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ORIGINAL PAPER

Architectural design strategies based on climatic zoning and thermal comfort indices (Case study: Qazvin)

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Abstract
Climate and climatic factors influence live creatures and their activities. Climatic design is a method for coping with challenging climatic conditions and creating comfort. Indeed, architectural design can be done by utilizing data related to climatic conditions and the thermal needs of the desired location. Hence, the current study presented strategies for architectural design based on climatic zoning and indices of thermal comfort in Qazvin city. The study data were obtained through library research and documents, analyzing and combining the data, and by applying an experimental-analytical method. Some compatible climate strategies and measuring thermal comfort indices were presented (based on data from Qazvin Meteorological Organization until 2017). TCIC software was used to calculate thermal comfort indices. Considering that Qazvin climate is cold-arid and according to the analysis of thermal comfort indices in different months, building heating has been paid more attention to rather than cooling in architectural design. Different strategies in this area and methods to gain maximum benefit from climatic facilities (in Qazvin) in other parts of a building have been presented in the suggested tables.

1 Introduction

Architecture and climate are two manufactured and natural systems that affect each other closely. That is investigating the effect of climatic factors and their feedback on architecture is inevitable (Kamyabi 2016:159). Human thermal comfort is influenced by different climatic parameters. The impact of rain and snow events on human thermal comfort has been less explored in the available literature (Roshan and Moghbel 2020: 1581). The building is the first defensive measure against exterior climate conditions. The theory of climatic design principles is obtained by investigating and analyzing the good situation in interaction among human beings, the environment, and architecture. Creating comfort in architectural spaces depends on the function of the building in climate and human behavior in different sections of a building (Pour Dehimi, 2011:98–99). Hence, implementing climatic design is a particular construction method that is obtained via investigating climate conditions. Based on human comfort, interaction with different environments and spaces, and physical body design (executive techniques of a building including thermal insulation, window installation, central courtyard dimensions, etc.) (Watson and Kent, 2011:4).

Climatic design (inactive design) does not mean eliminating heating or cooling systems (functional design) or decreasing comfort standards. the Mere use of passive design is not possible in some climatic conditions.

The plan aims at applying a combination of active and passive methods to eliminate or reduce mechanical systems during the day (Nielson, 2010:13). Generally, the purpose of climatic design is resistance to heat loss, emitting heat and absorbing more radiation heat from a southern window in winter and resistance to radiation heat by creating shadow and losing more heat inside the building in summer by physical architectural design (Watson and Kent, 2011:14).

Iran is a country that has valuable experience in utilizing natural energy. Its brilliant civilization and long history of habitation have given us such experiences.

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Despite having many desert regions, people have been able to inhabit for many years (Tahbaz and Jalilian 2011:1). Knowing climatic zoning and thermal comfort indices and presenting strategies for architectural design with climatic factors and people's needs are some of the designers' purposes for achieving climatic design goals. Accordingly, Qazvin city has been studied as a case study. Indigenous buildings in Qazvin, like other regions of the country had been compatible with human comfort conditions. Therefore, accurate knowledge of its climatic zoning and corresponding design to thermal comfort indices can provide an appropriate and desirable environment for inhabitation. Determining the climatic zoning of Qazvin and investigating indices of thermal comfort besides climatic design can be helpful.

2 Materials and methods

2.1 Research structure

Based on Fig. 1, the first climate of Qazvin has been determined by investigating some of the current categories in climatic zoning (Meteorological organization of Qazvin province, 2011). Then, the most effective index of thermal comfort and also bioclimatic indices have been measured by analytical comparison of different indices, thermal comfort range in warm and cold months has been determined. Finally, based on this comparison and climatic design, strategies have been extracted for climatic architectural design (Fig. 1).

2.2 Literature review

In recent years, different methods and models have been invented to know the degree of influence of climatic elements on human organisms. Many types of research have been done on measuring human comfort conditions. Olgyay's model is the oldest study from the 1960s. In this model, separate and specific roles of factors have been determined by a bioclimatic figure (Terjung 1968). By utilizing effective temperature, Hounam (1967) studied the climatic comfort of a city. It was observed that a noticeable part of the warm season had undesirable climatic comfort. In recent years, studies have been done on resort climatology of Arizona in the USA (Hartz et al. 2006) and determination of bioclimatic comfort in the Erzurum expressway corridor by using the Geographical Intelligence System (GIS) (Zengin et al. 2009). The bulk of studies done in the context of evaluating the bioclimatic of Iran embodies various subjects. They can be divided into three groups: some of these studies have investigated the evaluation of only bioclimatic and human comfort conditions on different days in studied regions, such as Kaviani (1993:32), Zolfaghari (2007:29), and Mahmoudi (2008:44). Their primary purpose had been the evaluation of climate effects on live creatures, especially human beings. Another group of studies has evaluated the bioclimatic of building by indices of Mahoney, Givoni, and Terjung. Some of them are Razjouyan (2009), Shahbakhti and Shafiei (2010:59), and Khoshhal et al. (2006:173). Paying attention to the primary purposes of climatic design in each climatic region and predicting conditions for knowing them to make buildings compatible with climatic conditions, lead to energy saving, and create an appropriate opportunity to revise architectural design in each climate.

