climate analysis and software simulation

Considering the importance of thermal behavior among the samples, 5 key samples (according to Tables 5 to 7) were selected for software simulation, with the following characteristics:
The selected houses have historical and architectural value.
Sufficient photos, figures, and documentation of the houses are available or can be obtained.
They represent different arrangements of mass and space.
The key samples were chosen based on the prevalence of the desired house type among their respective categories.
The examined houses include:
From category 1: Naraqi House (CF5) and Entezam House (CF2)
From category 2: Zarabi House (CF3)

From category 3: Mazouchi House (CF1) and Ebadi House (CF6)

Table 5
The plan and size of the sample houses of type 1, modeled in Design Builder software, source of the maps: Cultural Heritage Organization of Hamedan Province

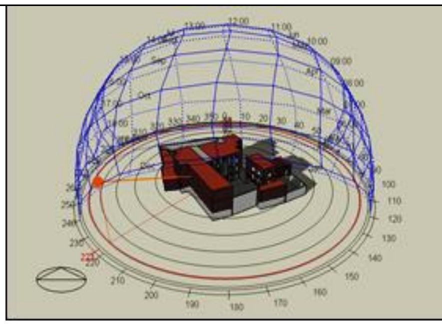
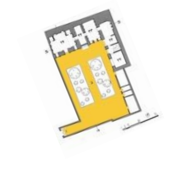
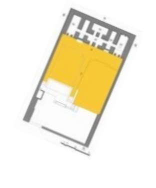
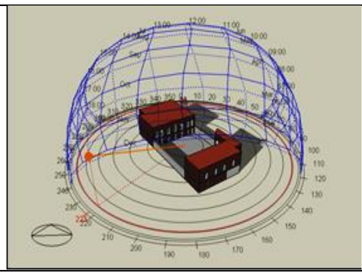
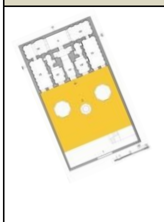
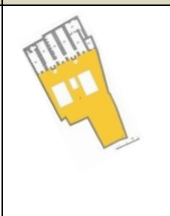
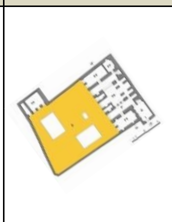
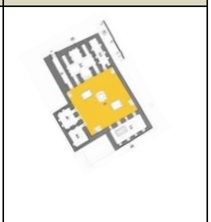
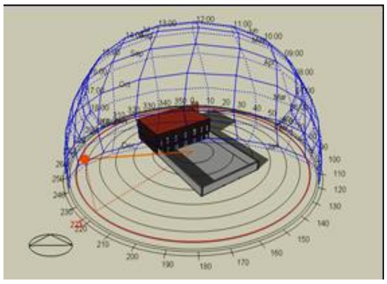
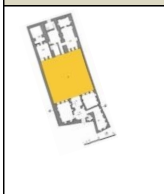
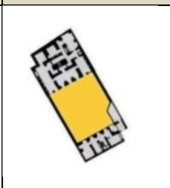
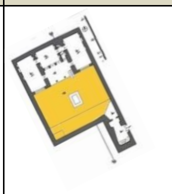
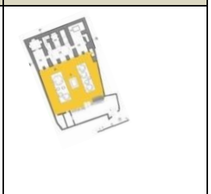
Type A	empty ■ full ☐			Modeled volume of Naraghi house
Qajar period	**Naraghi**	**Entezam**	**Ghazanfari**	
				
	CF5	**CF2**	**CF1**	

Table 6
The plan and size of the sample houses of type 2, modeled in Design Builder software, source of the maps: Cultural Heritage Organization of Hamedan Province

Type B	empty ■ full ☐				The modeled volume of the Zarabi house
Eclectic period	**Sharafi**	**Sharifi**	**Seyfi**	**Khalabani**	
					
	CF3	**CF1**	**CF2**	**CF4**	The modeled volume of Khalabani house
	Samadian	**Zarabi**	**Tajbakhshian**	**Samavat**	
					
	CF3	**CF3**	**CF3**	**CF3**	

(Source: Research findings, 2024- extracted and compiled by the authors)

Table 7
The plan and size of the sample houses of type 3, modeled in Design Builder software, source of maps: Cultural Heritage Organization of Hamedan Province

Type C	empty ■ full ☐			Modeled volume of Ebadi house
P a h	**Saberioun**	**Mazouchi**	**Ebadi**	

