Morphological Elements Responsive to Climate Change at the city Block-Scale: Insights from Meybod, Iran

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Abstract

Climate change is a global concern today. Cities are one of the most critical factors influencing the creation and aggravation of climate change. A large area of Iran's climatic geography is located in a hot and dry region, and the number of cities in this climate is significant.

This study investigates the conditions of hot and dry cities in Iran against the inevitable climate changes. It examines the conditions of urban structures in hot and dry areas of Iran against the threats caused by climate change. For this purpose, the city of Meybod in the region of hot and dry climate and its new urban context is taken as the case study, and possible climatic change for the next 50 years is considered.

The research question is, which morphological elements and indicators are more effective in dealing with the threats of climate change on the city-block-scale and help to ensure the climate comfort of the space users?. The research method was based on analyzing relevant literature and the extraction of elements, shape indicators of the city-block sector, and their prioritization using the AHP method. The LARS-WG5 modeling and the simulation method has been used in ENVI-met software to discover the effectiveness of each element and indicator.

The results show that the four main elements of urban blocks are street network, mass, design pattern, and open space, and the most significant effect of dealing with the threats of climate change is related to the street network element.

Keywords: Climate change**,** Morphology**,** Hot and dry climate**,** Street network**,** Urban ventilation, City block. Meybod, Iran.

Introduction

Climate change has endangered the livability of cities in many parts of the world (Trájer et al., 2022). Climate change and the consumption of energy resources are not the only factors that affect the pattern of human settlements. Issues such as limitations of ecologically rich land (Seppelt et al., 2022) and lack of potable water (Stringer et al., 2021) affect matters like; changes in the family size, labor force, an increase of disabled people, and the changes in the social structure (Kosanic, et al., 2022) arising problems related to personal health and environmental protection (Luyten et al., 2023) and finally the increase in climate refugees.

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Cities have a crucial role in accelerating climate change because 70 to 80 percent of carbon dioxide, which is the leading cause of climate change, is produced in cities. Responding to climate change and the future energy challenge will not be possible without a sustainable form of urbanization (Calthorpe, 2011). However, the fundamental question is which urban morphology is responsive to climate change (Curdes, 2013).

Many specialists have commented on this issue; for example, Caltrop (2011) believes that the form of a compact city will reduce the land use and increase agricultural land, parks, and protected open spaces. Therefore, it is the best urban form to respond to the climate change. Ding et al. (2022) say that the compactness of the urban form has a negative relationship with CO_2 emissions. Therefore, compact cities do not necessarily provide a suitable response to climate change. Frey (2003) argues that regional cities respond better to climate and sustainability than satellite cities. Tavassoli (2016) (2020) says that controlling and strengthening the structure of cities, especially in hot and dry climates are significant factors in livability, increasing climatic comfort, and responding to climate change. Batley (2010) points out that biophilic cities planned according to the integration of city design and Nature will give a good answer to the issue of climate change. Blanco et al. (2009) argue that a city's vulnerability to climate change is not a fixed and uncontrollable dilemma. However, with the intelligent use of land, any existing vulnerability can be reduced and often become controllable to some extent.

Previous research shows that specialists propose various strategies regarding the city to respond to climate change, which indicates the broad and interdisciplinary topic of climate change. Due to the increase in risks and the uncertainty of the results of studies related to climate change, more attention should be paid to the strategies for adapting to climate change.

Historically, people have always been self-adaptive to the surrounding environment. However, climate change has created new and particular challenges that seriously threaten human life, and this issue has become more prominent in the last two decades. Although climate change is a problem at a global scale and has often been discussed at the national level in many countries, today, the distinctive role of urban areas in climate change is increasing from the perspective of reducing risks and the possibility of adaptation (Doherty et al., 2016).

In this paper, an attempt has been made to collect the most critical morphological indicators influencing the creation of climate comfort and to determine their importance relative to each other. This paper aims to investigate, identify and measure essential indicators of an urban morphology that are effective in reducing the effects of climate change and creating climate comfort for residents.

Theoretical Foundations

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through the variations in the solar cycle. However, since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil, and gas. Burning fossil fuels generates greenhouse gas emissions like a blanket wrapped around the Earth, trapping the sun’s heat and raising temperatures. (United Nation, 2022).

The exact amount of greenhouse gas production by human beings in the future is uncertain; therefore, to predict the future climate, different scenarios are used, which are based on atmospheric general circulation models (AOGCM). The scenarios are divided into non-climatic and climatic scenarios. The non-climatic scenario contains information about the socio-economic situation and the amount of greenhouse gas emissions in the planet's atmosphere, also called the Emissions Scenarios.

The Inter-governmental Panel on Climate Change, responsible for understanding all aspects of the climate change phenomenon has predicted the amount of greenhouse gases in different scenarios until 2100 (Table 1).

- A Scenarios: Usually, Scenario
- B Scenarios: Low emission Scenario

- C Scenarios: Control policies Scenario
- D Scenarios: Accelerate policies Scenario

Each scenario is divided into different sub-scenarios that follow different futures and policies. For example, scenario A has two sub-scenarios, which are:

Table 1: Climate change Scenario
Source**:** (Department of Environment, 2021)

Scenario	Sub Scenarios	Vision
A	**A1**	- The world is considered unified. - Economic growth is fast. - The world population will reach 9 billion in 2050 and gradually decrease. - There is a rapid expansion of social and cultural communication in the world.
	A2	- Countries act independently - The world's population is constantly increasing - The ultimate goal of countries is economic development

It should be noted that climate scenarios are scenarios that show the possible future weather conditions and are not considered weather forecasting (Carvalho, et al., 2017).

Climate Change and the City

The issue of climate change and its effects has been seriously considered by the specialists since the 1970s and 1980s, especially by politicians since the 1980s (Calthorpe, 2011). According to the specialists, climate change can be caused by various factors; most specialists agree that the emission of greenhouse gases, especially carbon dioxide, which is the result of using fossil fuels is the main reason for global warming (Stringer et al., 2021).

