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EVALUATION OF COMFORTABLE CLIMATE OF ISFAHAN USING INDICATORS OF BIOCLIMATIC (TCI, THERMO-HYGROMETRIC, TERJONG, BIKER, OLEG)

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ABSTRACT

Recognition of natural potentials as a bed for human activities are the basis for most environmental planning and form the logistic of land, in this regard, climate features and dominant elements in the formation and spatial distribution and environmental behavior of human societies play a decisive role. In this paper, the range of human comfort in Isfahan based on the model and indicators of environmental climate (Biker, the more Jong-Term hygrometric, Oleg, TCI) using climatic data of 59 years have been studied and the best time has been set to do environmental and tourism activities in the city. The results show that according to TCI the best and most suitable months the city during the months for tourists are May, June, September, April. It was also found that comfort in Isfahan, on average, is according to the index of Terjong, Biker, and Thermo-hygrometric in the three months of May, June, September. According to Oleg index, April, May, October and comfort at night in this city is only in July.

Keywords: Climatic comfort, Isfahan, bioclimatic index

INTRODUCTION AND LITERATURE

City and climate are two man-made and natural systems that have close interactions. One of the factors that affect the life, health and welfare of people is the climate, which is now studied and investigated as a branch of science as the human bioclimatic. Tourism and climate highly dependent on each other so that the number of tourists alters with

climate change. Most of the passengers pay attention to weather conditions in the choice of location and travel time. Climate conditions are usually expressed by indicators where a set of cognitive elements, air, human and environmental factors are involved. These indexes make interpretation of complex effects of atmospheric elements of human prosperity easier and provide the possibility of comparing different place from the perspective of comfortable climate (2001: 4.De).

Scott and De Fretisat (2004) studied effects of climate change on the tourism using TCI in the North American region. The results of this study show that the number of cities in North America with ideal or favorable climatic conditions for the month of June and July will be changed during 2050 and 2080. Boudenc c, Ghrab (2005) evaluate the thermal comfort in the five cities of Tunisia from two regions. In their study, they asked 200 people about their normal living conditions in the workplace and place of residence in any month of the year and the results showed a significant correlation between perceived thermal comfort conditions with thermal comfort index.

Tplin et al (2007) in a study entitled potentially vital climate and tourism in the national park in Taiwan stated that possible changes in the global climate would affect the tourism industry. Also in this research parameters of temperature and rain were analyzed separately and then simultaneously. Finally, the temperature comfort and tolerable temperature for tourism became identified in the park. Bazrpash et al., (2008), in an article titled investigating outdoor thermal comfort for ecotourism in the city of Babolsar evaluated climatic comfort indexes Mahoney, Biker & Tarjung. The results show that the city of Babolsar has optimal conditions for nature and outdoor tourism in terms of thermal comfort from May to late November. Ziaee et al., (2009), in a study titled Kish Island Tourism Climate Index, determined the comfortable climate tourism in the region and came to the conclusion that (March) and the first half of April are the highest rating months of the year in terms of climatic comfort. December, January and February are rated excellent. In fact, Kish Island is one of the areas that have the best conditions for attracting visitors in winter. It is important to study and identify constraints and risks threatening climate and awareness of attractions and potentials in climatic features of wide geography of the country in different months of year in order to include them in different levels of national, provincial and municipal planning,

particularly tourism development. Therefore, the basic question in this paper are that what the results are for Tarjung, TCI, Oleg, Biker and Thermo-Hygrometric in terms of bioclimatic assessment of Isfahan city and which months have the best conditions in terms of environmental climate. The aim of this research is to recognize and influence each of the indicators of climate on human physiological structure in each of the months of the year in Isfahan and the implementation of the results of each method with each other.