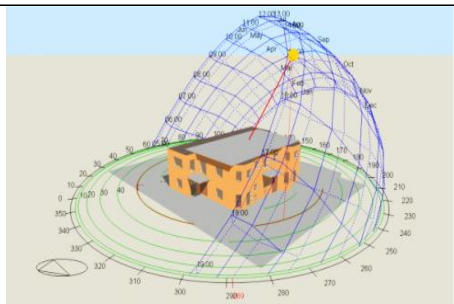
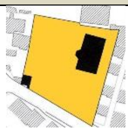
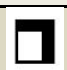
				
	CF1	**CF1**	**CF6**	Modeled volume of Mazouchi house
	Poustzadeh	**Sarem aslani**	**Nazari garden**	
				
	CF6	**CF6**	**CF6**	

Table 8
Physical parameters affecting the climatic performance of selected examples of vernacular houses in Hamedan for energy simulation.

type	house	Plan floor mass	Date of building	Thermal mass	External wall depth	Ratio of total infrastructure to volume (A/V)	The ratio of lateral surface area to volume (S/V)	Opening surface to lateral surface	The ratio of length to width of the plan	No. of floors	plan
A	Entezam		Qajar	0.148	0.90	0.24	0.39	0.189	1.7	2	
A	Naraghi		Qajar	0.158	0.95	0.27	0.39	0.169	1.4	3	
B	Zarabi		Pahlavi	0.155	0.70	0.28	0.41	0.10	2.35	3	
B	Khalabani		Pahlavi	0.176	1.10	0.26	0.42	0.146	1.8	2	
C	Mazouchi		Pahlavi	0.160	0.75	0.36	0.22	0.154	1.45	3	
C	Ebadi		Qajar	0.158	0.80	0.35	0.22	0.10	1.2	3	

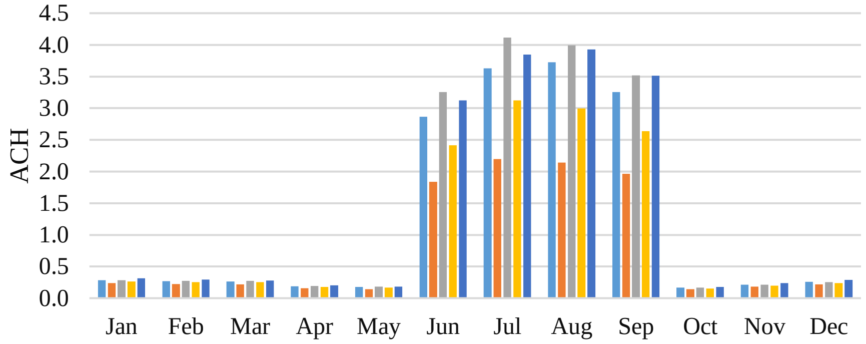
6.2.2. Thermal comfort and air-conditioning simulation

In order to evaluate the performance of traditional buildings, samples are analyzed after modeling in two stages with appropriate filters for summer and winter. The heat transfer items from surfaces, the amount of received radiation, the level of natural ventilation, and ultimately the cooling and heating needs of the buildings are examined. For an accurate comparison, the results are presented per square meter to ensure a proper comparison due to the differences in building foundation.

6.2.3. Energy simulation

In this model, it is assumed that if the outside air temperature is suitable during the warm seasons, the windows are opened, and natural ventilation takes place.

Therefore, natural ventilation is inactive during the cold seasons. Now, the number of air changes per hour (ACH) throughout the year for all forms is as shown below. The optimal performance in natural ventilation is attributed to the Ebadi and Naraghi houses.



Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Nara:gh House
Fig 10.The number of air conditioning based on ACH unit throughout the year

The heat transfer of building through the windows can be observed in the following figure in which the greatest heat waste through window is attributed to Naraghi and Entezam houses.

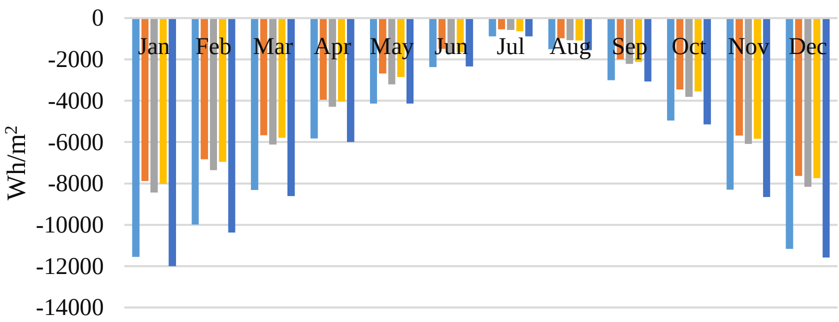


Fig 11. Heat transfer from building glass - source : research finding
Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Naragh House

The heat transfer of building through the walls can be observed in the following figure in which the greatest heat waste through window is attributed to Naraghi,Zarabi and Entezam houses.