Cities account for 60-80% of the world's energy consumption (Tereci et al., 2013). Cities are also responsible for 60-75% of carbon dioxide emissions (Liu & Shen, 2011) and 60-80 % of greenhouse gas emissions (Pardo, 2015). Therefore, cities play an essential role in reducing global climate change's effects by reducing fossil energy consumption, increasing energy efficiency, and reducing carbon emissions. The practical actions should have comprehensive policies and executive actions in the building sector. Therefore, urban planners and designers have a significant and influential role in creating cities with less energy consumption; as many theorists point out, the construction and transportation sectors are directly influenced by urban planning and design (Aghakarimi & Bahrainy, 2016).

The urban form and fabric influence energy consumption and emission of greenhouse gases in cities. This impact of cities has widely been accepted in the studies conducted in this field; thus, a comprehensive understanding of the relationship between the urban context and energy consumption plays a key role in creating policies to reduce the effects of climate change at different scales, especially at the scale of neighborhoods and urban blocks. These two scales are the main building units of the city shape and thus play an essential role in achieving urban sustainability (Azizi & Javanmardi, 2017). Therefore, identifying and measuring the nature of this relationship is of great importance.

Specialists and theoreticians in different countries are trying to identify the relationship between urban form, climate change, and energy from different theoretical and practical aspects and address it. Although the urban form is still a unique tool for controlling climate change and energy consumption, there is a need for more empirical studies (Li et al., 2016).

Most research supports the idea that urban forms affect energy consumption, and forms that sprawl increase energy consumption. Nevertheless, the analyses performed concerning the density variable do not provide any definite and generalizable comments. Some researchers have confirmed the effect of increasing density on reducing energy consumption, and others have rejected it. Therefore, a definitive and comprehensive conclusion has yet to be provided on the effect of density on energy production or consumption.

Review of Literature

Various theories have been proposed regarding the relationship between urban morphology and reducing the effects of climate change and creating thermal comfort. In this regard, Tavassol, (2020), Aghakarimi & Bahrainy (2016), AlKhaled, et al., (2020) and Arboit, et al., (2008) along with many other researchers have worked on the issue of building typology. Li, et al. (2016) has investigated the street network form and transportation. Modarres (2017) and Cooper, et al. (2001) have worked on land use. Hsieh, et al. (2017) and Pardo (2015) have examined the social and economic factors. Ye, et al. (2017) have focused on the potential of solar energy production. Lin, et al. (2022) have investigated the effect of urban form on building performance. Azizi & Javanmardi (2017), and Robinson, et al (2017) have focusd on the effect of street or urban canyons on urban ventilation. Mazhar, et al., (2015) Jie He, et al., (2020) have considered urban blocks in this regard, but Jin, et al., (2020), Curdes, (2013), Arboit, et al., (2008), have focused on the neighborhood units and Li, et al., (2016), Robinson, et al. (2017) have examined urban parts.

Another group including Cajot, et al., (2017) and Tavassoli, (2020) point out that the urban form as a complex system includes many components and features. Most of the studies conducted by these groups have examined only one or more specific factors. The review of these studies is a re-emphasis that shows that urban form is a multi-dimensional concept and its complex relationships can only be investigated using interdisciplinary methods. However, only a few other studies have considered this issue as, displayed in the table 2.

Table 2: Classification of selected articles by topic
Source: Authors

Issue	References
Urban form (with emphasis on building and density) and energy	Tavassoli,2016; Clark,2013; Dawodu& Cheshmehzangi,2017; Hsieh et al., 2017; Rylatt et al.,2003; Steemers, 2003; Yongling, 2011; Aghakarimi et al.,2016
Urban form (with emphasis on land use) and energy	Inturri et al.,2017; Liu & Shen, 2020, Pardo Martinez, 2015; Hsieh et al., 2017; Larson et al., 2012, Owens, 2019; Stevens &Snebel, 2017
Urban form (with emphasis on the role of transportation), energy and climate change	Frost et al., 1997; Keirstead& Shah, 2011; Liu et al.,2015; Mariqueet al.,2013; Modarres,2013;2017
Urban form (a combination of construction and transportation) and energy	Gu et al., 2013; Mörtberg et al., 2017; Muñiz et al., 2013; Stephan etal., 2013; Yezer et al.,2012
Urban form and structure and its relationship with climate change, heat islands, climatic comfort and sustainability	Badach et al.,2020; Peng et al.,2020; Jin et al.,2020; Privitera, 2018; Fang al.,2021; Wilson.,2013
Urban form and thermal stress	Javanroodi et al.,2018; Hemsath, 2016; Abdallah,2015
Energy planning and energy policies	Cajot et al.,2017; Clair ,2009; Sampaio et al., 2013; Sadownik et al., 2001

Iran and Climate change

Iran is very vulnerable to climate change. About 82 % of Iran's area has a hot and dry or hot and semi-dry climate, and the annual rainfall is about 250 mm, which is less than the world average (Tavassoli, 2016). As a result, climate change will cause extensive droughts in Iran, and cities in hot and dry climates are the most vulnerable to climate change.

Climate change threatens the cities of the hot and dry region in Iran, and other cities in Iran will suffer the destructive consequences of this phenomenon. Iran's vulnerability to climate change will be higher than the world average. Even now, the consequences and losses of climate change can be seen in Iran. In Fig. 1, the threats quoted by Iran's environmental organization has been summarized.

