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Sustainable Strategies for Comfort in Cold Climate through Mahani and Effective Temperature Indicators: A Case Study in Zanjan, Iran

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Abstract

Cold climate cities in Iran have always encountered many harsh conditions such as annual and daily fluctuations in temperature, dry weather, very cold winter wind, and warm and dusty weather in the summer. In such a condition residential complexes are of vital importance in keeping human comfort zone against highly unstable climate. There is a considerable amount of researches on different climates and cities. Farajzade has conducted a research on bioclimatic conditions in Sanandaj, Iran. Tahbaz has conducted research titled "Ehe way of analyzing weather forecast for designing climatically compatible architecture". At the present research due to young population of Zanjan city and the need to urban residential areas we have studied ways for optimal utilization of national resources with regard to designing buildings compatible with existing climatic and regional parameters. Moreover for studying bioclimatic condition and presenting sustainable architectural strategies to utilize more renewable resources (such wind and solar energies …) and to cut fossil fuel consumption as a part of an economy drive, we have considered a 25-year average weather data (1980-2005), relative temperature and humidity in Zanjan weather station through Mahani model and effective temperature indicator. The aim of this research is to answer the following question: can we suggest a sustainable architectural design compatible with climatic condition of the area under study through the abovementioned methods and the obtained results? Research method in this study is descriptive – analytic and data collection was done through library method and studying documents. According to the obtained results applying bioclimatic comfort model is effective in achieving bioclimatic condition with regard to sustainable architecture.

Keywords: effective temperature, Zanjan, Mahani, climate compatible architecture, sustainable architecture

Introduction

Climatic compatible design is to keep microclimatic condition of a building at a comfort level irrespective of unstable outside conditions. Comfort level is a condition in which about 80 percent of people feel comfort. For designing an economical building, which provides residents' comfort it is necessary to recognize climate and effective factors on it (Qiabeklou, 2011, P 31). Four factors must meet climatically for establishing human comfort condition: temperature, humidity, wind, and sunshine. Among these factors temperature and humidity are considered more effective; hence they form the basis of many models evaluating human comfort (Alikhani, 1994).

Despite the vital importance of climatology in architecture it received little attention in practice. Sam and Cheng in Hong Kong, for example, have conducted important studies on using climatic elements in architecture designing and energy of a building and suggest local climatic condition for improving climatic designing and energy simulation of the building. In order to define reliable indicators for preserving thermal pressures in Nigeria, Bouga and Ola compared different indicators such as Mahani, bioclimatic graph and effective temperature. Through studying the effects of land coverage on thermal comfort of the houses in Colombo, Sri Lanka, Emanuel

concluded that the process of thermal comfort increase is due to land coverage variations specially buildings. In their research Bowden and Grob have studied thermal comfort from two different climatic regions in five cities of Tunisia. In their research they asked 200 people about their normal life conditions in their houses and work places in different months of a year and compared the obtained results with thermal comfort indicators. The results of their research indicated a meaningful relationship between the declared thermal comfort and thermal comfort indicators. Climate and architecture are now discussed as a modern science in optimal utilization of natural resources, economical use of energy and creating thermal comfort. For defining the required climatic data in designing a building and for the effective use of such data, it is necessary to have an overall perception of the climatic and local conditions in the related region as well as the condition of a building design.

Objectives of the study

The aim of this research is to analyze climate compatible architecture in Zanjan on the basis of Mahani method and effective temperature indicators in line with sustainable architecture.

Research questions

Q1. Is it possible to study climate compatible architecture in Zanjan on the basis of Mahani method and effective temperature indicators in line with sustainable architecture?

Q2. Is it possible to suggest sustainable architecture to create compatibility between buildings and local climate through the obtained data?

Research hypotheses

H1. Applying climatic comfort models seems effective in achieving to sustainable architecture.

H2. Applying climatic comfort indicators for achieving to sustainable architecture in Zanjan seems to cut the costs from cooling and heating systems?