The bulk of Razjouyan's studies was done on adjustment thermal conditions inside the building via transparent and open parts of its external boundary. Shahbakhti and Shafiei believe that knowing climatic factors related to human comfort is results from factors such as solar radiation, temperature, humidity, wind, and rain intensity that make buildings

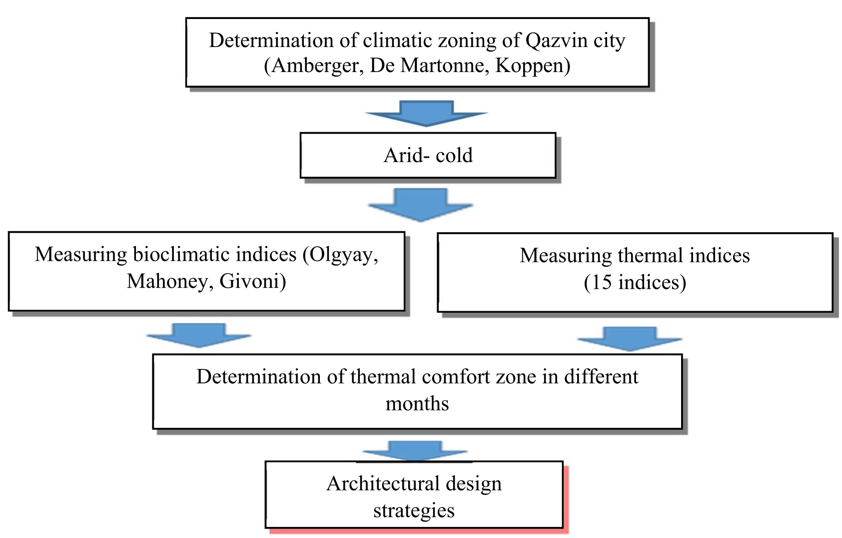


Fig. 1 Research theoretical framework

Table 1 Grouping climatic studies

Research groups	Research area	Researchers, authors
Group 1	Evaluation of only bioclimatic and human comfort conditions on different days	Kaviani (1993:32), Zolfaghari (2007:29), Mahmoudi (2008:44)
Group 2	Climatic studies on architecture and building	Razjouyan (2009), Shahbakhti and Shafiei (2010:59), Khoshhal et al. (2006:173)
Group 3	Investigating bioclimatic of Iran	Bazrpash et al. (2008:94), Farajzadeh and Ahmadabadi (2009:32)

compatible with climatic conditions according to purposes of climatic design in each climatic region.

According to these factors in the current study, human comfort or discomfort has been evaluated and compared based on Olgyay's bioclimatic indices and models and Givoni's model using statistics from Synoptic Meteorology Station of Babolsar. Khoshhal et al. (2006) study presented a comprehensive bioclimatic grouping that addressed daily warm and cold conditions during all months and in all stations in Esfahan province by actual temperature and humidity values. Four human bioclimatic categorization methods by indices of Mahoney, Terjung, Olgyay, and Givoni that decisions on building design compatible with climate are usually based on have been tested for categorizing human bioclimatic in Esfahan province. The other group of studies also investigates bioclimatic of Iran concerning tourism activities, such as Bazrpash and colleagues (2008:94), and Farajzadeh and Ahmadabadi (2009:32). The current research investigates climatic zoning along with thermal comfort indices (Table 1). Kakavand and Bakhshi have compared it with Zaragoza, Spain, as a historical region with a similar climate, using the Koppen and Keiger method and zoning Qazvin in the semi-arid and cold range. In this area, most of the design strategies have similar solutions, among them, we can mention the existence of a central courtyard, materials with high thermal capacity, using shading, creating humidity, and using geothermal energy (2023).

2.3 Methodology and analyzing data

In the current study, climatic design strategies using climatic zoning via thermal indices in Qazvin have been studied. Data obtained by library research after analyzing data compatible systems with climate and were presented by measuring thermal comfort (based on statistics until 2017) by an experimental- analytical method. Known techniques for the architecture of Qazvin have been proposed based on features of comfort zone in analyzing thermal comfort indices. Thermal comfort indices were calculated by TCIC (Thermal Comfort Indices Climate) software. Investigating these indices and the presented tables show the effect of practical factors on comfort. Hence it can be helpful for architectures in climatic design in the considered region (Qazvin). It can be said that the results are practical.

Table 2 Climatic data of Qazvin city

Classification system	Obtained value	Zoning region
Amberger	26.73	Cold-arid
De Martonne	12.61	Semi-dry
Koppen	-	Cold-arid (Bsk)

Table 3 Investigating climatic zoning of Qazvin

Studied region	The yearly average of rainfall (mm)	The average minimum temperature in the coldest month (°C)	Average maximum temperature in the warmest month (°C)
Qazvin	309	-4	36

2.4 Knowing the studied region

Qazvin is the largest city and capital of the province of Qazvin, located between 48-50 east of Greenwich Meridian of longitude and 35-45 north latitude quarter. It is at an altitude of about 1277 m above sea level (Kasmaie, 2010:282). Qazvin is bounded on the north by Rudbar and Kouhin, on the west by Takestan, on the south by Buin Zahra, and on the east by Alvand and Abyek (Famili et al. 2004:11). Over 15 years period, the temperature typically is 14/5°C and the average rain intensity in the same period is 290 mm (Statistics from Meteorology Station of Qazvin) (1997-2011) (Tables 2 and 3).

The climatic categorization system presents a set of rules that can be utilized to separate regions based on their standard features. Then common areas are categorized in a group (Jafarpour 1998:259). For determining climatic zoning of Qazvin and by using obtained data and studies from the Meteorological Organization of Qazvin Province, some standard classifications, including Amberger, De Martonne, and Koppen, have been investigated (Table 2).