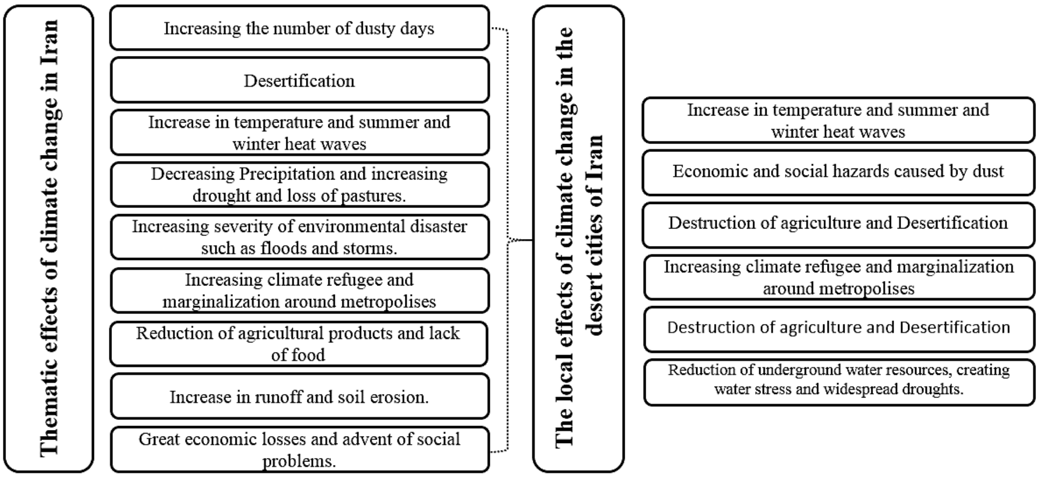
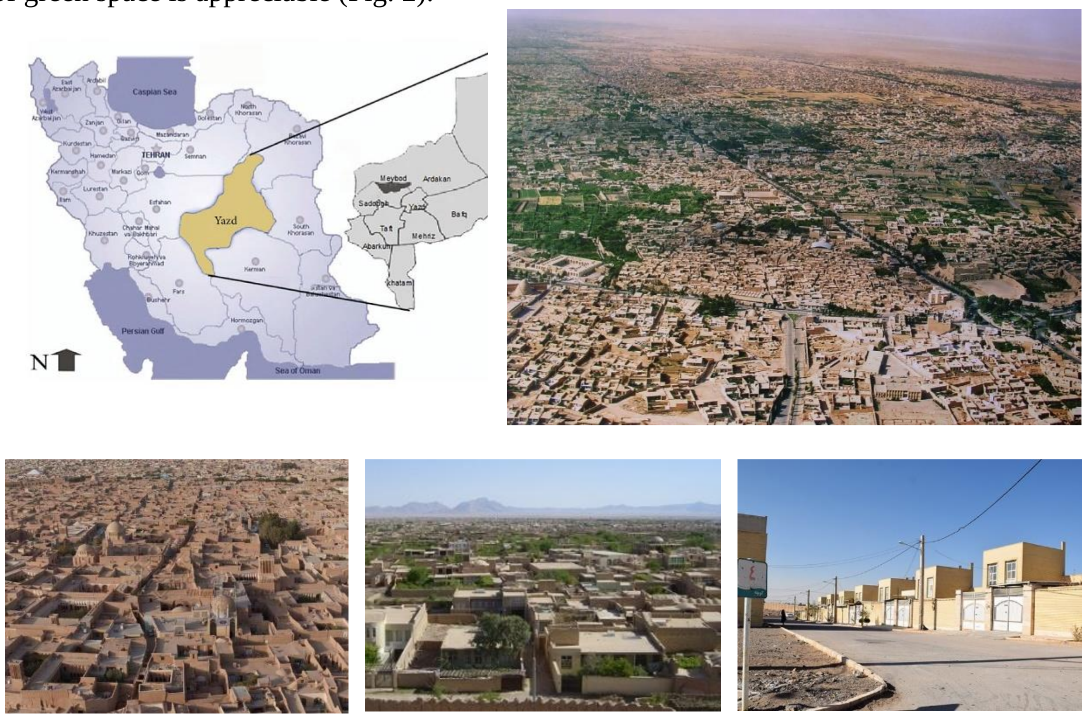


Fig 1: Destructive effects of climate change in Iran and hot and dry climate cities
Source**:** (Department of Environment, 2021)

The Case Study

Meybod is located in the North of Yazd province, and according to some evidence, this city is considered one of the first settled areas in the center of Iran. The city is 7000 years old, is located in the hot and dry region of Iran, and has an organic and rich architecture. Despite the city's location in a hot and dry climate due to the use of the Aqueduct system, the amount of green space is appreciable (Fig. 2).



Historic urban fabric | Urban fabric built in 1975-2000 | New urban fabric

Fig 2: Meybod Townscape
Source: Authors

Three models of urban fabric exist in the city of Meybod, which consist of the old fabric, the urban fabric from the 90s, and the new fabric. The new fabric of the city is grid-iron and needs to follow the city's urban planning principles and vernacular architecture.

Due to the decrease in precipitation in recent years and the increase in the consequences of climate change, the amount of water storage in the city has decreased significantly; underground water reserves also cannot supply urban water. On the other hand, many farmers are migrating to other cities due to the lack of water for agricultural purposes and its allocation to potable water. Iran's desert cities will suffer drastically from climate change due to high heat and lack of water. The possibility of evacuation of these cities and the migration of their residents to the northern regions of Iran is likely soon.

Research Methodology

Because a significant part of the world's energy is consumed in cities and one of the influencing factors on this matter is the morphology and urban fabric,

To identify the morphological indicators affecting climate change, the combination of keywords "urban morphology and urban ventilation," "climate comfort," "climate change," and "climate change and energy consumption" were searched in scientific databases, and 1289 articles were found.

Articles with the following conditions were selected to identify a manageable subset of these articles. First, the most relevant articles include all three words, "urban morphology," "climate change," and "climate comfort" or their derivatives. Second, those mainly focus on climate change and urban morphology, and finally, those related to European countries, the Middle East, or China. The obtained results included 129 articles (Table 3).

Of these 129 articles, 37 were excluded due to content inconsistency with other articles despite having the conditions mentioned above. Finally, 96 articles remained for the final analysis, from which the most frequent morphological indicators affecting climate change and comfort were extracted. After finding these indicators, the AHP method was used to rank them to determine the percentage of importance of each indicator.

Table 3: Effective factors in searching and categorizing articles
Source: Authors

Search title	Urban morphology responsive to climate change	**Keywords**	**Climate change** **Urban form** **Morphology** **Climate comfort** **Urban ventilation**	**The language of texts**	English, Persian
Purpose	Review and ranking of principal morphological indicators in hot and dry climate cities			**Database**	Specialized books, Scopus, Web of Science, Noormags, SID,
Question	Which indicators of urban morphology reduce the effects of climate change?			**Publication date**	2000-2022

After ranking the indicators, to verify their measurement, the future climate change of Meybod city was estimated in scenario A2 of the IPCC organization in 2070 using the LARS-WG5 software. The HADCM3 model was used for accurate zooming and scaling of climatic variables (rainfall, minimum and maximum temperature), which makes the data obtained more spatially accurate. Then, according to the estimation of climate variables obtained in 2070, an urban block in the new context of Meybod city was simulated with Envi-met software to make the morphological indicators determined in theoretical studies more precise (Fig. 3).