Materials and methods

Research method in this study is descriptive – analytic and data collection was done through library method and field study using synaptic weather forecasting station in Zanjan. We have studied records and documents related to the subject under study as well as books, magazines and the related papers and researches. The required map and climatic data were collected by referring to Zanjan weather forecasting center and weather center website. For more clarification of the subject and providing tables and graphs we used a 25-year weather average data through some software (such as Word, Excel AutoCAD).

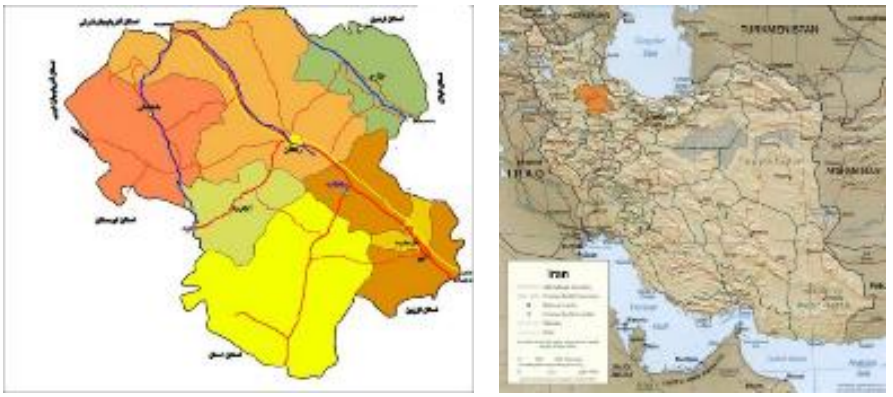

Figure 1: (a) the position of Zanjan city in Zanjan province; (b) the position of Zanjan province in Iran

Literature review

Table 1: The studies done in this area

Row	date	Authors	reference	Title	Results and findings
1	1992	Razjouyan Mahmoud	Book	Comfort with climate compatible architecture	It evaluates climatic condition and the effect of sunshine and airflow on feeling comfort and the manner in which it can be controlled through windows and other vents.
2	1988	Kasmaei Morteza	Book	Climate and architecture	Deals with recognizing Iran climatic condition and its effect on residential buildings. In his book, Kasmaei presented some suggestion on climate compatible architecture and some guidelines about creating suitable space for building and its thermal comfort.
3	2005	Farajzade et al	Paper	To study architectural compatibility of Sanandaj buildings with climatic condition through Mahani method	In this paper through comprehensive study of Sanandaj climate with Mahani method and field study of the buildings in this city the authors have tried to compare the compatibility of the buildings with architectural suggestions of Mahani method and the findings have presented for optimizing architecture in this city.
4	2007	Tahbaz Mansoura	Paper	The method of analyzing weather forecasting statistics for designing climate compatible architecture	In this paper through studying the importance of climate in architecture and analyzing bioenvironmental factors and climate role in decreasing energy use the author describes the manner of analyzing weather forecasting statistics and through introducing Oleg indicator and performing analysis presented some suggestions for architecture in the area under study.

The region under study

This research is conducted in Zanjan city in the northwest of Iran. Due to its different altitudes in its different parts on the one hand and being effected by several climates (i.e., Caspian, Mediterranean and central desert climates) on the other hand, Zanjan is of different climates and ecosystems. It is among the cold mountainous areas in Iran; about 70 percent of the areas in this province are of semi-arid extra cold weather and the remaining 30 percent of the areas are of different climatic and weather conditions. Data used in this research have mined from Zanjan synoptic station in a 10-year period (from 1995 to 2005). The used climatic data include the followings:

- Average maximum and minimum temperature;
- Average monthly fluctuations in temperature;
- Average annual fluctuations in temperature;
- Average maximum and minimum relative humidity;
- Average relative humidity per month;
- Total annual raining.

Climate compatible architecture in Zanjan on the basis of Mahani indicator

Mahani table defines daily and nightly comfort zone for every month with regard to average annual temperature of the area under study and average relative humidity of that month. Table 2 summarizes average monthly temperature and relative humidity, rainfall, wind direction, average annual temperature and its fluctuations. For defining humidity level following table is used in which Zanjan with the average annual temperature of 10.5 is placed in the 1st column.