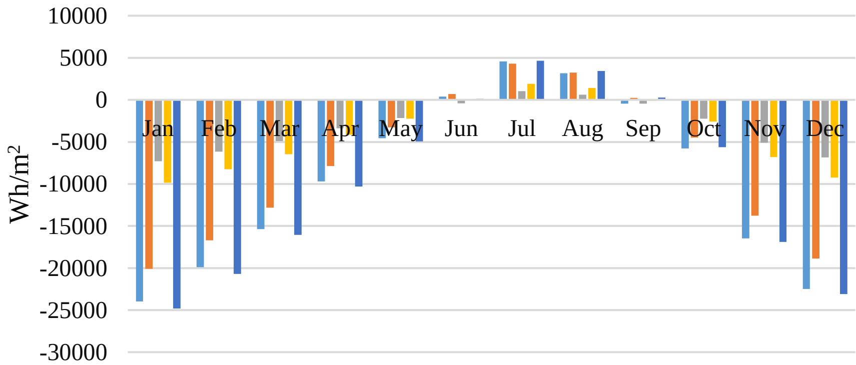


Fig 12.Heat transfer from the wall of the building
Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Naragh House

The heat transfer of building through the roof can be observed in the following figure in which the greatest heat waste through window is attributed to Naraghi,Zarabi and Entezam houses.

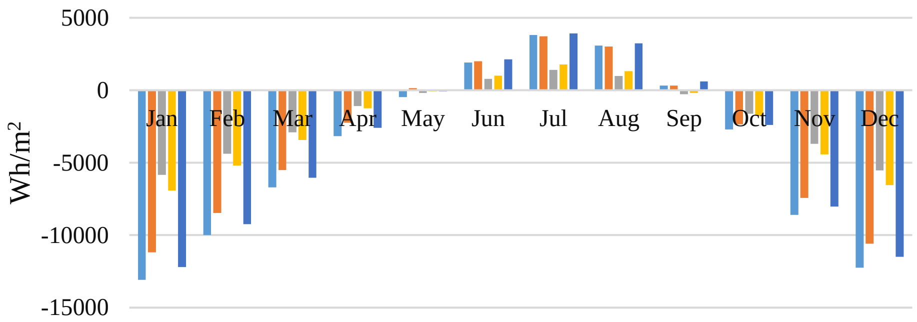


Fig 13.Heat transfer from the roof of the building
Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Naragh House

The radiation rate received from the windows is seen in the following figure in which the highest radiation is attributed to Entezam house.

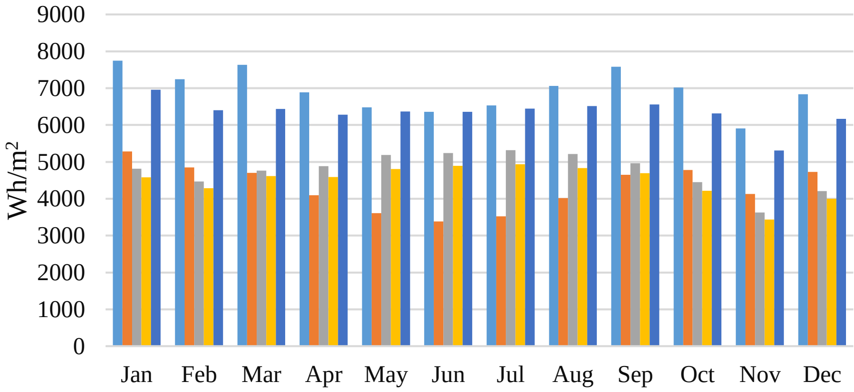


Fig 14. The amount of radiation received from the windows of the building
Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Naragh House

The sum of heating and cooling requirement in the building is seen in Figure 25 in which the greatest and lowest energy requirement is attributed to Naraghi and Entezam houses , and Ebadi house , respectively.

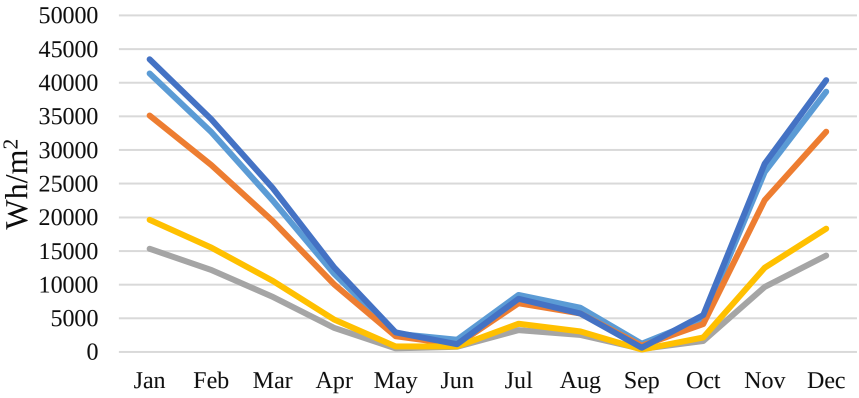


Fig 15.The total cooling and heating needs of the building
Entezam House , Zarabi House , Ebadi House ,Mazhuchi House , Naragh House

Table 9
Summary of energy simulation analysis results with Design Builder software There is a comparison for the energy requirement in the houses , based on kwh/m2.