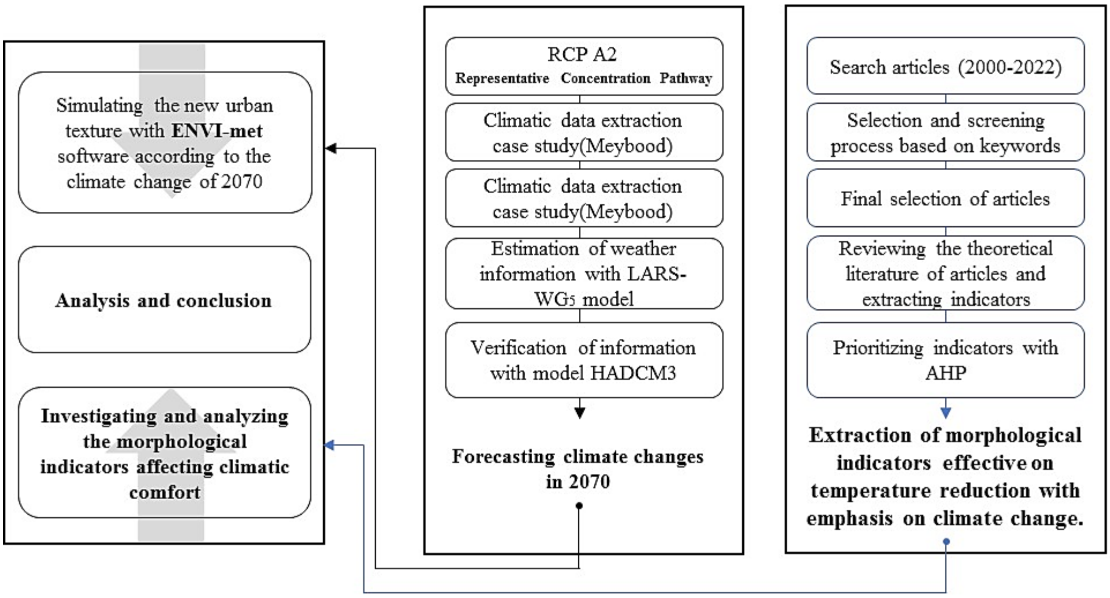


Fig 3: Research process
Source: Authors

The Simulation

In this paper, the study area was entered into the ENVI-met software as a three-dimensional urban simulation and was analyzed by this software. The simulation model includes the three-dimensional urban model and existing materials, including the building shell, soil type, urban street network, urban traffic, and the weather information of the region.

In examining the simulation model of this research, attention was paid to the urban context, climate comfort and climate change simultaneously. Considering that the case study is located in Iran's hot and dry climate, it has been tried to use the average summer temperature and the hottest day of the year as the basis for examining thermal comfort.

The method of "intermediation" was used to obtain climatic data, and the data of meteorological stations in the surrounding area were used as the basis of climatic data calculations. Meteonorm software, which obtains weather data through "intermediation," was also used to obtain this data.

Findings

Analysis of the Literature

According to the examination of literature, the analysis of the relationship between urban morphology and climate change has been done at all scales of building, street, urban block, neighborhood unit, section/zone, city, and country (Fig. 4).

Most studies on urban morphology and climate change have been carried out at two scales: the city and the neighborhood unit.

According to the results, four morphological elements determine the formal pattern of the urban blocks. These elements include building mass, design pattern, street network, and open spaces. Among these elements, the street network plays a more significant role in determining the form of the blocks. Because the cities' forms are created by placing blocks and neighboring units together; if urban blocks are designed according to the environmental principles and climate change, the cities respond better to the threats of climate change in the future.

Table 4: Effective indicators on reducing the impact of climate change on the urban block scale
Source: Authors

Elements	No	Indicators	Reference
Street network	1	Street Pattern	Georgakis,Santamouris(2006); He et al(2020); Tavasoli (2016); Darabi et al (2020); Azizibabani(2021); Aghakarimi(2016)
	2	street Orientations	Deng et al (2012); Azizi et al (2017); He et al (2020); Xi et al (2020); Peng et al (2020); Vaccari et al (2013); Ma .et al (2022); Tavasoli (2016); Darabi et al (2020)
	3	street width	Lin, et al (2014); Deng et al (2012); Hu et al (2013); Chen et al(2017); Azizi et al (2017); Luo et al(2017); Merlier et al (2017); Xi et al (2020); Peng et al(2020); Curdes (2010)
	4	street length	Lin, et al (2014); Luo et al (2017); Gülten et al (2020), Peng et al (2020), Vaccari et al (2013); PrimoVaccari et al (2013)
	5	The ratio of street dimensions	Georgakis,Santamouris(2006), Yim, et al(2009); Merlier et al (2017);Tavasoli(2016)
	6	enclosure	Fang et al (2021); Curdes (2010); AlKhaleda et al (2020); Tavasoli (2016); Mazhara et al (2015); Darabi et al (2020)
	7	Density of street canyons	Badach et al (2020); Xu et al (2020); Darabi et al (2020)
Design pattern	8	porosity	Edussuriya, et al (2011); Merlier et al (2017); Curdes (2010)
	9	Spatial configuration of buildings	Gülten et al (2020); Tavasoli (2016); Darabi et al (2020)
	10	Spatial arrangement of buildings	Hu et al (2013); Yang et al (2013); Tavasoli (2016)
	11	Average building mass	Kubota, et al (2008); Luo et al (2017); Wang (2019); Badach et al (2020); Kaseb et al (2020); He et al (2020)
	12	Building Density	Edussuriya, et al (2011); Panagiotou et al(2013); Razak(2012); Hang et al(2015); Chen et al(2017); Guo et al(2017); Merlier et al (2017); Kaseb et al (2020); He et al(2020); He et al(2020), Fang et al (2021); Peng et al(2020); Privitera et al (2018); Xu et al(2020); AlKhaleda et l(2020); Ma .et al(2022)
	13	Standard deviation of building height	Hu et al (2013), Hang et al (2015), Chen et al (2017); Wang (2019); Yang et al (2019); Badach et al (2020); Kaseb et al (2020); Xi et al (2020); Peng et al (2020)
	14	the frontal area index	Yim, et al(2009);Lin, et al(2014); Ng, et al(2011); Panagiotou et al(2013); Razak(2012); Hang et al(2015); Chen et al(2017); Guo et al (2017), Luo et al(2017); Merlier et al (2017); Yang et al (2019); He et al(2020); He et al(2020); Badach et al (2020); Xi et al (2020); Peng et al(2020)
	15	Land use	Luo et al (2017); Wang (2019); Privitera et al (2018); AlKhaleda et al (2020)
Mass	16	Spatial continuity	Tavasoli (2016); Darabi et al (2020)
	17	construction type	Kubota, et al (2008); Yim, et al (2009); Tavasoli (2016); Darabi et al (2020)
	18	ratio of the dimensions of the buildings	Razak (2012); Gülten et al (2020); Tavasoli (2016) Darabi et al (2020)
	19	building Height	Kubota, et al(2008);Lin, et al(2014); Ng, et al(2011); Edussuriya, et al (2011), Deng et al(2012); Razak(2012); Azizi et al (2017); Luo et al(2017); He et al(2020); He et al(2020); He et al(2020); Xi et al (2020); Fang et al (2021); Gülten et al (2020); AlKhaleda et l(2020)
	20	plot buildings	Yang et al (2013); Wang (2019); Tavasoli (2016); Darabi et al (2020)
	21	Coefficient of gross floor area	Kubota, et al(2008); Ng, et al(2011); Edussuriya, et al (2011); Hu et al(2013); Yang et al (2013); Wang (2019); Yang et al (2019); He et al(2020), Gülten et al (2020); Peng et al(2020); Xu et al(2020)
Open space	22	Vegetation density	Yang et al (2013), Yang et al (2019); Badach et al (2020); Fang et al (2021); Privitera et al(2018); Vaccari et al(2013); PrimoVaccari et al(2013); Xu et al(2020); Tavasoli (2016); Mazhara et al(2015); Darabi et al (2020); Azizibabani(2021)
	23	SVF	Tavasoli(2016); Xi et al (2020); Fang et al (2021); Curdes (2010); Xu et al(2020); Darabi et al (2020)

