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Advances in Ecological and Environmental Research (ISSN 2517-9454, USA), 191-204 | Science Signpost Publishing

Proportional Optimization in Traditional Houses Based on Bioclimatic Design

Pourvahidi Parastoo[1], Masoud Jahangiri[2]

1. Architecture Department, Cyprus International University, Lefcosa, North Cyprus.

2. Architecture Department, Islamic Azad University (North branch), Tehran, Iran.

Received: June 18, 2018 / Accepted: July 22, 2018 / Published: October 25, 2018

Abstract: In the past inhabitants used different techniques for surviving harsh climatic conditions. Thus, the ability to understand and optimize their logic, knowledge and experience in creating buildings is significant. One of the techniques used in traditional houses for adapting to climatic conditions is the proper proportion of open space and closed space. Also, the proportion of the openings on the different façades of the structure. Therefore, this paper investigates the relationship between the proportions of traditional buildings located in Babolsar (temperate and humid climate) , Ghazvin (cold climate) and Lar (hot & dry) to reveal that proper proportion in design could be one step toward creating buildings consistent with thermal comfort factors.

Key words*:* Vernacular Building, Bioclimatic Design, Green Architecture, Zero energy

1. Introduction

Open and closed spaces and openings (doors and windows) in traditional buildings in temperate and humid, cold climate and hot & dry regions in Iran have played a significant role in the adaptation of inhabitants to live in harmony with climatic conditions. Traditional buildings in Babolsar (M-01), Ghazvin (M-02) and Lar (M-03) were measured in accordance with the proportion of the whole plan, the proportion of the façade in different directions, and with reference to daylight and shadows in June (the hottest month of a year) and January (the coldest month of a year) at different hours of the day. The aim of the research is to try and obtain a better understanding of these factors.

Furthermore, we have used a bioclimatic map (fig.1) created by Pourvahidi and Ozdeniz in 2013. This paper assumes the climatic conditions of Babolsar are temperate and humid, Ghazvin are cold climate and

Corresponding author: Pourvahidi Parastoo, Architecture Department, Cyprus International University, Lefcosa, North Cyprus.

Lar in hot & dry region (Parastoo Pourvahidi & Mesut B. Ozdeniz, 2013).

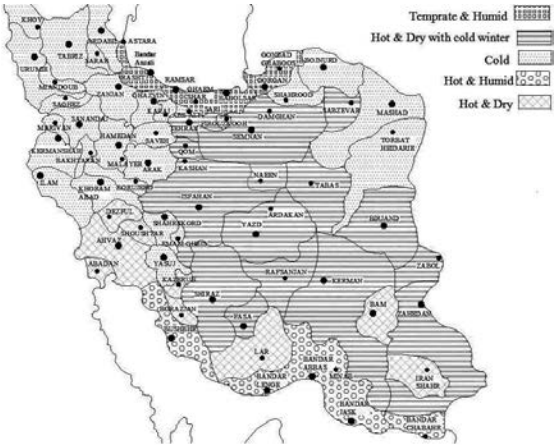


Fig. 1. Five different climatic zones of Iran (Parastoo Pourvahidi & Mesut B. Ozdeniz, 2013)

1.1. New Bioclimatic Analysis

The research used in the following indices was gathered by synoptic stations of meteorological organizations during a forty-six-year period:

1. Average maximum temperature 2. Average minimum temperature

3. Average maximum humidity 4. Average minimum humidity

Using this method, a new bioclimatic chart was achieved, delineating the specific type of climate in each region. The authors studied the traditional buildings in these regions using six steps, and discuss them in context to six corresponding factors: their forms and their positions on the site; proportions of the openings and facades; space relation between different parts of the structure; shadow positions during all months of the year; proportions of the yard and the levels usage; and finally, consideration of the direction and maximum speed of the wind. Determining the optimal position and placement of structures and their openings in relation to the wind throughout the year is another purpose of this essay.

The cities of Babolsar, Ghazvin and Lar were chosen because of their locations in three different geographical regions (fig.2). In addition the plan, elevation and 3D model of traditional houses in these three cities have been presented on table 1. In the manner of studying environmental factor considering the latitude and longitude and height above the see level are one of the significant factor which has been shown on table 2.