Amberger pattern is one of the authentic methods for determining the climatic condition of a region. The yearly rainfall, the average maximum temperature in the warmest month, average minimum temperature in the coldest month are the most critical factors for determining the climate of a region. De Martonne's pattern is based on the

Table 4 Climate of Qazvin based on Evans index

Thermal condition	January	February	March	April	May	June	July	August	September	October	November	December
Day	Cold	Cold	Cold	Comfort	Comfort	Warm	Warm	Warm	Warm	Warm*	Comfort	Comfort
Night	Cold	Cold	Cold	Cold	Cold	Cold	Cold	Comfort	Comfort	Cold	Cold	Cold

*When wind speed is 1 m/s, it is excellent

Table 5 Cooling power (CP) degrees and bioclimatic thresholds in Baker method

Month	Index number	Cooling power	Condition	
January	64.7187	undefined	undefined	H
February	71.9221	undefined	undefined	H
March	66.2700	undefined	undefined	H
April	57.0529	Extremely cold, immoderate	severe and fierce	G
May	52.1866	Extremely cold, immoderate	severe and fierce	G
June	33.3297	severe and fierce	medium to severe	E
July	20.7832	cool	a little biting	D
August	22.1883	cool	a little biting	D
September	26.6224	cool	a little biting	D
October	36.6432	severe and fierce	medium to severe	E
November	48.6124	very cold	mild	F
December	62.4080	undefined	undefined	H

dryness index, wherein temperature and rainfall are utilized for determining the type of climate. Koppen classification system, which most climatologists have accepted, is based on the relation between rainfall amount and its distribution during a year and temperature. Thus, the Amberger classification is based on yearly temperature changes and daytime.

3 Results and discussion

3.1 Investigating thermal comfort indices

To utilize climatic design principles, appropriate to the climatic of Qazvin city, some of the most common thermal comfort indices (12 indices) have been investigated.

3.1.1 Evans index

This index specifies the relation of dry temperature with four factors, including relative humidity, airflow, human activity, and clothing, for determining comfort zone (Razjouyan 2009:64). Accordingly, for presenting compatible climatic architecture, comfort and discomfort months can be separated (Table 4).

3.1.2 Baker index and wind-chill index (Ke)

In this index, cooling power (CP) and human bioclimatic movement range have been investigated by temperature and wind speed. In most the months, CP had been more than 20 (because of coldness). Hence, it can lead to climatic discomfort in those months. In wind-chill index comfort factor has been investigated based on climatic parameters such as temperature and wind speed. It can be said that the Baker index examines cold conditions in cold months during days and in warm months during nights (Tables 5 and 6).

Table 6 Wind-chill index and human feeling

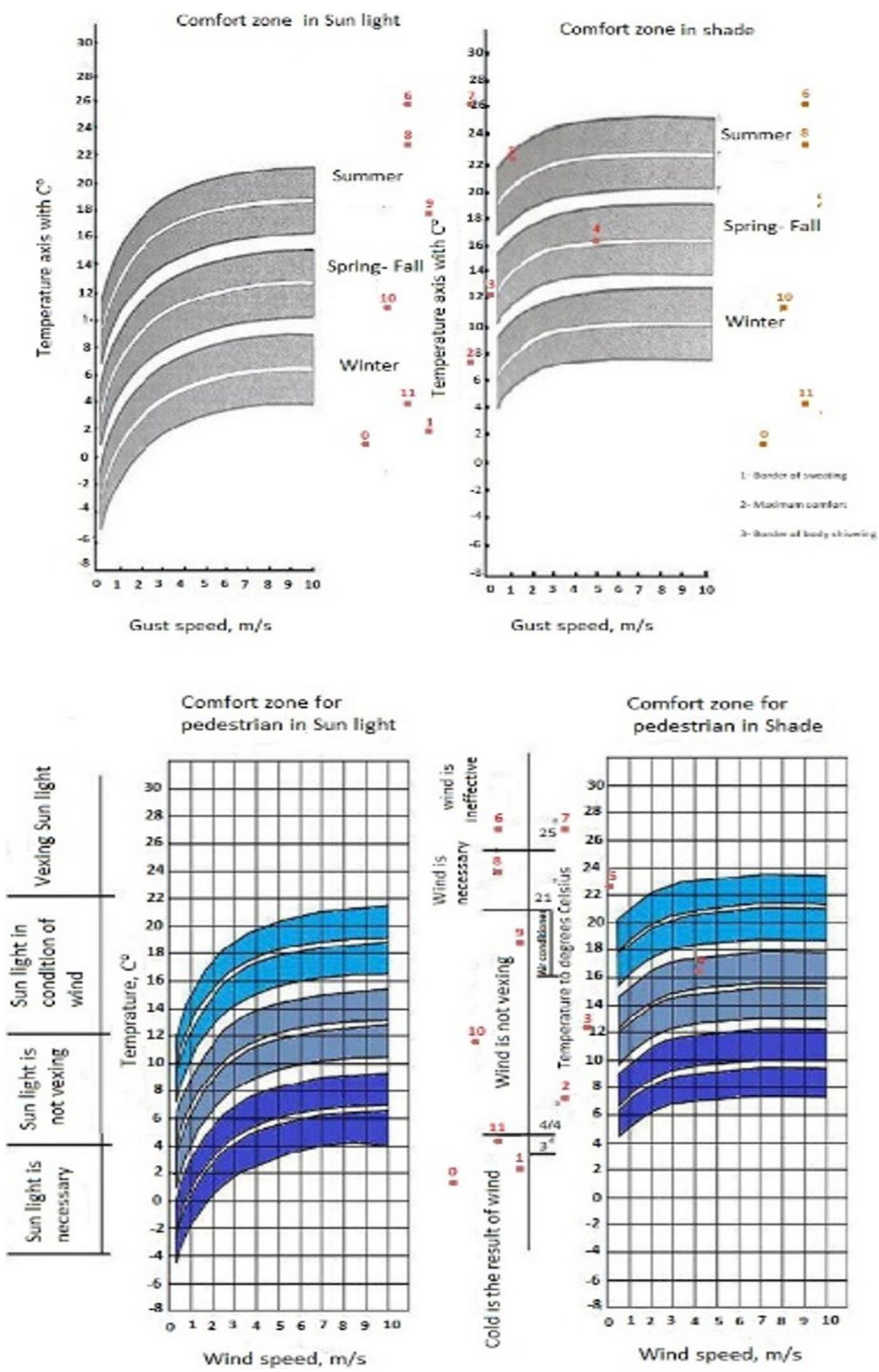
Month	Index Number	cooling power
January	713.8273	Cold
February	565.1430	Very cool
March	359.8494	Cool
April	220.1205	Cool
May	213.1222	Cool
June	315.6624	Cool
July	475.0051	Very cool
August	707.5765	Cold
September	918.7775	Extremely cold
October	1000.7033	Extremely cold
November	1015.7140	Biting
December	872.5116	Extremely cold