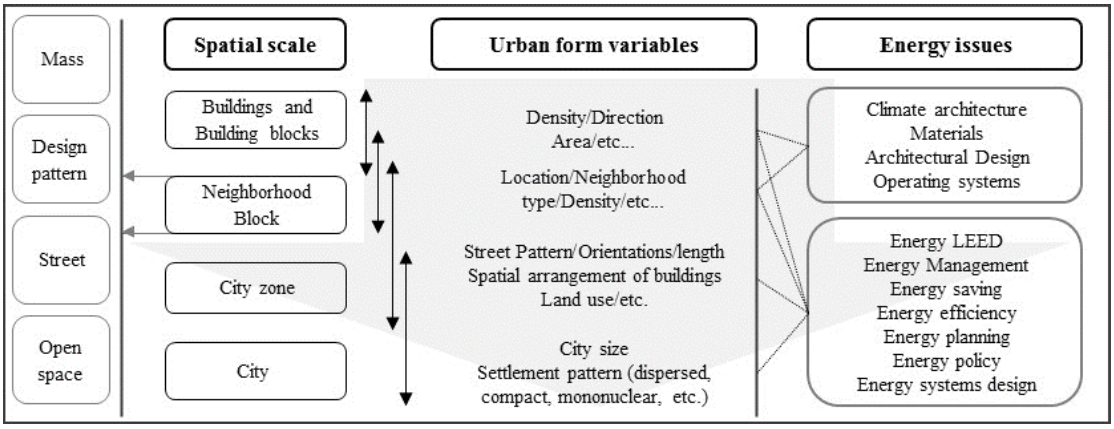
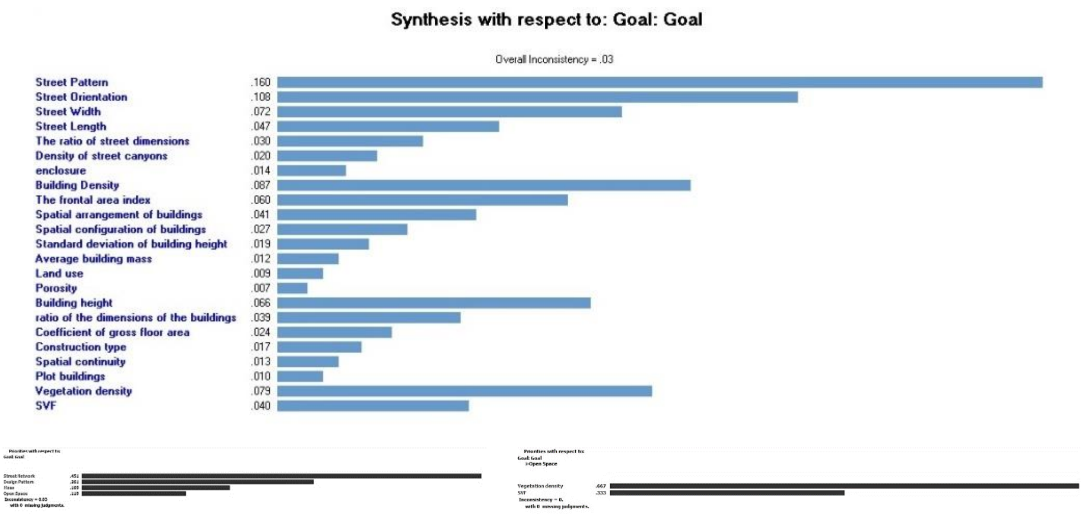


Fig 4: The framework for analyzing the relationship between urban form and energy in different scales
Source: Authors

After examining the literature, 23 non-repetitive indicators were extracted from the articles, and these indicators were classified into four groups: Mass, Design pattern, Street network, and Open spaces (Table 4). In the Street network element, the most critical indicator is the issue of street orientation and the street pattern. In the Mass element, the most critical indicator influencing the reduction of the effects of climate change is the building height. In the design pattern element, the building density indicator is the most important, and in the open spaces group, the vegetation density is the most important indicator.

In the review and prioritization of indicators using the AHP method, it was found that in the street network group, street pattern, street orientation, and street width; in the design pattern group design pattern, building density, and the frontal are the indexes. In the mass group, building height and the ratio of the dimensions of buildings, and in the open space group, vegetation density (SVF) plays the most critical role in determining the response of an urban block to creating climatic comfort. According to the prioritization of all the indicators in general, it was determined that the street pattern, street orientation, building density, vegetation density, building height and street length are the most essential morphological indicators to create climate comfort and reduce the effects of climate change on space users. In the diagram, the priority number of the indicators of each group and the priority ratio of the indicators as a whole are presented to each other (Fig. 5).