Houses	Heat transfer from glass	Heat transfer from the wall	Heat transfer from the ceiling	Number of air conditioning	cooling load	heating load	incoming radiation	The total load of the building
Entezam	72	127	66	3.4	18	181	83	199
Zarabi	49	106	57	2.0	15	154	52	169
Ebadi	53	40	28	3.7	7	65	57	72
Mazouchi	50	53	34	2.8	8	84	54	93
Naraghi	74	130	62	3.6	15.1	192	76	207

7. Discussion

With the researches obtained, in the late Qajar and Pahlavi period, the new way of life has made an impact in the macro, medium and micro areas of the residential space. The transformation in the field of macro space has led to the simplicity of the form, the shrinking of the house and the yard, and the reduction of the gender role of the space in the form of removing the outer yard. (Ebrahimi, Sultanzadeh, & Karamati, 2016, p. 36).

In response to the first question, according to the results of the existing houses in Hamadan, according to Figure 26 and paragraph 2-6, based on the physical criteria affecting the thermal performance of the houses in the period from Qajar to Pahlavi, they can be classified into three main types. Also, according to the presented analysis, it can be said that the mass and space of houses in the cold climate of Hamadan, whether small or large, follows a specific spatial system and three spatial groups, mass, empty and covered (semi-open) space in most These houses are present.

In response to the second question, the following aspects can be mentioned regarding the influence of the environment and the local context on the spatial configuration of mass and empty residential spaces in traditional Iranian architecture in the cold climate of Hamedan.

In the city of Hamedan, Qajar period houses were introverted with a central courtyard. They are Gradually influenced by the architectural culture of the west, consequently the plans have become extroverted, which has caused consistency problems(Mazinanian et al,2022).

After categorization and comparison, the findings from Criterion 1 in Hamedan houses indicate that 36% of the samples have a building mass on one side of the courtyard to maximize the use of solar energy. The one-sided and rectangular courtyard has the highest frequency among the samples and has shown the highest compatibility with the climate through simulation (Ebrahimi et.al , 2017).

- The examination of the angular orientations of the courtyards (Criterion 2) suggests that the most orientations are toward the southeast (SE), and the frequency of courtyard orientations decreases significantly outside the specified range, which shows harmony with the climate.
- The vertical body, especially on the southern side of the courtyard, usually lacks a significant height to avoid shading. However, increasing the height of the northern side (south-facing façade) enables for more solar radiation and passive heating of spaces facing south. The dimensions and proportions of facades, especially the southern ones, have an impact on the absorption of solar radiation. The northern and southern facades of the central courtyard in traditional Iranian architecture are taller, while the eastern and western facades are shorter (Soflaei et al. : 231).
- The area of the courtyards in Hamedan, except for extroverted houses enclosed within the courtyard, is relatively small (100 to 300 square meters). This helps prevent direct wind gusts onto the courtyard-facing walls, creating more shade during the cold seasons. However, it limits the amount of solar radiation in the cold seasons and reduces heat storage in the building envelope and near surfaces. However, the reduction in courtyard area and increased enclosure limit ventilation possibilities in the summer.
- One of the features of Hamedan houses is the presence of a space called " Seizan," located approximately half to one meter below the ground level or at the same level as the courtyard in some samples. This space serves as a service area, such as a kitchen, storage, etc. It has a lower ceiling height and less heat exchange, and the upper floor is used as a living space.

Table 10
Summary of the physical typology of Hamedan houses

Min	Max	Hysical features of houses
		Building orientation
700-1000 square meters	(33%) 100-300 square meters	Courtyard area
Base- ground floor-first floor	Ground floor- first floor	Floor mass
Above 2	0.5- 1	The ratio of mass to space
45% -55%	20% _ 30%	The ratio of openings to the total surface area
Above 1	0.5 -0.55	Ratio of width to length in oening of main facade

Table 11
Correlation coefficient (Lawner Weinbergn and Knapp, 2002)

correlation coefficients	interpretation
0-0.1	**Very low**
0.1-0.3	**low**
0.3- 0.5	**medium**
0.5- 1	**high**