3.1.3 Penwarden index

In this index, the relation of human comfort with two groups of climatic and human factors is presented in a figure (Fig. 2).

The condition of comfort outside the building in Qazvin city using maximum and minimum temperature and wind speed in all months concerning shadow and sun comfort zone has been investigated, and below results have been obtained:

1. March and April in the sun: If wind speed is faster than one m/s, it is cold in the morning but moderate throughout the day.
2. March and April in the shade: It is cold in the mornings and moderates throughout the day.



0	January
1	February
2	March
3	April
4	May
5	June
6	July
7	August
8	September
9	October
10	November
11	December

Fig. 2 Pedestrian comfort zone (PEN 1) and Comfort zone (PEN 2)

Table 7 Determined thresholds for TEK (°C)

Month	Steam pressure	TEK	Bioclimatic conditions
January	6.7589	22.2483	Cool
February	9.1464	30.5597	a little cool
March	9.9904	37.4957	comfort
April	12.0053	44.3480	sultry-hot
May	11.7358	44.3237	sultry-hot
June	10.1822	38.7134	comfort
July	8.3086	31.1030	a little cool
August	7.1173	21.8759	Cool
September	5.4290	13.1335	Cold
October	4.6640	8.91604	Cold
November	4.8100	9.7750	Cold
December	5.1660	15.0390	Cold

3. May in the sun: When wind speed is faster than one m/s, it is moderate, and other times of the day, it is warm.
4. May in the shade: It is moderate in the morning but warm throughout the day.
5. June, July, August, September, and October in the sun: When wind speed is faster than one m/s, it is moderate in the morning and warm at other times.
6. June, July, August, September, and October in the shade: It is usually moderate in the mornings and warm at other times. When wind speed is faster than 0/5 m/s, it is cold in the early mornings.
7. Sunny November: It is cold in the mornings unless airflow is very slow. It is warm at midday and moderates at other times.

   Shadowy November: It is moderate only at midday. Other times it is cold.
8. Sunny December, January and February: It is cold in the mornings except when airflow is less than 0/3 m/s. It is warm at midday and moderates at other times.

   Shadowy December, January, and February: It is moderate at midday and cold during other times of the day.

Based on evaluations in spring and summer mornings, considering the fabric, it is moderate and warm after midday, whether in the sun or shade. In autumn (November and December) and winter (January and February) weather is freezy, and afternoon, it gets warm, and at other times, it is moderate. By texture comfort index-free spaces and walkways, architectural features of the studied region can be determined well. Walkways and accessible areas in Qazvin city should be designed shadowy with the possibility of sensible airflow in summer and sunny away from the wind in winter.

3.1.4 Thermal equilibrium index (TEK)

This index evaluates equivalent temperature of usual effects of temperature on live creatures to temperature and steam pressure (Table 7).

3.1.5 Effective temperature of SET and NET

Comfort temperature from a psychological viewpoint, that is, being comforted and relaxed against external invasions, can be calculated via an effective temperature index (Tables 8 and 9).

3.1.6 Equivalent temperature of ET

This indicator has evaluated the combined effects of temperature and relative humidity in Qazvin city. During January, February,

Table 8 The impact of the effective temperature of SET

Month	SET	Bioclimatic conditions
January	11.7150	Very cool
February	15.6088	Cool
March	19.7077	Comfort
April	22.6229	Warm
May	22.7961	Warm
June	20.3574	Comfort
July	16.7461	Cool
August	11.0034	Very cool
September	5.6873	Very cool
October	2.9652	Very cool
November	3.5402	Very cool
December	7.7886	Very cool

Table 9 The effect of the effective temperature of NET

Month	NET	General effects on the human body
January	-0.8913	Very cold
February	4.8819	Cold
March	12.5838	Cool
April	17.7115	Cool
May	17.8927	Cool
June	14.1190	Cool
July	8.1827	Cold
August	-1.3204	Very cold
September	-10.1727	Very cold
October	-14.1485	Very cold
November	-14.1658	Very cold
December	-7.1395	Very cold