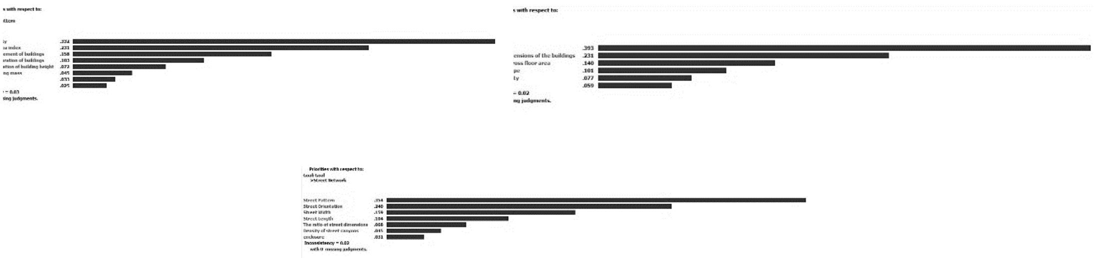


Fig 5: Prioritization of the morphological indicators affecting climate comfort.
Source: Authors

Estimated temperature

In this study, the temperature and precipitation data recorded by Meybod Meteorological Department were used. The time scale of these data is daily and the data are analyzed and reviewed in a 40-year statistical period from 1981 to 2021. Two criteria of data quality and location were considered in selecting the Meteorological Department station (Table 5).

Table 5: Name and type of weather station available in Meybod
Source: Authors

Organization	Station height(M)	Geographical attributes			Station
		latitude	Longitude	Station type	
Meteorological Organization	1110	32.230044	53.930766	Cinoptic station	Meybod

LARS-WG5 small-scaling software was used for the non-deterministic simulation of weather based on existing conditions. The input files to the Lars software were prepared with the appropriate text format for the software. In this research, rainfall data and minimum and maximum temperature variables are used as software input data. Data about the geographic location and the height of the selected station are among other software inputs that affect the results. The statistical characteristics of the data were determined and analyzed by the software.

The HADCM3 model (HadCM3) and the A2 release scenario were used among the models of the fourth evaluation report and the release scenarios. The results of this model were scaled for the scenario considered by Lars model. The Q test (quality test) is also performed to check the statistical properties of artificial and observational data so that there are no statistically significant differences between them. Probability distributions of synthetic and observational data were compared using KD (goodness of fit test), and averages and standard deviations were compared using T and F tests in order to validate the results.

After entering the data into the software and running the model, the quality test was performed automatically by the software. According to the p-values related to the t and f statistics obtained in this step, which are presented in the Table 6, in general, the output results of the Lars model can be trusted; because the results of the selected station showed that the simulations of minimum temperature, maximum temperature and precipitation were associated with a high p-value of t and f statistics and the p-value values are higher than the confidence level of 0.01 and 0.05 %. Therefore, the verification of the LARS-WG model outputs showed that this model has high reliability of the results for the desired area and parameters of minimum temperature, maximum temperature, and precipitation.

In order to scale down the temperature and precipitation data of the studied area, the LARS-WG model was used, which has a good ability to simulate temperature and precipitation in the area. Therefore, the long-term average temperature and precipitation of each month in the future periods were calculated according to the results of the HADCM3 model (Table 7). The Table shows the results related to downscaling of precipitation data, minimum temperature, and maximum temperature using the Lars method in the target area in the base period and the future period for the output of the HADCM3 model under the A2 scenario.

Table 6:The p-values obtained from the T-test of the synoptic station in Meybod city
Source: Authors

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum temperature	0/396	0/396	0/960	0/111	0/322	0/258	0/712	0/346	0/703	0/432	0/984	0/582
Maximum temperature	0/690	0/348	0/424	0/851	0/182	0/447	0/918	0/501	0/257	0/682	0/732	0/491
Precipitation	0/542	0/512	0/531	0/128	0/439	0/282	0/577	0/094	0/924	0/234	0/425	0/712

Table 7: The average annual difference of temperature and precipitation of future periods and the base period of Meybod synoptic station, HADCM3 model
Source:Authors

Scenario	Period	minimum temperature	maximum temperature	precipitation
A2	**2022-2070**	**+2.3**	**+2.31**	**-0.47**

Table 8: The average seasonal difference of temperature, precipitation of future periods and the base period of Meybod synoptic station, HADCM3 model
Source: Authors

Scenario	Period	Season	minimum temperature	maximum temperature	precipitation
A2	2022-2070	**winter**	+1.81	+0.9	-1.4
		Spring	+2.6	+2.7	+0.44
		Summer	+2.9	+0.6	+.017
		Fall	+2	+2.56	-1.2

Tables 6 and 8 indicate that the average annual temperature difference will increase. Based on the results, the highest temperature increase is at least 2.9 degrees Celsius in the summer season. The spring and autumn seasons show a higher maximum temperature increase than other seasons. The results of the tables show that precipitation decreases in winter and autumn and increases in spring and summer (Table 8).