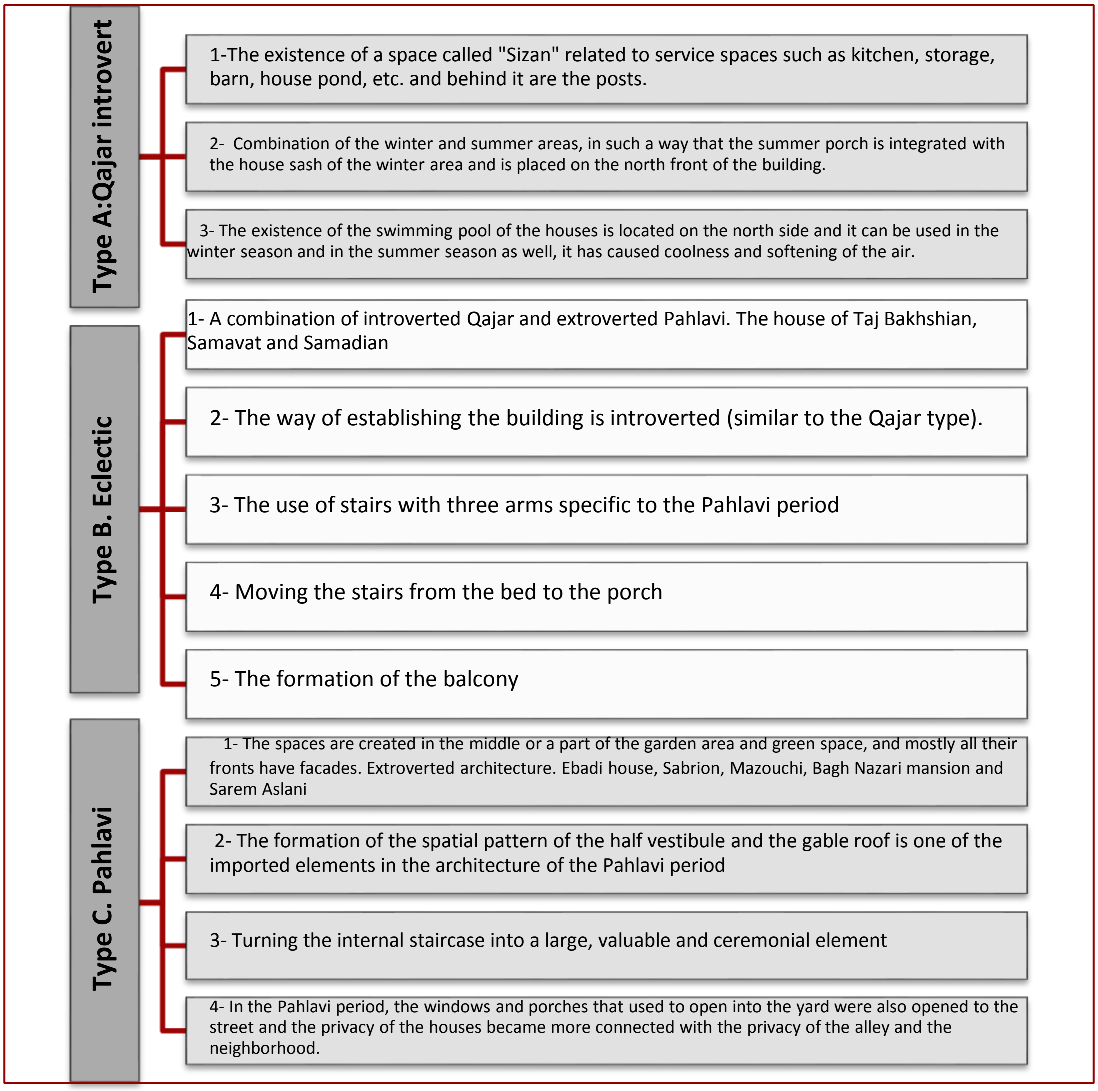


Fig 16. Characteristics of different types of vernacular houses in Hamedan

8. Conclusion

Correlation analysis was used to determine the relationships between physical indicators and their effects on climatic performance of houses .The correlation coefficients are determined as in Table 12.