March, and November, Qazvin is out of comfort zone and cold. During June, July, August and September, it is warm and in the summer comfort zone. There are winter comfort conditions in May and October. Hence, it can be comfortable for an individual who wears cool cloth in the summer and thick material in winter. According to effective temperature during the warm months of the year, thermal comfort at night and thermal discomfort during days. During cold months it is cold entirely. Based on hourly statistics, 6:30 has the lowest practical temperature during the year, only in August, this time has a soft comfort, in other months, the climatic condition of Qazvin city is cold and out of comfort zone. In all months, 15:30 has the highest effective temperature. In six months of year is in comfort zone. In other months, it is out of comfort zone. Therefore, it can be said that from 9:30 until 18 in May and October, the weather is in the comfort zone, in June, July, August, and September, thermal discomfort conditions (need to shade) from 9:30 to 15:30, in other months, it is cold and out of the comfort zone.

3.1.7 Temperature-humidity index (THI) and thermal humidity index (THI)

These two indexes are utilized for evaluating human comfort conditions in the environment (Tables 10 and 11).

3.1.8 Wind-chill index H or K_0

This index represents the amount of energy depletion from the body in average conditions, that is, physical inactivity and the normal skin temperature per hour (Table 12).

3.1.9 Olgey index

In Olgey's bioclimatic chart, the comfort zone is located in the middle of the chart with two summer and winter

Table 10 Changes thresholds of THI

Month	Temperature-Humidity Index (THI)	human feeling
January	-67.0791	Coldness feeling
February	190.3170	Uncomfortable
March	415.6715	Uncomfortable
April	575.5118	Uncomfortable
May	570.2184	Uncomfortable
June	445.1514	Uncomfortable
July	249.0904	Uncomfortable
August	-134.3287	Coldness feeling
September	-559.9962	Coldness feeling
October	-793.1838	Coldness feeling
November	-743.5395	Coldness feeling
December	-330.3320	Coldness feeling

Table 11 Categorization of THI2

Month	THI2	Bioclimatic conditions
January	12.7251	Cold
February	16.2608	Comfort
March	20.0429	Warm
April	22.6366	Warm
May	22.7767	Warm
June	20.6205	Warm
July	17.3922	Comfort
August	11.9430	Cold
September	6.8102	Cold
October	4.1576	Cold
November	4.7231	Cold
December	9.1141	Cold

conditions (Table 13). Considering the humidity index, the lower limit needs radiation, and the upper limit requires wind current. A significant part of the points in the evaluated station (Qazvin city) is located in region B (Coldness caused by water vapor in the air) in daylight and region D (need to radiation) at night. Regions of A, B, C, and D, are described in the chart as follows (Fig. 3):

- A Provided temperature and relative humidity are two points in Zone A, for being comfortable, not only is shade needed, but airflow with a certain speed is needed to accelerate body heat dissipation by compulsory convection and evaporation of sweat.
- B Being comfortable cannot be achieved without avoiding sunlight. Coldness caused by water evaporation into the air should be utilized, too.

Table 12 Wind effect coefficient in wind-chill scale

Month	Wind-Chill index H	bioclimatic conditionsH	Wind-Chill index K_0	Bioclimatic conditions K_0
January	-712.7828	Very cool	926.7938	cool
February	-564.3350	cool	731.9856	cool
March	-359.3249	cool	467.0180	Comfort
April	-219.7875	Pleasant	286.8089	Comfort
May	-212.8082	Pleasant	276.9065	Comfort
June	-315.1844	cool	411.3398	Comfort
July	-474.2871	cool	618.8591	cool
August	-706.4865	Very cool	923.7701	cool
September	-917.3740	Cold	1198.3976	Cold
October	-999.1493	Cold	1307.6189	Cold
November	-1014.1920	Very cold	1322.0796	Cold
December	-871.2261	Cold	1133.6414	Cold

Table 13 Olgey index

0	January in Day	12	January in Nigth
1	February in Day	13	February in Nigth
2	March in Day	14	March in Nigth
3	April in Day	15	April in Nigth
4	May in Day	16	May in Nigth
5	June in Day	17	June in Nigth
6	July in Day	18	July in Nigth
7	August in Day	19	August in Nigth
8	September in Day	20	September in Nigth
9	October in Day	21	October in Nigth
10	November in Day	22	November in Nigth
11	December in Day	23	December in Nigth

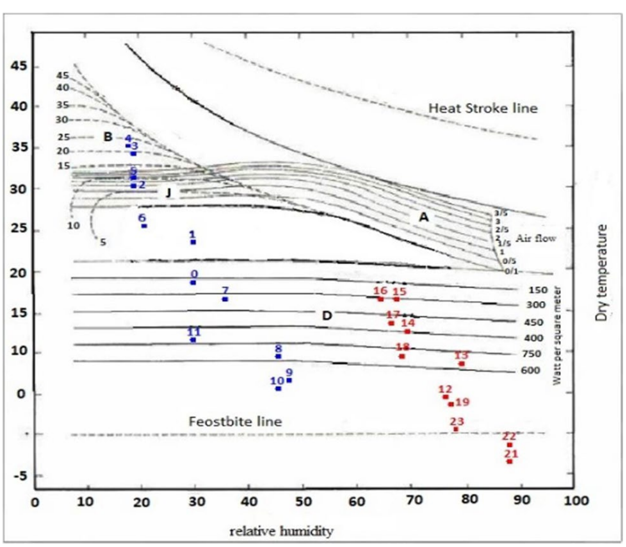


Fig. 3 Setting spots understudying in Bioclimatic

C It is possible to be comfortable with both flows and water evaporation into the air.