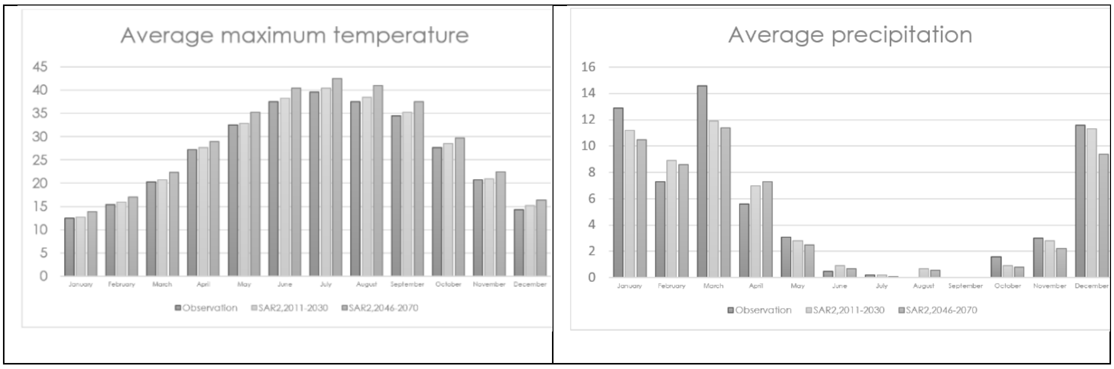
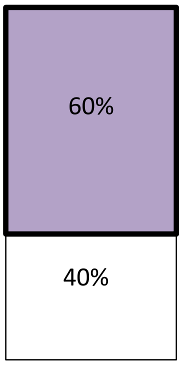
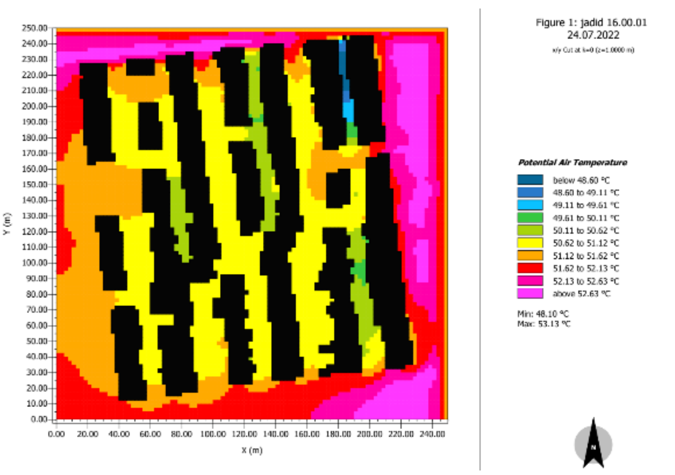


Chart 1: Forecast of average precipitation and average maximum air temperature in 2070
Source:Authors

The estimation of the weather in 2070 in the city of Meybod shows that hotter summers and winters are ahead in this city, so the average summers and winters will be 2 degrees warmer than the current time, which can cause a decrease in precipitation; as a result, a decrease in underground water reserves.

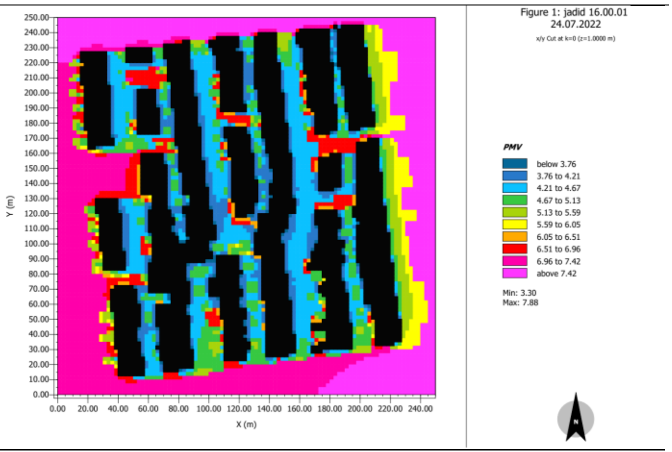
Simulation based Analysis

Table 9: Analysis and review of the simulated block in Envi-met software
Source: Authors

Analysis	Maps
The new fabric of Meybod city is mainly located in the south. This part of the city has straight streets and follows a general rule for the construction pattern: **The 60 to 40 rule** This law, which is currently implemented in all cities of Iran states that 60% of a building plot can be built, and 40% should be allocated to the yard. This law is implemented in all Iranian cities regardless of climatic conditions and social and economic issues. It has caused the formation of an identity-less and uniform urban fabric in all cities.  	
The hottest day of the year Examining the new urban texture shows that this texture has a high average temperature in the city. In this texture, due to the significant distance between the blocks, the amount of environmental heat between the blocks is high. In the upper right corner of the image, the temperature between two blocks is lower than in other places due to the short distance between the two blocks and shading; Therefore, by creating shading, the environmental temperature has decreased by about 4 degrees.	

The hottest day of the year

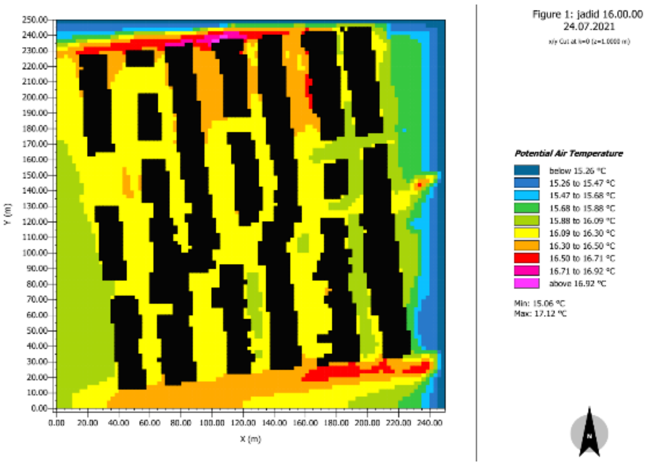
The PMV index indicates high environmental heat, and this means that at high environmental temperatures, the fabric cannot be considered as a fabric responsive to climate comfort.



Average summer temperature

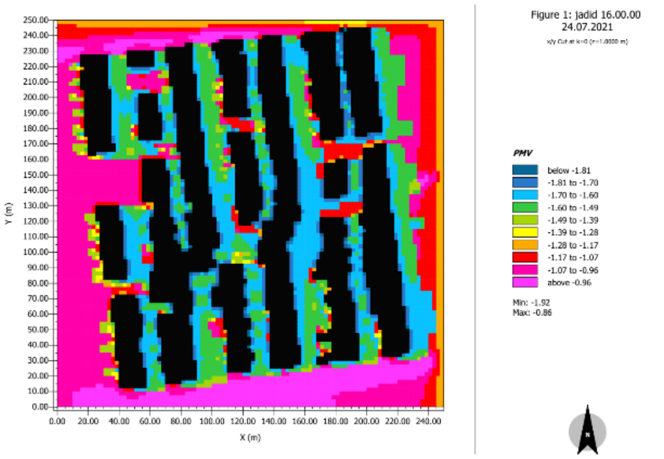
In the summer, the environmental conditions of the urban fabric are almost constant, and due to the considerable distance between the blocks, there is a more negligible temperature difference between different parts of the fabric. The temperature range of the whole range is between 15.06 and 17.12 degrees Celsius.