In response to the third question, based on the results:

- The correlation coefficient shows a direct relationship between the height-to-width ratio of the building's courtyard (H/W) and the energy consumption, with a low intensity of correlation.
- Increasing the height-to-length ratio of the courtyard (H/L) also leads to an increase in energy consumption, and there is a direct correlation with a low intensity of correlation.
- With an increase in the side area-to-volume ratio (S/V), the heating energy consumption increases. The correlation is direct and has a low intensity for heating energy, while it is average for cooling energy and total energy consumption.
- Furthermore, the results indicate that increasing the overall floor area-to-volume ratio (A/V) leads to a decrease in total energy consumption. There is an inverse correlation with a high intensity for heating, cooling, and total energy.
- As the mass-to-void ratio (compactnessy increases, energy consumption decreases, resulting in an inverse correlation with high intensity for total energy (cooling and heating).
- There is a weak direct correlation between the ratio of opening areas to side areas and energy consumption

Table 12
Analysis of the correlation coefficient between the criteria affecting the climatic performance of vernacular houses in Hamedan and energy consumption

Moderator variable	Author(s)	Year of Publicati	Interpretation of the correlation coefficient	Type of relationship
The ratio of the height to the width of the yard (H/W)	Heating Energy(KWh/m2)	0.297	low	Direct
	Cooling Energy (KWh/m2)	0.046	Very low	Direct
	Total Energy (KWh/m2)	0.194	low	Direct
The ratio of the height to the length of the yard (H/L)	Heating Energy(KWh/m2)	0.137	low	Direct
	Cooling Energy (KWh/m2)	0.145	low	Direct
	Total Energy (KWh/m2)	0.137	low	Direct
Side surface to volume ratio (S/V)	Heating Energy(KWh/m2)	0.302	Medium	Direct
	Cooling Energy (KWh/m2)	0.159	low	Direct
	Total Energy (KWh/m2)	0.241	low	Direct
The ratio of the total surface area to the volume (A/V)	Heating Energy(KWh/m2)	-0.505	Much	Reverse
	Cooling Energy (KWh/m2)	-0.730	Much	Reverse
	Total Energy (KWh/m2)	-0.601	Much	Reverse
Ratio of mass to space (density)	Heating Energy(KWh/m2)	-0.606	Much	Reverse
	Cooling Energy (KWh/m2)	-0.655	Much	Reverse
	Total Energy (KWh/m2)	-0.663	Much	Reverse
The area of the yards	Heating Energy(KWh/m2)	0.939	Much	Direct
	Cooling Energy (KWh/m2)	0.819	Much	Direct
	Total Energy (KWh/m2)	0.907	Much	Direct

- Increasing the courtyard area leads to an increase in energy consumption, so there is a strong direct correlation.

The classification of traditional houses in Hamedan was performed based on the criteria affecting their climatic performance, and the examination of the houses' results shows three different types of houses in Hamedan (Figure 26): the introverted Qajar type, the hybrid type, and the extroverted Pahlavi type. The latter type emerged as a result of lifestyle changes and the influence of Western architecture. Since evaluating climatic performance with only a few components does not yield accurate results, this research, in addition to simultaneous energy analysis, has also examined the cumulative effect of influential criteria on climatic performance. The summary of the results shows an inverse and significant correlation between the surface-to-volume ratio (S/V) and the mass-to-void ratio and energy consumption. On the other hand, there is a direct and significant correlation between the ratio of opening areas to side areas, courtyard area, and energy consumption. There is a weak direct correlation with low intensity between the height-to-width ratio (H/W), height-to-length ratio (H/L), side area-to-volume ratio, and energy consumption. The analysis of the obtained results also indicates that energy consumption in different types of houses depends on their location and orientation. Energy consumption in the Zarrabi house of Type B (introverted) is higher than the Saarem Aslani house of Type C (extroverted). In general, the analysis shows that in vernacular architecture, the harmonization of human and environmental factors has been considered as a two-way relationship, and the houses have demonstrated suitable performance against the climate. Organizational and spatial solutions, such as placing the mass on the northern and eastern fronts, orienting the house toward the southern side, seasonal use of building facades, using thick materials and walls, the existence of a space called "Sizan," a higher proportion of southern facades compared to other facades, are all effective climatic measures. Additionally, the higher proportion of southern facades compared to the other two facades results in more solar energy utilization, which is fully compatible with a cold climate. The orientation of Qajar and hybrid houses corresponds to the viewpoint presented in Kasmayi's book, but it does not align with the Kermani perspective.

References

Ahmadi, Z. Hbib, F., Nghizadeh, M. (2020). The paradigm of Emptiness and fullness in vernacular architecture of Iran: form and fabric aspects. Journal of Environmental Science and Technology, 22(2 (93)),pp: 195-207.

Amir B. , Mofidi Shemirani S. M., Khanmohammadi M. , Sajadzadeh H. (2022). Surveying the typology of mass and space in the structure of vernacular houses in cold climates; Case study: Tabriz, Journal of Housing and Rural Environment, 41 (179). pp.47-60.

Chun,Ch, Kwok,A., Tamura A. (2004). Thermal comfort in transitional spaces-basic concepts: literature review and trial measurements. Building and Environment:, 39(10). pp.1187-1192.