D In existing conditions, a person is not comfortable unless he exposures to heat (from any source).

3.1.10 Givoni's bioclimatic building index

In the Givoni diagram, the role of architecture in designing, and selecting materials is ignored and only shadow, sunlight, and wind currents have been noticed. While building components, types of materials, sizes and materials of windows, and other similar items can be effective in decreasing or increasing comfort zone. By making curves on psychrometrics diagram, Givoni diagram shows utility, limitations of using natural ventilation, materials features adding humidity to indoor air, and necessary for using mechanical devices in other thermal conditions. The position of day and night on different months is as same as Olgey's index.

Based on climatic conditions every 3 h, during a day bioclimatic index of Qazvin was implemented on psychrometrics diagram. They were divided into smaller tables, architectural suggestions have been presented as follows:

1. The months of May and October are located in region N. Based on architectural principles, their positions were in areas 5 and between 4 and 7. Region N determines the summer comfort zone in the shade for an environment that temperature at night equals outdoor temperature. In this zone, occupant comfort is provided naturally. During nights, there is no need to utilize thermal appliances. In this zone, adequate radiation heat onto the building should be minimized architecturally, entering sunlight into the building should be prevented.
2. The months of June, July, August, and September are located in region M, and their position on the diagram is

in regions 10, 11, 15, 7, respectively. Region M shows a set of conditions within the interior wall of the building that can reduce the indoor temperature, as its occupants feel comfortable while doing light physical activities and in the absence of sensible airflow. For this reason, by selecting and utilizing sturdy materials against heat and outdoor heat, penetrating heatwave into the interior can be prevented. At nights of mentioned months located in regions H and H', there is no need to utilize thermal appliances. Architecturally following steps need to be done:

3. Minimizing effective thermal radiation on the building, using coldness caused by high thermal waves on building walls in June, July, and August. Minimizing exchange of thermal energy via walls, utilizing air current and coldness caused by surface evaporation.
4. The months of May and November located in regions H and H' are in intervals 1–3. Zone H shows conditions where the minimum interior temperature is higher than the outdoor temperature, as there is no need for the thermal reservoir. The nights of these months locate out of zone H. It is necessity to utilize thermal systems to be comfortable during these hours. It is needed to minimize thermal exchange via walls. Penetrating airflow and sunlight should be prevented.
5. The months of December, January, February, and March are out of zone H and H' during all day hours. They are out of Givoni's bioclimatic diagram towards the left side (except March at 12/5 and 15/5 in zone H). Architecturally they are in zone 1 on the chart. To provide thermal comfort in these months, it is necessary to utilize mechanical, thermal systems along with solar systems. Based on architectural principles, thermal exchange via walls is minimized, air cannot penetrate, and solar energy is used (Fig. 4).

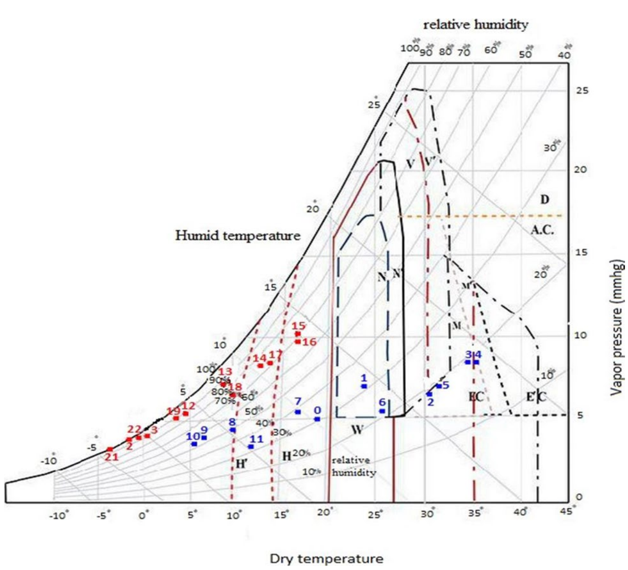


Fig. 4 Givoni bioclimatic-building index on different months

3.1.11 Mahoney index

In this index, practical factors on comfort, including temperature, wind, humidity, and radiation, are evaluated, and the comfort condition of each station is determined by standard temperature and humidity (experimental studies). In the Mahoney index, based on the yearly average, day, and night comfort zones each month are studied and the average relative humidity of each month is determined. For evaluating the thermal condition of a place following steps should be followed:

1. Determining average yearly temperature and average maximum and minimum temperature of each studied zone or place.
2. Calculating the average relative humidity of each month.
3. Recognizing climatic group of the studied month for the average yearly temperature and relative humidity of each month using presented table and then extracting logical limitation of day and night in studied month.
4. Measuring average maximum temperature of each month against day comfort zone. If average maximum temperature is:

   A) Higher than the upper limit of the comfort zone of day, days of the studied month are warm.
   B) Higher than the upper limit of the comfort zone of night, days of the studied month are moderate.
   C) Smaller than the lower limit of the comfort zone of night, nights are cold (Razjouyan 2009:54–55) (Table 14).

In the Mahoney table, besides separation of comfort, cold and warm months, discomfort months have been differentiated, indices are presented for the discomfort caused by different climatic conditions:

A) Indices related to humidity

   H1: This index shows a condition in which it is warm with a high relative humidity (group 4) or medium relative humidity (groups 2 & 3), temperature variation is less than 10 °C. In such cases, sensible airflow is necessary for feeling comfortable.