Table 2: Geographical information of Zanjan city

Location	Longitude	Latitude	Altitude
Zanjan	48 29	36 14	16630

Table 3: First part of Mahani table (Negarande)

Temperature (in centigrade)		January	February	March	April	May	June	July	August	September	October	November	December
The monthly average of maximum temperature		2.6	4.7	10.3	17.2	22.7	28.6	31.9	31.9	28.0	20.6	12.3	5.8
monthly average of The minimum temperature		-7.5	-6.0	-1.3	3.9	3.9	11.1	14.7	14.3	9.8	5.4	0.5	-4.1
Temperature fluctuations		-4.9	-1.3	11.6	13.3	18.8	17.5	17.2	17.6	18.2	15.2	11.8	1.7
Average annual temperature						Maximum temp				Minimum temp			
10.5						31.9				7.5-			
Relative humidity	Maximum monthly average	86	85	82	79	77	66	63	62	62	71	80	85
	Minimum monthly average	57	52	42	36	31	25	26	25	24	32	43	52
	Total	73	69	61	55	51	42	41	40	40	51	62	70
Relative humidity level		4	3	3	3	3	2	2	2	2	3	3	3

Table 4: Second part of Mahani table (Negarande)

Monthly average of the max temp		2.6	4.7	10.3	17.2	22.7	28.6	31.9	31.9	28.0	20.6	12.3	5.8
Day comfort zone	Max	24	26	26	28	29	31	31	31	31	29	26	19
	Min	18	19	19	21	23	25	25	25	25	23	19	24
Monthly average of min temp		-7.5	-6.0	-1.3	3.9	3.9	11.1	14.7	14.3	9.8	5.4	0.5	-4.1
Night comfort zone	Max	18	19	19	21	23	24	24	24	24	23	19	12
	Min	12	12	12	14	17	17	17	17	17	17	12	18
Thermal conditions	Day	C	C	C	C	C	O	H	H	O	C	C	C
	Night	C	C	C	C	C	C	C	C	C	C	C	C

After determining thermal condition of the station and defining human comfort zone in different months, we determined humidity of each month the results of which is summarized in the 3rd part of Mahani table (table 5).

Table 5: Third part of Mahani table (Negarande)

Thermal indicators	January	February	March	April	May	June	July	August	September	October	November	December
The necessity of airflow H1												
Appropriateness of airflow H2												
The necessity of acting against rain H3												
The necessity of heat storage in the walls A1				✓	✓	✓	✓	✓	✓			
Open-air sleep A2								✓				
Cold month problems A3	✓	✓	✓	✓							✓	✓

Table 6: Primary and detailed suggestions using Mahani table (Negarande)

H1	H2	H3	A1	A2	A3	Suggestion	
0	0	0	6	2	6		
The buildings' location							
			0-10			1	1- Buildings' length along with east and west
			12&11		5-12		2-dense architecture with yard
					0-4	2	
The space between the buildings							
12&11						3	3-expanded open space to use wind
2-10						4	4- as above and in order to prevent cold and hot wind
0&1	----------	----------	----------	----------	---------->	5	5-dense set
Airflow in the building							
3-12						6	6- single rooms
1&2			0-5				
			6-12			7	7- connected rooms and predicting temporary airflow when required
0	2-12						
↘	0&1	---------->	---------->			8	8- No need for airflow
Windows							
		0&1		0		9	9- Large windows covering up to 40 to 80 % of north and south walls
		11&12				10	10-very small windows up to 10 to 20%
		other conditions	---------->			11	11- medium-sized windows up to 20 to 40%
Walls							
		0-2				12	12-light walls- short delay time
		2-12	----------	---------->		13	13- internal and external heavy walls
Roofs							
		0-5				14	14-light roof with thermal insulation
		6-12	----------	---------->		15	15-heavy roofs- delay time more than 8 hours
Open-air night sleep							
			2-12	---------->		16	16- the necessity to provide a space for night sleep
Rain protection							
	3-12					17	17. the necessity to protect against heavy rain

At this stage the number of cold and temperate months is added to architectural primary suggestion table (table 6) and detailed suggestion table on the basis of indicators' concepts, then analysis is performed.