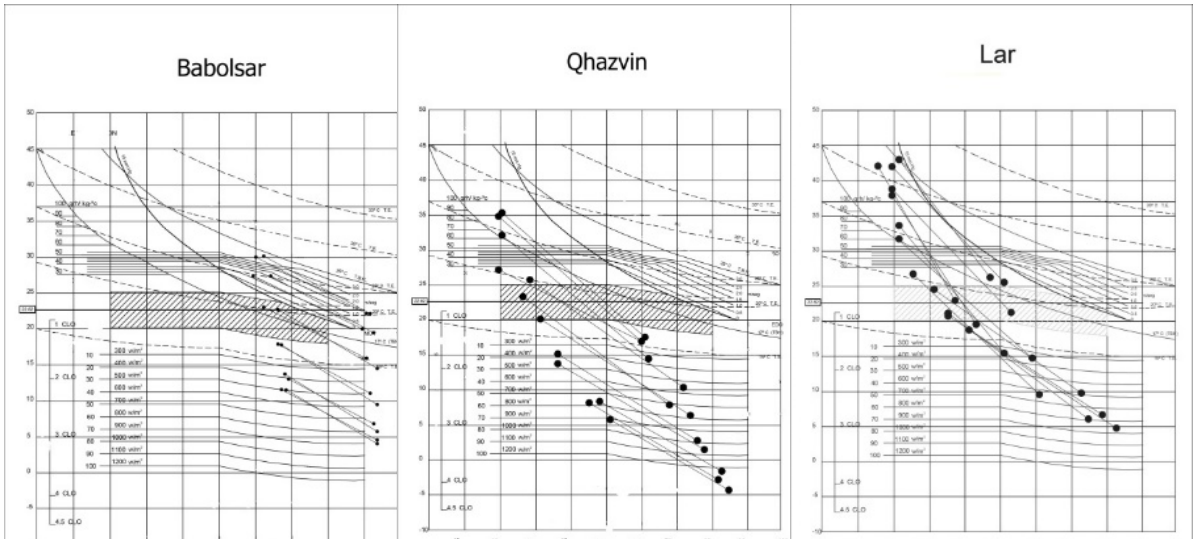


Fig. 2. New bioclimatic chart of case studies

Table 1. 3D model of the traditional Houses in Lar (M-03), Ghazvin(M-02) and Babolsar(M-01)

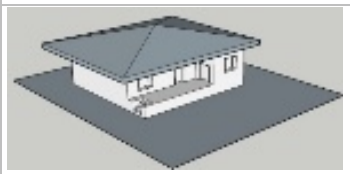
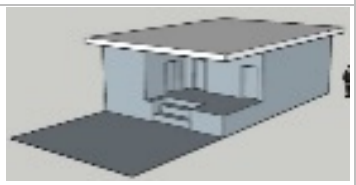
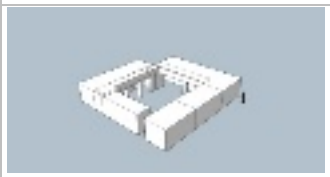
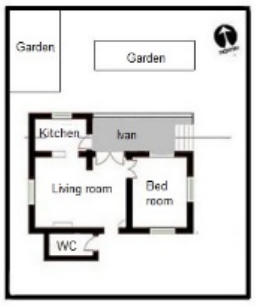
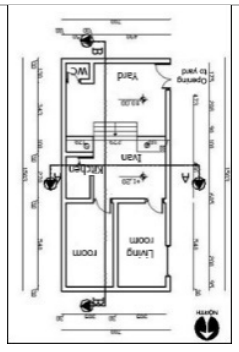
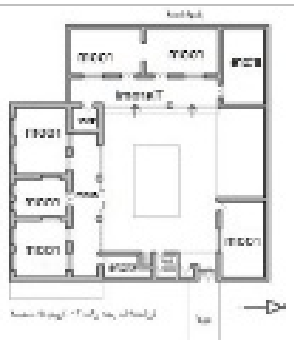
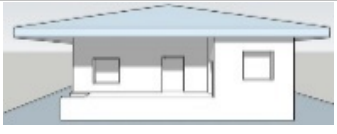
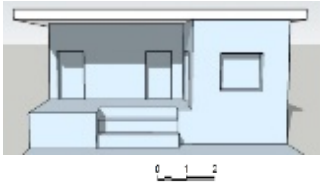
	M-01	**M-02**	**M-03**
form			
Plan			
Façade			

Table 2. Latitude and altitude of case studies (Iran Metrological Organization, 2017)

City	latitude	Longitude	Above sea level
Babolsar	36°43 '	52° 39' 30"	**-21 meter**
Qazvin	35° 37' - 36° 45'	48° 45' - 50° 55'	**2700 meter**
Lar	27° 41'	54° 17'	**800 meter**

Furthermore, this research compares the outcomes of the new bioclimatic chart with the theories of previous researchers (table 3).