   H2: This index shows a condition in which temperature is in the comfort zone based on the Mahoney index. Then, environment's high relative humidity (relative humidity of group 4) causes discomfort. In such situations, wind current is desirable.

   H3: This index shows a condition in which raining and penetration into the building cause discomfort. When rainfall is more than 200 mm, essential prediction for preventing possible dangers is necessary.

Table 14 Mahoney table-comfort zone of day and night (Razjouyan 2009:55)

Climatic Group	Average relative humidity (%)	Average of yearly temperature					
		20<		15–20		< 15	
		Day	Night	Day	Night	Day	Night
1	30 – 0	34	25	32	23	30	21
		26	17	23	14	21	12
2	50 – 30	31	24	30	22	27	20
		25	17	22	14	20	12
3	70 – 50	29	23	28	21	26	19
		23	17	21	14	19	12
4	100 – 70	27	21	25	20	24	18
		22	17	20	14	18	12

B) Indices related to aridness

A1: This index presents a situation in which temperature difference between day and night (daily temperature variation is more than ten°C) causes discomfort. When days are warm, and relative humidity is low or medium (groups 1, 2, and even 3), it gets cold at night.

Table 15 Architecture suggestion based on Mahoney

Suggestions	Heat status indexes					
	A3	A2	A1	H3	H2	H1
	4	5	10	0	0	2
How to place the building						
1- Length			0-10			
2- Buildings along the east and west	-125		11, 12			
3- Compression architecture with yard	0-4					
Space between Buildings						
4- An open and vast complex for utilizing wind						11, 12
5- stated above , provided the cold and warm wind is prevented.						2-10
6- Compressed complex						0, 10
Interior airflow						
7- Single rooms for utilizing permanent air current						3-12
			0-5			1, 2
8- Adjacent rooms and Anticipation in case of air ventilating			6-12			
					2-12	0
9- No need for sensible airflow					0, 1	
Windows						
10- Big windows, 40 to 80 percent of southern and northern walls			0, 1			
11- Tiny windows, 10 to 20 percent	0, 1		11, 12			
12- Medium windows 20 to 40 percent	All other conditions			All other conditions		
Walls						
13- Light walls, short delay time			0-2			
14- Heavy walls, interior, and exterior			3-12			
Roofs						
15- Light roofs with thermal insulation			0-2			
16- Heavy roofs, delay time more than 8 hours			6-12			
Sleeping outside overnight		2-12				
17- Necessity to provide space for sleeping						
Downpour protection						
17				123-		

This requires occupants to change the clothes which can make them feel uncomfortable.

A2: This index shows a condition in which night heat with low indoor relative causes discomfort. Fortunately, in such situations, the sky is clear, which makes body temperature reduce, it gets six°C cooler than the temperature of the environment.

A3: This index shows situations where the temperature during the day is lower than the minimum temperature of the comfort zone. Therefore much coldness annoys.

In the following table, values have been presented as a climatic index with related suggestions (Table 15):

Finally, in cases climatic requirements of Qazvin city, shadow and sun Calendar, climatic index - building and effective temperature index and Results of Architecture of Qazvin city in a cold and dry climate, there is this conclusion (Fig. 5; Tables 16 and 17):

4 Conclusion

In general, several studies have been conducted in Iran regarding the use of thermal comfort indices to investigate the climate and provide architectural solutions. In all the studies, one or two indicators have been examined and their achievements have been examined with the architecture of Qazvin region.

In the most recent studies, Kakavand and Bakhshi have compared it with Zaragoza, Spain, as a historical region with a similar climate, using the Koppen and Keiger method and zoning Qazvin in the semi-arid and cold range. In this area, most of the design strategies have similar solutions, among them, we can mention the existence of a central courtyard, materials with high thermal capacity, using shading, creating humidity, and using geothermal energy. The present article also tries to present a comprehensive strategy on climate issues by examining all the indicators.

Knowing the climate of each region is one of the most essential factors in environmental planning. Whereas climatic requirements in different places such as homes, caravans, mosques, are identical to exact extent, principles of compatible architectural design with each climate are the same, too. Reducing heat dissipation, utilizing renewable energy, including sunlight, wind, and utilizing solar energy are some essential items. Generally, the climate of Qazvin city is cold and dry; according to its climatic indices and architecture, avoidance of winter coldness is of high importance. Because of warm weather in May, June, July, August, September, and October need to the shade is felt. In June, July, August, September, and October, shadow is not enough at midday; utilizing suitable materials and evaporative cooling by water and plants can provide comfort. Except for July, August, and September which have cool nights (terraces can be designed

Table 16 Climatic requirements of Qazvin city

Temperature conditions	Climatic requirements of Qazvin city	Time	
		Day	Night
Cold	Frostiness	3 months	
	Avoiding cold wind	2 months	6 months
	Thermal appliance		7 months
	Capacitor		All year
	Sun	5 months	
Warm	Shadow and utilizing outdoor air	7 months	
	Evaporative cooling and air current	5 months	
	Evaporative cooling and capacitor	5 months	