MATERIALS AND METHODS

In this article, we have used descriptive and analytical techniques and bioclimatic analysis and statistical methods to analyze comfort climate of Isfahan. For this purpose, the data and required information have been extracted from Chahar Mahal Bakhtiari Weather Organization for a period of 59 years for Isfahan Province and using computer software (such as Excel) we analyzed the data using bioclimatic index (TCI, Biker, Oleg, Tarjung, thermo-hygrometric). The amount of comfort of Isfahan has been set in different months of the year during day and night. To determine TCI, we have used the parameters of the daily average of maximum temperatures in ° C per month, the daily average of minimum relative humidity in percent per month, the daily average of temperature in ° C, the average percentage of daily relative humidity in percent per month, the daily average of precipitation in millimeters, the daily average of wind speed in kilometers per hour in each month and the daily average number of sunshine hours per month.

Introduction of the study area

Isfahan province with an area of 106,179 square kilometers has allocated about 6.25 percent of the total area of the country. The province is located at 30 degrees and 42 minutes to 34 degrees, 30 minutes north latitude and 49 degrees 36 minutes and 55 degrees 32 minutes east latitude in central Iran (Shafaghi, 1381, 6).

Precipitation and temperature are important factors in determining climate and are the important parameters to determine type of climate and drought, floods, and water underground. Figure 2 shows the isotherm map of Isfahan Province and Figure 3 presents the isorain map of Isfahan Province, respectively.

According to Figure 2, one can say that places like Khansar and Golpayegan that is mountainous region and their average air temperatures are lower in relation to the East region as a desert, have less height. In general, it can be said that the mountainous areas of West and Southwest have low

average temperature and East and Northeast regions have high average temperature.

As shown in Figure 3, it appears that most precipitations of this province are mountainous and the highest amount of rainfall is in the West Region and lowest is in the East of province. Precipitation regime also follows the height. The precipitation fluctuates from 1,300 mm to 60 mm in the western highlands in the eastern lowlands.

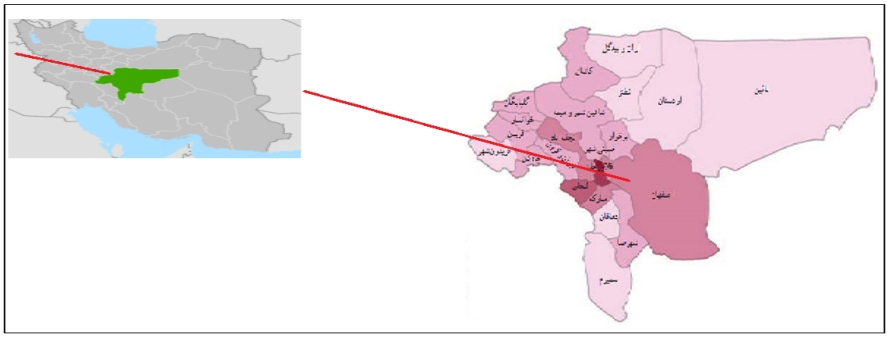

Figure 1: Location of Isfahan

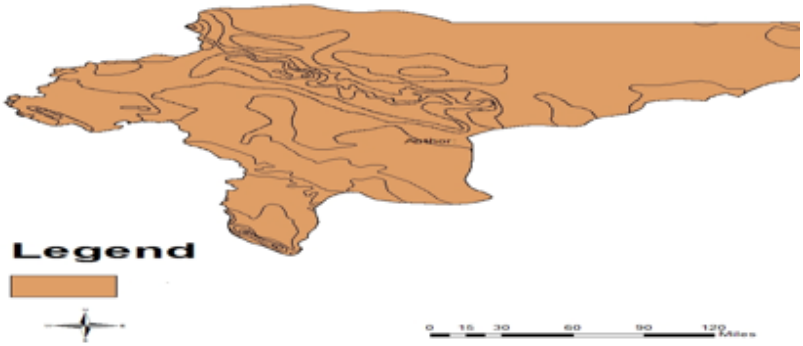

Figure 2) isotherm map of Isfahan Province

Fig. 3) the precipitation map of Isfahan Province

ANALYSIS

Tourism Climate index calculation (TCI)

Mieczkowski has developed TCI. This composite index systematically investigates the climatic elements that are most relevant to quality of the tourist experience for most tourists.