Table 3. Climatic classification of scientists

Researcher /city	Babolsar	Ghazvin	Lar	Researcher method
(Koppen.W, 1936)	Bsk= arid-summer arid Cold and arid	csa=warm And arid summer	Bsh=arid-steppe, hot arid	**Based on the growth and development of plants, air temperature and air humidity**
(Riazee J, 1977)	Temperate and humid in summer, temperate humid in winter	Hot- dry summer, very cold winter	Hot- dry summer, Temperate winter	**Based on Olgyay's method**
(Kasmaee.M, 1993)	Cold and humid	Cold and temperate	Hot- dry	**Givoni's method**
(Ganji H, 2006)	temperate and humid climate	cool climate	Hot- dry	**based on koppen division**
(Tahbaz M & Jalilian S, 2008)	Relatively cold winter, Relatively warm summer, High humidity of air and soil	Relatively warm and dry summer, Cold winter	Very hot and dry summer, Temperate winter	**Based on olgyay's method**
(Parastoo Pourvahidi & Mesut B. Ozdeniz, 2013)	Temperate and humid	Cold	Hot and dry	**Bioclimatic analysis**
Jahangiri 2018	Temperate and humid	Hot and dry with cold winter	Hot and dry with Relatively cold winter	**Bioclimatic analysis**

Koppen was the first scientist to study the world's weather, but there are some mistakes in his classifications (1936), such as claiming the summers are hot in the north west of Iran, although the average summer and winter temperatures are much lower than the rest of the country in that area. In In Olgyay's 1963 classification Iran was considered a hot, dry area, but taking into consideration its geographic features, including a mountain range and the seas around it, a different type of weather is observed (Koppen.W, 1936).

Climate classifications of Iran have been done by Iranian scientists such as Tahbaz and Jalilian and Kasmayi and Riazi, based on Olgyay and Gioni's method. These classifications were based on the seasons, but is not suitable for modern houses which have smaller spaces and do not contain winter or summer rooms (Kasmaee, 2003).

Pourvahidi considered the bioclimatic analysis method. She studied sixty-eight meteorological stations in Iran, dividing Iran into five different climatic regions: temperate and humid; hot and dry with a cold winter; hot and dry; hot and humid; and a cold climate (Pourvahidi & Ozdeniz, 2013).

1.2. Proportion

In 2012 Nabavi studied thirty traditional houses in the city of Yazd, and suggested proportions for the main yards of the houses, creating rooms with five openings (Panjdari), openings based on the incoming light of day, and the golden rectangle proportion used in the current design of houses.

However, in Nabavi’s article other features of the climate went unnoticed. For example, in the hot and dry with cold winter climate of Yazd, while the sunlight in winter is pleasant, its intensity during the summer makes the houses very hot. Direct light, daytime temperature and humidity are all factors involved in a building (Faezeh Nabavi, Yahaya Ahmad, & All Tee Goh, 2012).

Perhaps using the golden rectangle proportion in traditional buildings in Iran is only for aesthetics, and not climate factors or energy stability.

In 2015 Shahmortezayi and Sabernejad investigated the houses of the Qajar period in the city of Bushehr, including proportions of the yards, levels of shadows on the walls, and the comfort level with regard to local weather conditions. Data obtained from meteorological stations in the region over a fourteen-year period were examined, and they concluded that by optimizing the floor to wall ratio of the central courtyard, increased shaded areas in the yard reduced the temperature of the walls. Less energy was used to cool the buildings and it reduced the temperature in the yard using natural air currents (Seyed Reza Shahmortezaei & Jaleh Sabernejad, 2015).

2. Methodology

As a first step in the study, the houses are modelled using Rhino and Google's Sketch Up software. The case studies in the three different climatic zone cities each have one floor, and the form of the structures is displayed in table 4.

Table 4. Structure form

Table 5	**Structure form**	**Floors**		
Code		Underground	Ground level	First level
M-01	Building on one side of the yard at a distance			X
M-02	Building on one side of the yard			X
M-03	Building on around side of the yard		X	

Table 5 demonstrates the proportions of the buildings on all sides in each direction, north, south, east, and west.