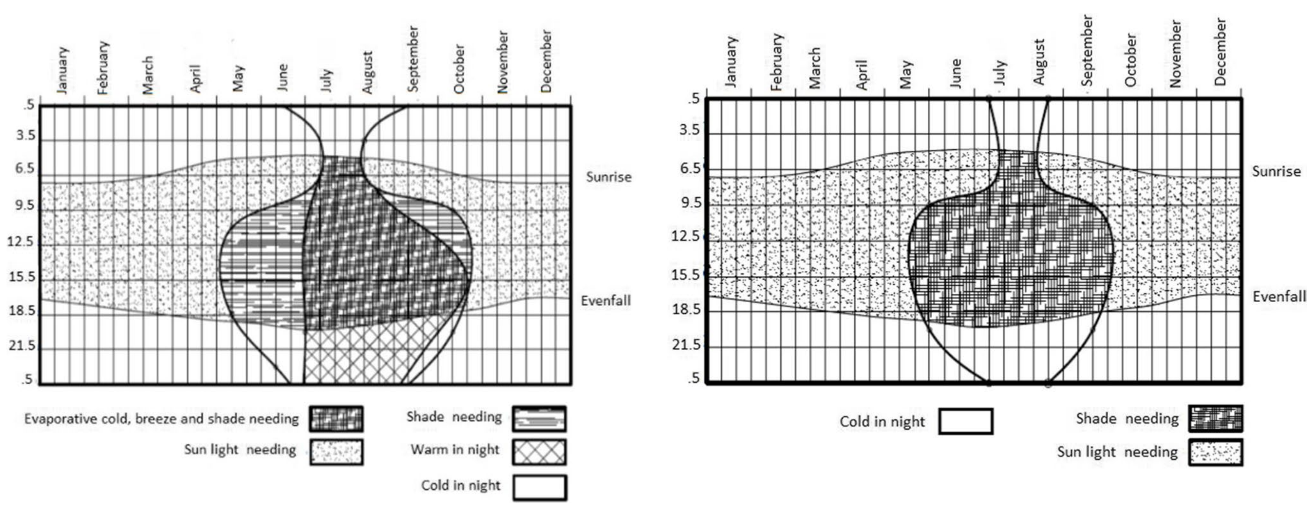


Fig. 5 shadow and sun Calendar, climatic index - building and effective temperature index

Table 17 Results of architecture design strategies in Qazvin based on bioclimatic findings

Climatic design in Qazvin city	Climate type	Primary purposes of climatic design	Walkways and paths (Evans, Mahoney, Penwarden)	Building density(Mahone y)	Direction (Mahoney)	Thermal requirements of building THI, ET)	Type of materials 9Mahone y)	Suggested format (wind-chill)
	Amberger: Dry- arid; De Martonne: Semi-dry 	Keeping indoor heat, reducing heat loss, utilizing solar energy, utilizing solarization	Walkways and free spaces in Qazvin should be designed in the shade with the possibility of sensible airflow in summer and the possibility of being sunny away from the wind in winter.	Wide and open space design for utilizing wind provided the cold and hot wind is prevented.	Building along east and west, making for warmth in winter and coolness in summer.	Solar heat is needed to be minimized in May and October, utilizing the thermal appliances, mechanical, thermal systems is necessary for November until March.	Applying heavy materials with high heat capacity, roofing delays more than 8 hours.	When buildings are in a line, we will have maximum wind. Therefore buildings should be built in staggered form.

Building climatic design requirements					
	Plan type (Mahoney)	Plan form (wind, NET, DI	CONSTRUCTION FORM (Mahoney) and building volume (Baker)	Type of roof and ceiling (Mahoney)	Relation to earth (Evans,Baker, Mahoney)
	Near rooms and predicting permanent airflow temporarily, if necessary, predicting appropriate space for sleeping (terrace) for nights of June until September because of moderate weather in comfort temperature zone.	Building plans are dense and compressed; most plans are square or circular. 	Compressed architecture with a yard, utilizing cubic shapes, having a central courtyard and semi-introverted 	Light ceilings with thermal insulation, heavy roofs, delay times more than 8 hours, flat roof 	Building a part as basement underground, covering exterior walls with soil, utilizing the basement for cooling, thermal conductivity, and reduction of thermal exchange. 
	Facade (Baker)	Wall (Givoni,Baker)	ventilation and controlling air in the building (Givoni, texture comfort, effective temperature, Olgyay, DI, TEK, SET, NET, THI, ET)		Level and number of windows (Mahony, Givoni)
			Summer	Winter	
	Utilizing facades to not creating shadows and using solar energy as much as possible.	Heavy walls, thick walls for delaying heat from entering, Trombe wall (preventing air from entering through cracks, utilizing solar heating	No need for sensible airflow to prevent airflow temporarily for all rooms, if necessary.	Utilizing thermal appliance s and heating mechanic al systems and inactive solar systems	Medium windows that opened 20 to 40 percent in southern and northern walls.

for taking rest and sleeping), other months have freezing nights, except May and October nights, utilizing thermal appliances is necessary. Cooling can be done by evaporative cooling caused by water and plant surfaces in May, June, July, August, September, and October which it is hot from 9 a.m. until 6 p.m. It may be frosty in December, January, and February. In November, December, June, February, March, and April temperature is below zero. In December, January, and February, materials can be melted, frozen, and damaged. In late days of January, February temperature is less than 5 °C all day long; coldness is accompanied by a blast of cold wind that should be prevented. Applying materials with high thermal capacity (capacitor) for keeping indoor temperature is necessary in June, July, August, September, December, June, and February. In April, November, December, January, February, and March, thermal exchange of walls should be utilized; air penetration through cracks should be prevented by climatic design and static methods.

According to studied indices, because of coldness days and nights of January, February, March, November, and December and nights of April, May, and October are out of comfort zone; days of April, May, October, and November and nights of June, July, August, and September in comfort zone and days of June, July, August, September are out of comfort zone because of high temperature.

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