After calculating the final formula, equation (1)

CI=2[(4*CID)+CIA+(2*P)+(2*S)+W]=?T

We implement the final value obtained by the table (1) and ultimately determine the quality of the regional tourism climate. Here, we calculated the coefficients of each of the five indicators, in a period of 59 years (1951-2010) and for 12 months of the year for Isfahan.

The table 2 shows CAD Rating in Isfahan that five is the highest number and two is the least number. In April, May, September, October, ratings are high and they are the most suitable months. November, December, January, February, March are allocated to low ratings.

The calculated CIA values are rated from zero to five that five is the most score and two is the least score. The months of September, October, April, May have the highest score indicating that conditions are favorable. There is not a good situation in November, December, January, February, March, and CIA level is low (Table 3).

Precipitation reduced with increased amount of rainfall in this sub-index, which negatively affects the comfort of tourists. In terms of this index the months of September, October, April and May have favorable conditions for tourists and also the months of December, January, February, March does not show the proper conditions in terms of increased number of rainy days and precipitation (Table 4).

Sunshine is an important parameter in tourism. This index has the highest score in the months of May, June, July, August, and September and in most months except (December, January); there is no limit in terms of sunshine (Table 5).

As shown in table (6) there is no significant difference in rating the amount of wind speed during the months of the year. In general, the months of September, October, November, December, and January have higher rank.

In Table (7), whatever values become closer to 100, it indicates an appropriate climate in that month, so we can say that the months of October, April, May, September are the best months for the presence of tourists in Isfahan and climate condition is ideal. June and July are in next rating and in these months, Isfahan is in very good condition. March and October are in good situation due to high rainfall and coldness. The other three months (January, February, and March) are inacceptable conditions because of the cold and precipitation and have the poorest conditions for the tourists.

Thermo-hygrometric index

In this index, we have used drying temperature and dew point temperature that its application is in warm and dry areas. The index does not consider the wind and is calculated as follows:

DI= 0.99Td 0.36 Tdp+41.5……equation (2)

Where Td is dry temperature and Tdp is dew point temperature in centigrade. Table (8) shows the thermo-hygrometric conditions.

Table 1: Conversion of numerical values (TCI) into qualitative values

Limit of index TCI	Ranking	The state of class
Ideal	9	100-90
Perfect	8	90-80
Very good	7	80-70
Good	6	70-60
Acceptable	5	60-50
Relative	4	50-40
Undesirable	3	40-30
Very undesirable	2	30-20
Extremely undesirable	1	20-10
Impossible	0	10-0

Reference (221:: 1985 Mieczkowski)

Table 2: Ranking - CID of Isfahan

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2	2.5	3	5	5	4	3	3.5	5	5	3	2.5

Table 3) CIA rating of Isfahan

Jan	Feb	Mar	Apr	MAY	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	2.5	3	5	5	4	3	3.5	5	5	3	2.5

Table 4) rating of precipitation amount of Isfahan

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2	2.5	3	5	5	4	3	3.5	5	5	3	2.5

Table 5) Rating amounts of sunlight hours in Isfahan

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
3	4	3.5	4	5	5	5	5	5	4.5	3.5	3

Table 6) rating of wind speed in Isfahan

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
4.5	4	4	4	4	4	4	4.5	4.5	4.5	4.5	4.5

Table 7) calculated values of TCI, in Isfahan in all months of the year

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
49	59	64	94	98	84	76	78	99	97	65	57

Table (8) thermo-hygrometric

Human bioclimatic conditions	Values
One hundred percent of people suffer inconvenience due to heat	DI>80
50% of people suffer inconvenience due to heat feeling comfortable	DI>75
Feeling cold	DI<75
	DI<60