Table 5. Proportions of building in directions

Table 6	**Proportions of building in directions**			
code	North	South	East	west
M-01	1:1	----	----	----
M-02	1:1	1:25	1:12	----
M-03	1:5	2:5	2:5	1:5

In table 6 the ratio of the traditional buildings' surface to the yard surface is considered, and it was determined the ratio of mass surface in Babolsar is lower. This is might be due to the air stream between the

buildings' masses, but in Lar and Ghazvin this is done to prevent the wind blowing into the buildings.

Table 6. Proportion of building mass to yard surface

Table 6	**Proportion of building mass to yard surface**
code	
M-01	1:1.5
M-02	1.5:1
M-03	3:1

In Babolsar, the stretch direction of the building is east to west, in Ghazvin it is north to south and in Lar be like square form. As described in the plans of the buildings where are located in Babolsar the building's mass is positioned on the northern section of the ground, in Ghazvin on the northern section and in Lar are around of the ground and the building's entrance position is shown in table 7.

Table 7. Orientation and position

Table 7	**Orientation and position**		
code	entrance position to the building	Building mass position	To stretch the yard
M-01	South	Centre	Eastern- Western
M-02	South	North	Northern-Southern
M-03	West	Around the ground	Square form

Table 8. Proportion of building mass to Ivan

Table 8	proportion of building mass to Ivan
code	
M-01	1:5
M-02	1:4
M-03	1:3

The relationship between the different functions of the building, residential and service, is defined on all sides (table 9). This includes the ratio of space used, semi-open and connected to the building, all of which is on the first level (Table 10).

Table 9. Relationship between spaces

	Relationship between spaces							
code	west		East		South		North	
M-01	service	residential	service	residential	service	residential	service	residential
	indirect		direct		direct		direct	
	residential	residential	residential	residential	residential	residential	residential	residential
	direct		direct		------		direct	
M-02	service	residential	service	residential	service	residential	service	residential
	indirect		indirect		indirect		indirect	
	residential	residential	residential	residential	residential	residential	residential	residential
	indirect		indirect		------		indirect	
M-03	service	residential	service	residential	service	residential	service	residential
	indirect		indirect		direct		indirect	
	residential	residential	residential	residential	residential	residential	residential	residential
	-------		direct		direct		indirect	

Table 10. Proportion of usage to building mass

	proportion of usage to building mass							
	South west				North east			
Code	communicational	Services	Residential	Half semi open	communicational	services	residential	Half semi open
M-01	---	---	---	---	1:20	1:7	1:2	1:5
M-02	--	---	---	---	1:20	1:8	1:2	1:6
M-03	1:2	1:3	1:2	1:2	1:3	1:6	1:3	1:4

The proportion of length to width in plan is described in table 11 and the ratio of used space to the whole building space was defined in all four directions, as shown in table 12.

Table 11. Proportion of length to width in plan

Table 11	**proportion of length to width in plan**
Code	
M-01	1:1.5
M-02	1:2
M-03	1:1

Table 12. Proportion of building mass in side to whole mass

	proportion of building mass in side to whole mass			
Code	west	East	South	North
M-01	----	----	----	1:1
M-02	---	1:12	1:25	1:1
M-03	1:10	1:3	1:3	1:5

The second step includes the proportions of height on the north side in Ghazvin and Lar, and in Babolsar on south side. all three vernacular buildings which includes the ratio of height to width of the façade, the ratio of height to the perpendicular side, the ratio of opening level to the façade level, the ratio of façade level to the whole façade (table 13) and the ratio of the yard level height from the road level and the yard level. This height difference in Babolsar is to prevent humidity from the ground, and is used in Ghazvin to

confront the ground slope issues (table 14).

Table 13. Proportion of northern elevation

	Proportion of northern elevation			
Code	Proportion of facade to whole mass	Proportion of opening to facade	Proportion of height to the vertical side (2 faced)	Proportion of height to width facade
M-01	1:5	1:15	1:3	1:4
M-02	1:5	1:15	1:4	1:2.5
M-03	1:8	1:4	1:3	1:2

Table 14. Proportion of building level

Table 14	**proportion of building level**	
Code	The ground level height from The yard surface (meter)	The ground level height from road Level (meter)
M-01	+1.00	+0.9
M-02	+1.20	+0.8
M-03	+0.10	-0.3

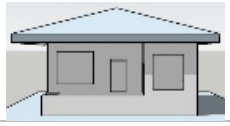
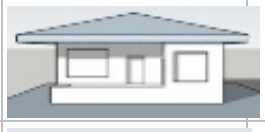
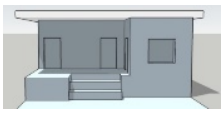
The third step includes the number and proportions of openings and the ratio of window height to ground level, as shown in table 15.