Based on the above table and Zanjan climatic condition we suggest the followings in designing sustainable architecture.

- Orientation of the building should be in such a way that maximizes the use of solar energy;
- Minimizing lateral areas of buildings and creating dense and compact urban areas;
- Using materials with low conductivity;
- Using dark-colored materials;
- Using tall southern porches to enjoy the winter sunshine as well as blocking it in the summer;
- The use of flat roofs to maximize using solar energy in the winter.
- The use of triple-glaze windows to prevent energy waste.

Climate compatible architecture in Zanjan based on Psychrometrics chart

In this method we identified features of buildings necessary to keep human comfort zone without being effected by outdoor climatic conditions. Through drawing curves on Psychrometrics table some factors such as the amount of natural ventilation, construction materials properties, humidifying indoor areas as well as the necessity of using mechanical devices based on different thermal conditions are identified on a chart called building bioclimatic chart.

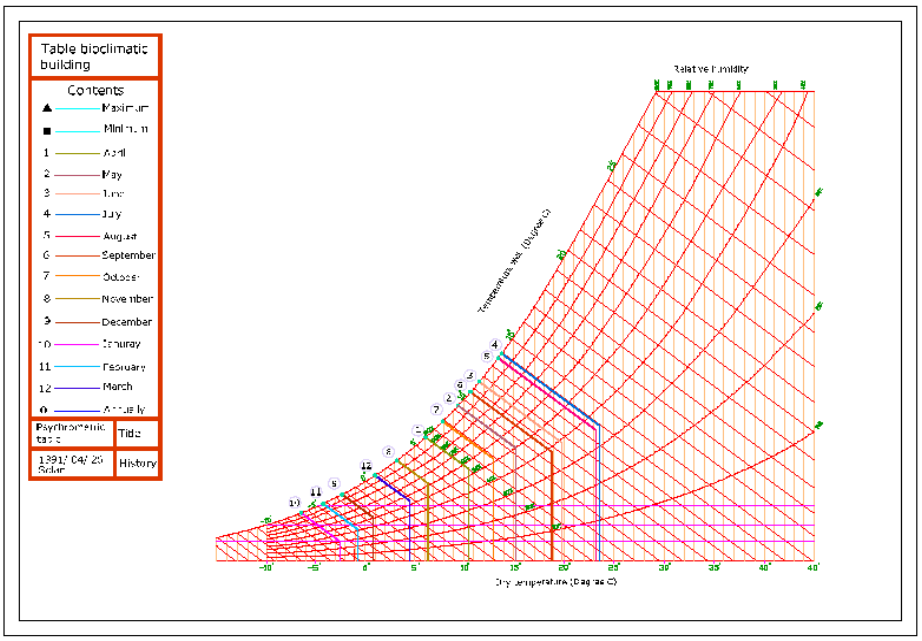

Figure 2: Psychrometrics chart of Zanjan city (Negarande)

Zanjan climate compatible architecture based on effective temperature indicator

One of the oldest and most common indicators of thermal condition is effective temperature indicator. For analyzing this indicator we use such data as relative humidity, wet temperature, dry air temperature and airflow velocity. This indicator shows the value of temperature, humidity and airflow as a joint figure (Jahanbakhsh, 1997).

For determining effective temperature of Zanjan city, given dry air temperature and relative humidity of each month separately, first we extracted wet point temperature from Psychrometrics table and drew a line through transferring those points to effective temperature chart; the drawn line indicates meeting winter/summer comfort zones or none of them. Through extracting wet temperature from Psychrometrics table we transferred the obtained parameters to the chart of effective temperature indicator.