Table 9) component of comfort index of thermo-hygrometric

ماهها / Parameter	Jan	Feb	*Mar*	Apr	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Dry temperature	**2.9**	**5.9**	**10.6**	**16**	**21. 3**	**27**	**29.4**	**27.8**	**23.5**	**17**	**9.7**	**4.4**
Dew point temperature	**-5.1**	**-5.2**	***-3.5***	**1.3**	**2.8**	**3.3**	**5.5**	**4.5**	3	**0.6**	**-1.7**	**-3.7**
DI	**36.22**	**30.56**	***63.08***	**43.21**	**62.75**	**69.35**	**99.12**	**86.08**	**66.62**	**45.13**	**35.62**	**35.69**

According to the amount of DI in the table (9), it can be seen that in the months of January, February, March, April, October, November, December, these the amount of are below 60 indicating the lack of comfort conditions (cold weather). In the months of July and August amount of DI is above 80, indicating the warm weather conditions and the lack of comfort. In the months of May, June, and September amount of DI is between 60 and 70 indicating the comfort conditions.

Tarjung Index

Tarjung index is one of the most human bioclimatic methods for evaluating human comfort. We can recognize the most suitable area for stay and residence of people using this index. Using this method may help to understand the climatic conditions of the region under study which can be applicable in determining the appropriate place of buildings, hospitals, etc., (Kaviani, 1993, 77). Tarjung index is based on the comfort coefficient and coefficient of cooling effect of wind. We use figure (5) to determine comfort coefficient. This figure, in fact, represents a level of comfort that people gain in different combinations of temperature and humidity conditions and normal conditions i.e. normal coverage and lack of physical activity (Tarjung, 1968, 119-123-141).

According to the charts, tables and climatic regional data of relative humidity and monthly average temperature in terms of Fahrenheit given in table (11), the level of comfort has been calculated based on Tarjung index for 12 months of Isfahan.

According to the table (14) observed that in the months of December and January there are unfavorable conditions (very cold) and also in the November, February and March we have unfavorable conditions (cool). In July and August, also there are hot conditions during a day, and only in April, May and October we are faced with appropriate daily conditions.

Determining night comfort coefficient

According to Tarjung index, night comfort coefficient of average daily minimum temperature is calculated in degrees

Fahrenheit and the daily average of maximum relative humidity is set in percentage. Table (15) show maximum and minimum amount of relative humidity and temperature in Fahrenheit, respectively and table (16) indicate the level of night comfort in Isfahan.

According to the table (16) it is clear that nights in December are cold (unfavorable) and nights of February, March, April, May, October, November are very cool nights and we witness cold weather in nights of June, July, August and in July Isfahan has comfort conditions at night.

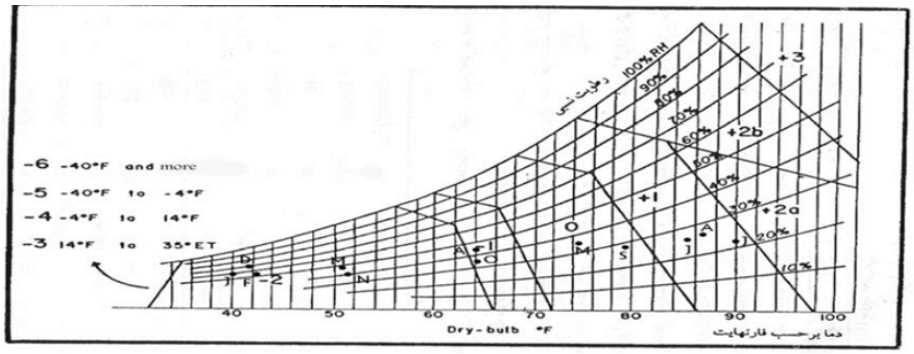

Fig. 5) range of comfort coefficient in terms of Tarjung index in 1968

Table 10) concepts, symbols and chart signs of comfort coefficient in terms of Tarjung index