Table 15. Proportion of opening in north elevation

Table 15	proportion of opening in north elevation		
Code	proportion of windows height from ground level	proportion of windows height to Width	Number of opening
M-01	1:0.75	1:1	8
M-02	1:2	1:1	3
M-03	1:1	1:2	5

The fourth step uses the shadow setting in the software, the exact position of the site on the map, counting geographical latitude and azimuth parameters to define the shadow positions of the vernacular buildings in all seasons and conditions. The ratio between the depth and height of the IVANS beams in the winter (January) allows sunshine on the openings and building façade and warms the internal space, but in the summer (June) takes into account the changing position of the sun so it does not shine directly into the openings (table 16).

Table 16. Ratio between depth and height of the IVANS (I.R.OF IRAN Meteorological Organization, 2017)

Table 16 **ratio between depth and height of the IVANS**		**City sample**	**latitude**	**Angle of radiation**		**ratio between the depth and height of Ivan**
Summer	Winter			JULY	JANUARY	
		M-01	36° N	74.8	32.0	1:3
		M-02	35° N	75.2	32.8	1:3
		M-03	24° N	81.5	36.6	1:2

In the fifth step, (table 17), the buildings' positions are determined by the yard, and in Babolsar and Ghazvin are higher than yard level but in Lar is on ground level. In table 18, the longitudinal direction and the entrance position of the buildings are described, not to be confused with the entrance to the yard.

Table 17. The buildings position from the yard

	the buildings position from the yard		
	Below the surface of the yard	Garden level	Above the yard
M-01			X
M-02			X
M-03		X	

Table 18. Orientation and position

Table 18	**Orientation and position**	
Code	Entrance to the building	Longitudinal direction of the yard
M-01	South	Eastern - Western
M-02	South	North-South
M-03	South	Central-Square form

With respect to the yard, how the space is used determines whether it is residential or service (table 19). In table 20, all proportions of the yard are determined, including the pool and garden.

Table 19. The spaces usage with respect to the yard

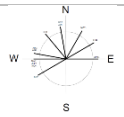
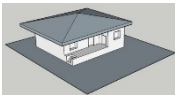
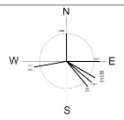
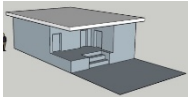
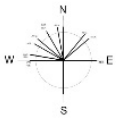
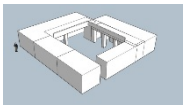
	The spaces usage with respect to the yard							
	west		East		South		North	
Code	Services	Residential	Services	Residential	Services	Residential	Services	Residential
M-01	X		X			X	X	X
M-02		**X**	**X**					**X**
M-03	X			X		X	X	X

Table 20. Proportions

Table 20		Proportions		
Code	Proportions of garden surface to yard surface	Proportions of pool surface to yard surface	Proportions of yard surface to whole surface	Proportions of length to width in yard
M-01	1:12	---	2:3	1:2
M-02	---	---	1:2.5	1:2
M-03	1:10	1:4	1:3	1:1.5

As a final step, the monthly direction and maximum speed of the wind was provided as climatic and historic data by the metrological organization so we could evaluate the direction of the wind and compare it with building mass. As is evident in table 21, the building's position in Babolsar is open because the air circulation surrounding the structure in this climate is pleasant. But in Ghazvin the position of the structure blocks the cold winds of winter and autumn. And in Lar is block the warm winds in summer and prevent to entering the dust into the building.

Table 21. Building position to the wind direction (I.R.OF IRAN Meteorological Organization, 2017)

Building position to the wind direction				**Wind direction**		**code**
winter	autumn	Summer	Spring			
open	open	open	open			M-01
close	close	open	open			M-02
close	close	close	close			M-03

3. Conclusions

Living in a crowded city with rapid construction of high rise buildings, a lack of land and concern for limited natural resources, understanding the proper proportions while designing could be the key to creating comfortable conditions in future buildings. This paper investigates traditional buildings to examine what form of building, proportion of plans, and openings on different façades are consistent with environmental factors.

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