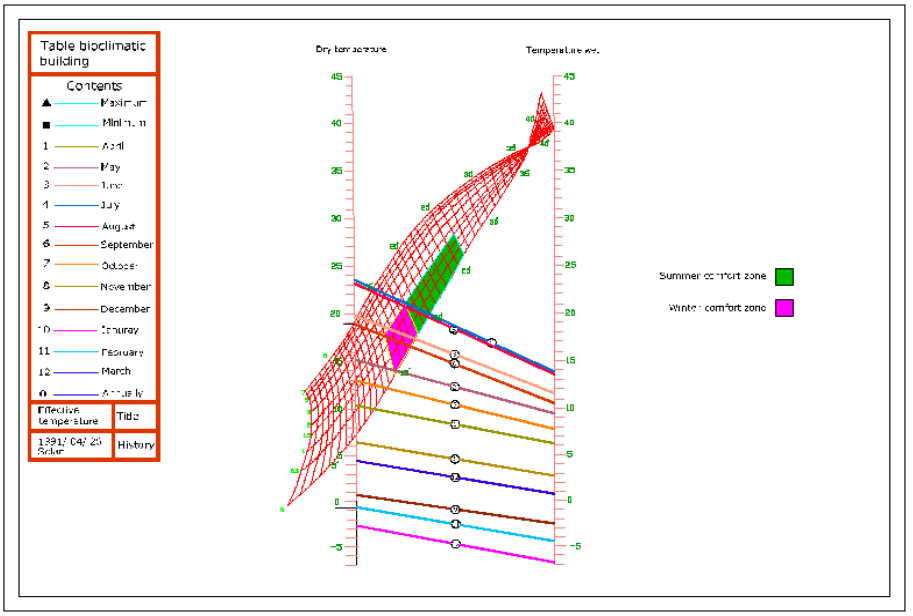

Figure 3: Effective temperature chart of Zanjan city (Negarande)

Table 7: Minimum and maximum monthly temperature indicators

	January	February	March	April	May	June
Average effective temp	0	0	0	0	10.3	12.7
Unfavorable summer and winter comfort zone	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness	The decrease in wind speed from its 1.5 m/s in summer comfort zone

Table 8: Minimum and maximum monthly temperature indicators

	July	August	September	October	November	December
Average effective temp	20.3	20.2	18.2	13.8	6.4	0
Unfavorable summer and winter comfort zone	The decrease in wind speed from its 1.5 m/s in summer comfort zone	The decrease in wind speed from its 1.5 m/s in summer comfort zone	The decrease in wind speed from its 1.5 m/s in summer comfort zone	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness	Unfavorable and cold zone, wind drop would moderate coldness

On the basis of wind speed in January, February, March, April and May in unfavorable and cold zone the decrease in wind speed moderates the cold, which naturally decreases the need for heating; and in June, July, August and September are placed in the zones with decrease in wind speed from 1.5 m/s.

Conclusion

Mahani tables indicate that climatically cold weather is dominant in this area and the lack of relative humidity and the fluctuations in temperatures above 10° centigrade in all months of a year would create discomfort. In more than six months of a year we need heating to keep human comfort zone in Zanjan. With regard to the findings it is clear that fluctuations in the degree of temperature are more important than other climatic elements and temperature plays an important role climatic condition as well as bioclimatic indicator. With regard to the obtained results some strategies for sustainable designing are presented in the following table for cold climate.

Table 9: Designing strategies based on the obtained results

Design strategies	Indoor strategy	Outdoor strategy
Cooling and heating	Horizontal ventilation and providing 30° centigrade temperature through ventilation channel	Controlled solar panels and passive or combined cooling system for optimizing southward walls to maximize the use of solar energy
Providing light	Light controllers with automatic modifying or turn-off system for saving energy	Using southward light and locating the length of the building in east-west direction for maximizing the use of daily light especially during cold seasons
Materials	Using triple-glaze windows around atrium and complete insulation of indoor vents	Triple-glazing exterior windows
Designing	Using atrium for vertical and horizontal ventilation	Using the exterior shape of a building for blocking sunshine

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