Group	Dominant feeling	Symbols
Uc	Extra cold	-6
Ec	Extremely cold	-5
Vc	Very cold	-4
Cd	Cols	-3
K	Very cool	-2
C	Cool	-1
M	Desirable	0
W	Warm	+1
H	Hot	+2a
S	Very hot	+2b
Eh	Extremely Hot	+3

Table 11) the level of relative humidity and average temperature (F)

Month / Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature	38.12	42.8	50.9	60.8	69.8	79.52	86.02	81. 32	73.94	62.42	50.18	41
Relative humidity	60	50	42	39	34	25	25	25	28	38	50	60

Source: Isfahan Weather Organization

Table 12) the levels of comfort of Isfahan based on Tarjung index

Jan	Feb	*Mar*	*Apr*	May	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Very cool	Very cool	Very cool	Cool	Desirable	Desirable	Warm	Warm	Desirable	Cool	Very cool	Very cool

Source: Isfahan Weather Organization

Table 13) the least levels of relative humidity and maximum temperature of Isfahan

month / Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum temperature	48.56	54.5	62.6	72.86	82.76	93.74	98.06	96.08	89.24	77	62. 6	51.8
Minimum humidity	38	30	24	22	20	14	15	15	16	21	30	38

Source: Isfahan Weather Organization

Table 14) the levels of daily comfort in Isfahan based on Tarjung index

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Very cool	Cool	Cool	Desirable	Desirable	Hot	Hot	Hot	Warm	Desirable	Cool	Very cool

Table 15) the level of maximum relative humidity (temperature) and least (in Fahrenheit) of Isfahan

month / Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum temperature	27/5	31/28	39/28	48/74	56/66	65/3	69/8	66/36	58/46	02/48	37/76	30/2
Maximum humidity	80	73	65	61	53	40	39	40	44	57	71	80

Source: Isfahan Weather Organization

Table 16) the levels of night comfort in Isfahan

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cold	Very cool	Very cold	Very cold	Very cool	Cool	Desirable	Cool	Cool	Very cool	Very cool	Cold

Bioclimatic index of Biker

Biker index is more comprehensive and more appropriate, because it is among all the elements of climate related to human bioclimatic combination, which is a combination of temperature and wind flow quantities. Baker has proposed the following equation to calculated cooling environment index.

Cp= (0.26+0.34*V.637)*36.5-T)

mcal/cm2/sec equation ……..(3)

In the above equation, v is wind speed in meters per second and t is the average daily temperature in degrees Celsius.

Biker has provided degrees of power of cooling environment and human bioclimatic stimulation thresholds in Table (17). According to the method Biker used and table (17), if CRP levels is less than 5, or more than 50 there will be bioclimatic pressure. In the first case, there is an unpleasant condition due to the high temperature and in the second case, there is undesirable condition because cold environment. Given the need of this index to wind speed and temperature according to Celsius, table (18) shows this parameters in Isfahan, and table (19) indicate the level of climate comfort in Isfahan according to information in table (18) based in Biker index.

In the winter, the CP is higher than 20 that indicate excitation of light and cool, and bioclimatic is due to the coldness in winter. In the spring, the cold weather gradually reduced so that the excitation mode and environmental conditions will change to average pressure and excitation mode, which are range of comfort conditions. In June, the amount of CP reaches to the number 8 that represents tolerable hot environmental conditions. In the summer, the amount of CP has declined and its value reached to 6.16 micro-calories in July, which indicates the hot conditions, and in autumn, conditions are cool and desirable and it is in comfort situation.

Olgie index

We can find climatic conditions in different areas using this index in terms of human comfort and durability of annual coldness and warmth of different cities and seriousness of thermal conditions and the type of the mechanical systems and the need for mechanical systems according to amount of humidity and the intensity of heat or cold are achieved. Oleg has proposed temperature of 21.2 to 26.7 degrees Celsius for summer and 20 to 24.4 degrees for winter and relative humidity of 30 to 65 percent as favorable weather conditions. He suggested that this table can be used with changes in other areas. To determine the climatic comfort based on Olegie method we require two variables, the average temperature and relative humidity. To determine night comfort we require two variables minimum and maximum humidity and to determine day comfort we need two variables of maximum temperature and minimum humidity, which are shown in table (20).