Cho,S., Mohammadzadeh,N.(2013).Thermal comfort analysis of a traditional Iranian courtyard for the design of sustainable residential buildings:, In: Proceedings of the 13th conference of international building performance simulation association (BS2013), Chambéry, France. pp.2326–2333.

Ebrahimi, Gholamreza, Sultanzadeh, Hossein, Karamati, Ghazal. (2017). Reflection of western culture in the evolution of the lifestyle and architecture of late Qajar houses in Hamedan:, Bagh Nazar magazine, number 47. pp.29-38.

Etemad Sheikh al-Islami, F. (2011). Climatic survey of Hamadan housing:, Sofe Journal.

Falahat, M. S., Shahidi, S. (2014).The role of the concept of mass - space in the explanation of architectural spac:, Bagh Nazar magazine, number 35, year 12 .pp. 27-38.

Farrokhzadeh, Mohammad and Modiri, Iman. (2014). digging into the design principles of open spaces with regard to the background of Iranian architecture and urban planning :, Iranian Islamic City Studies Quarterly, No. 16, Summer 2013. pp. 81-95.

Ghobadi, B. (2002).Solutions for Energy Conservation Optimization in the Building Sector:, Proceedings of the Iranian Fuel Conservation Organization. Tehran, 11-12 March,pp.543-551.

Gokce, D. Chen, F.(2018). Sense of Place in the Changing Process of House Form: Case Studies from Ankara, Turkey:, Environ. Plan. B-Urban Anal. City Sci. 45, pp.772–796. [CrossRef]

Hashem Nejad H., Molanai S. (2008). Architecture with a view toward the sky Rural Settlements – Especial patterns in Rural Architecture of Zagros (Province of Kurdistan), Honar-haye-Ziba Magazine. 4(36), pp.17-26.

Karahan, F., Davardoust, S. (2020). Evaluation of vernacular architecture of Uzundere District (architectural typology and physical form of building) in relation to ecological sustainable development. Journal of Asian Architecture and Building Engineering, 19(5), 490–501.

Kasmai, Morteza. (2013).Climate and Architecture:, Tehran:Khak Publishing House, eighth edition.

Kazanasmaz,T.,Uygun, I.E., Akkurt,G.G., Cihan,T., Kenan,E.E.(2014). On the relation between architectural considerations and heating energy performance of Turkish residential buildings in Izmir:, Energy and Buildings,Vol. 72, pp. 38-50.

Kirbas, B Neslinur, H. (2016). Learning from Vernacular Architecture: Ecological Solutions in Traditional Erzurum Houses, Journal of Procedia Social and Behavioral Sciences ,(216), pp.788-799.

L. Belussi, B. Barozzi, A. Bellazzi, L. Danza, A. Devitofrancesco, C. Fanciulli, M. Ghellere, G. Guazzi, I. Meroni, F. Salamone, F. Scamoni, C. Scrosati. (2019). A review of performance of zero 25 energy buildings and energy efficiency solutions, J. Build. Eng 25, pp. 13-142.

Mahdavinejad,M. Mansourpour,M. Masoudinejad,M. (2016). The place of climate in the composition of contemporary buildings: case study: Qajar era houses in Dezful city, Hoviat Shahr magazine, 26th issue, 10th year, pp.61-74. (In Persian).

Malekzadeh,M.,Loveday, D.L.(2008).Toward the integrated thermal simulation of indoor and outdoor building spaces, In: Proceedings of the international conference of Air conditioning and the low carbon cooling challenge, Cumberland Lodge, Windsor,UK. pp. 27–9.

Mazinanian, B., Sabernejad, J. , Dolati,M., Nikghadam, N.,The Influence of Culture in the Body of Traditional Courtyards of Hamedan Based on Data Theory, Space Ontology International Journal, Volume:11 Issue: 1, Winter 2022. 33 to 43.

Mehrabian, S. Majdi,SH . Farazjoo, F. (2016) Comparative comparison of the proportions of mass and space in the architecture of vernacular houses in the plains and mountains in the east of Gilan , International Conference on Architecture, Urban Planning, Civil Engineering, Art and Environment; Future horizons and Retrospect, Tehran, Iran. (In Persian).

Mozafar Moghaddam,Y., Ahmadi, V., Farkisch, H., Ostadi,M.(2023). Analysis of Physical Identity via House Typology(Case Study: Sabzevar City), Space Ontology International Journal, Volume:12 Issue: 4, pp: 13 to 30.

Nematchoua, M. K, Tchinda,R and Orosa, J.A. (2014). Thermal Comfort and Energy Consumption in Modern Versus Traditional Buildings in Cameroon:

A Questionnaire-Based Statistical Study, Applied Energy (114), pp.687–699.