Table 17) degrees of cooling power of environment and bioclimatic threshold according to the Biker method

Human bioclimatic conditions	Environment condition	Levels
Bioclimatic pressure	**Hot, warm and sultry and undesirable**	4-0
Bioclimatic comfort zones	**Tolerable Hot**	9-5
Bioclimatic comfort zones Mild	**Desirable light**	19-10
irritation Moderate to severe	**Cold**	29-20
irritation On average annoying	**Cold and slightly restrainer**	39-30
Extremely annoying	**Very cold**	49-40
	Undesirable cold	59-50

Table 18) the average temperature and wind speed in Isfahan

month / parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature	**3.4**	**6.2**	**10.7**	**16**	**21.1**	**26.5**	29	**27.4**	**23. 3**	**17**	**10.1**	**5**
Wind speed	**1.4**	**2.2**	**3**	**3**	**2.7**	**2.3**	**2.2**	**2**	**1.6**	**1.4**	**1.2**	**1.1**

Source: Isfahan Weather Organization

Table 19) CP levels for different month of year in Isfahan

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22.55	24.90	24.36	19.36	13.59	8.37	6.16	7./1	9.5	13.28	16.94	19.57

Table (20) required variables for day and night comfort according to Olegie method in Isfahan

Month parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum temperature	-2.5	-0.2	4/3	9.3	13.8	18.6	21.1	19.1	14.8	9	3.2	-1
Maximum humidity	80	73	65	61	53	40	39	40	44	57	71	80
Maximum temperature	9.2	12/6	17.2	22.7	28.3	34.3	36.8	35.6	31.8	25.1	17	10.9
Minimum humidity	38	30	24	22	20	14	15	15	16	21	30	38
Average temperature	3.4	6/2	10.7	16	21.1	26.4	26.5	27.4	23.3	17	10. 1	5
Relative humidity	60	50	44	39	34	25	25	25	28	37	50	60

Source: Isfahan Weather Organization

Level of comfort is determined considering the average temperature and relative humidity in Isfahan. The city has only comfort conditions in May and June; August and September have bearable conditions. In July, this city is above the comfort zone and there is warm condition (discomfort) and in other month is under comfort zone that indicates discomfort condition. On the other hand, variables used to determine the daily comfort and maximum temperature and minimum humidity. In April, May and October Isfahan has tolerable conditions and in the months of June, July, August and September, which is in the upper range comfort conditions indicating undesirable condition and in the remaining months it is below comfort zone, which indicates the cold conditions (discomfort). It is found that to determine night comfort using maximum humidity and minimum temperature there is only desirable condition in the night of July in Isfahan and the other months are below the comfort condition range indicating cold condition (discomfort).

CONCLUSION

What perceived from different index tables of climate comfort is that almost most of them include similar conclusions and are compatible with region climate. The results show that the climatic conditions are different in various months of Isfahan. According to calculations based on the Thermo-hygrometric, Tarjung and Biker methods, comfort zone is designated by the indexes for Isfahan in May, June, and September. Needless to say, this conclusion is regardless of considering comfort at night and day. Also comfort zone is set by TCI in April, May, June, September, and October

and discomfort (heat and cold) is shown in January, February, March, June and July. Every four index of July and August have been introduced undesirable conditions in which case Isfahan has inappropriate conditions in these two months. and the amount of nighttime comfort only in July, has introduced since the natural attraction for many tourist attraction are the main source of tourism destinations and increasingly tourists interest spend their vacations in natural places, knowing these factors and study of climatic comforting different seasons for daytime and nocturnal for planning, for officials and tourists are very useful. Because the climate and tourism have mutual relationship and climate conditions and comfort in the success and long-term development of the region also plays an important role.

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