Nikghadam, Nilofar. (2013). The pattern of semi-open spaces of vernacular houses in Dezful, Bushehr and Bandar Lange in relation to local climate components, Fine Arts Magazine No. 3. pp.69-80.

Oikonomou,A., Bougiatioti, F. (2011). Architectural structure and environmental performance of the traditional buildings in Florina. NW Greece, Journal of Building and Environment, Issue 3 (46). pp. 669-689.

Oveisi Kokha,Z, HosseinAli,K., Heydari A., Davtalab,J.(2020). Typology of spatial organization of vernacular housing in Sistan in terms of the formation of open and closed space , Journal of Housing and Rural Environment, 39 (171) , pp. 61-72.

Pardo, J.M.F.(2023) Challenges and Current Research Trends for Vernacular Architecture in a Global World: A Literature Review. Buildings Journal, 13, 162.

Pfeifer, G. Brauneck, P. (2008). Courtyard House: A Housing Typology, Berlin, springer, Birkhäuser Basel publisher.

Pirnia, M.K. (2016). Stalystic of Iranin architecture, compiled by Memarian,G. , Soroush Danesh Publications, Third print, Tehran . (In Persian).

Rapaport, Imas. (2013). Housing Anthropology, translated by: Khosro Afzalian, Tehran, Kasari Library Publisher, second edition: 26. [Translated In Persian].

Roth, L.M. (1994) Understanding Architecture: Its Elements, History, and Meaning , The Herbert Press Ltd., London.

Philokyprou, M. Michael, A.(2020). Environmental Sustainability in the Conservation of vernacular Architecture. The Case of Rural and Urban Traditional Settlements in Cyprus, Int. J. Archit. Herit, 15, 1741–1763.

Philokyprou, M., Aimilios, M., & Stavroula, T. (2013). Assessment of the bioclimatic Elements of vernacular Architecture. The Historic Center of Nicosia, Cyprus. Building and Environment, 3, 54, 666–675.

Rakoto-Joseph O., Garde F., David M.,Adelard,L., Randriamanantany,Z.A.(2009). Development of climatic zones and passive solar design in Madagascar.Journal of Energy Conversion and Management. 50(4), pp.1004-1010.

Rudofsky, B.(1987). Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture, University of New Mexico Press: Albuquerque, NM,USA, ISBN 978-0-8263-1004-0.

S. Naylor, M Meroni, F. Salamone,. Gillott, T. Lau.(2018). A review of occupant-centric building control strategies to reduce building energy use, Renew. Sustain. Energy Rev. 96. Pp:1–10.

Saad. H., Abdullah, A.S.N., Azni, M.E., Yaocob, Z., & Ghazali, M.S. (2019). Typology of Malay Traditional House and its Response to The Thermal Environment, Materials Today: Proceedings, 19, 4,1761-1770.

Sadeghi pei, N.(2012). History and causes of tendency toward vernacular architecture in the West, Islamic countries and Iran, City and vernacular architecture, Number 2: 7-24. (In Persian).

Shams Azad,F.,Fooladi,V. (2022). Assessment of Thermal Comfort in Vernacular Buildings in the Cold and Mountainous Region (Case S tudy: Hamadan, Iran) , International Journal of Architecture and Urban Development ,Vol.12, No.1, pp. 55-70.

Shanthi Priya, R., Sundarraja, M. C., Radhakrishnan, S. & Vijayalakshmi L. (2012). Solar passive techniques in the vernacular buildings of coastal regions in Nagapattinam,TamilNadu-India–a qualitative and quantitative analysis, Energy and Buildings, 49: 50–61.

Shuji, Funo, Bambang ,F.F., Yamada,K. (2005). Consideration on typology of Kampung house and Betawi house of Kampung Laur Patang (Jalcarta) , Journal of Asian Architecture and Building Engineering, Vol. 4,No.1, pp.129-136.

Soflaei, F., Shokouhian, M., Zhu, W. (2016) c. Socio-environmental sustainability in traditional courtyard houses of Iran and China, Renew. Sustain. Energy Rev. 69, pp.226–238.

Soflaei F., Shokouhian M., Mofidi Shemirani S.(2016). ‘ Traditional Iranian courtyards as microclimate modifiers by considering orientation, dimensions, and proportions, Frontiers of Architectural Research, Volume 5, Issue 2, pp:225-238.

Zarei, M.I.and Hatami Majed, F. and Mohammadian Mansour, S. (2018). Hamedan Old Houses, Hamedan, Golden Publishing.

Zwerger, K.(2019). Vernacular Architecture: A Term Denoting and Transporting Diverse Content. Built Herit, 3, pp. 14–25. [CrossRef]