In some places where there are streets, the temperature is slightly higher than in other places. This shows that in the new context, due to the openness between the city blocks and the lack of enclosure, it is not possible to have much effect on the ambient temperature of the city.



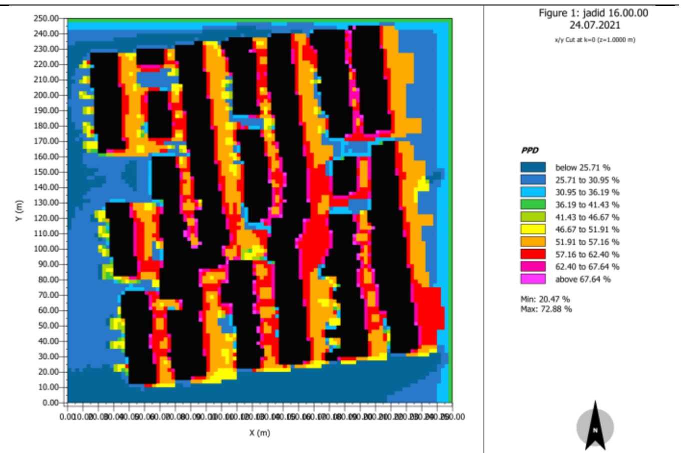
Average summer temperature

PMV values indicate that the effect of weather factors on human thermal comfort is very different from the critical state in the average summer. This indicates a significant temperature difference between the hottest and coldest hours of the day and night. Also, unlike the most critical state, the average state shows the amount of cold at night compared to the amount of heat during the day, and in some hours, there will be complete thermal comfort, but what is certain is that compared to other cases of this context, the level of comfort of people in the cold and very Cold is placed in the average mode and its value is between -0.86 and -1.92



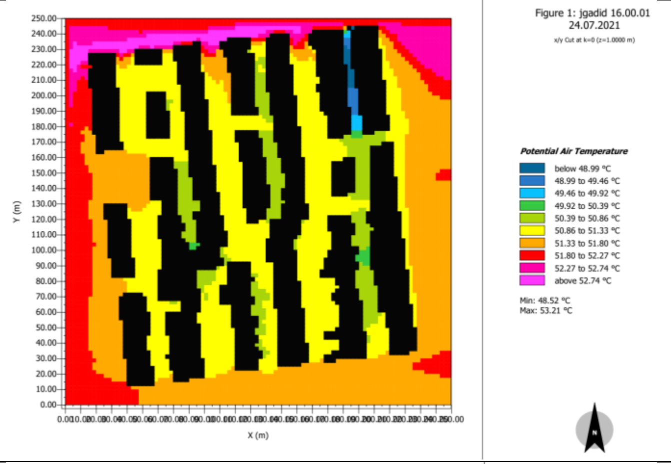
Average summer temperature

In examining the level of dissatisfaction, we have seen a decrease from 100% to the range of 20.47 to 72.88.



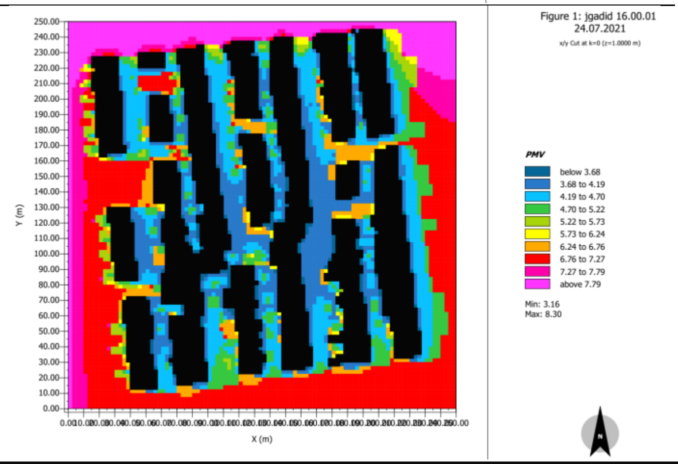
2070 climate forecast

The lowest recorded temperature in this state has reached 48.59 degrees, and the maximum temperature has also reached 53.21 degrees.



2070 climate forecast

After the climate changes, the thermal dissatisfaction will remain, and only the minimum PMV will be from 3.16 to 8.30, which means that the conditions will worsen in some areas. The alignment of streets with a favorable wind causes wind penetration into the streets and improves comfort conditions



The results show that the effect of climate change on thermal comfort conditions on the most critical day of the year makes the space unlivable.

The conditions can be made more favorable by observing the points in the design, such as paying attention to the direction of the street to increase the penetration of wind among the masses during the day, increasing the amount of shading by green spaces, reducing the width of the streets and increasing the enclosure of the spaces. In addition to these, using trees with a high height and increasing the height of buildings can create more shading for the passages to improve thermal comfort to some extent. In addition to the mentioned cases, using water in the form of a spray or a fountain also increases the humidity and, consequently, decreases the temperature of the environment, which can significantly optimize the climatic comfort conditions (Table 9).

Conclusions

Climate change threatens many cities in Iran. Meanwhile, cities in hot and dry climates and on the edge of deserts are more at risk than other cities. Lack of water resources, fine dust blowing, dusty air, and very hot summers are the most important things that will make the cities of this area unlivable soon. Therefore, it is necessary to pay attention to design mechanisms to reduce the effects of climate change in such cities.

This research showed that each of the four elements has indicators mentioned in the table.

This study also showed which index in each element is more effective in reducing the threats of climate change and creating climate comfort for space users, which is ready below:

- In the design pattern element of the building density index,
- In the street network element, the index of the street pattern and its direction,
- In the mass element of the building height index,
- In the open space element, the vegetation density index(Chart 1).

The simulation from 2022 to 2070 also showed that two policies play an essential role in reducing the effects of climate change in Iran's hot and dry cities, which include shading and the permeability of wind flow into the block. These two factors refer to the morphological indicators mentioned in the table below.

Table 10: Indicators affecting climatic comfort in hot and dry cities
Source: Authors

Elements	Indicators	Policies affecting climate comfort in hot and dry cities.
Street network	Enclosure	shading
Mass	building Height	
Street network	street width	
Open space	Vegetation density	
design pattern	Building Density	
Street network	Density of street canyons	Urban Wind Permeability
Street network	street Orientations	
Street network	Street Pattern	
Street network	street length	
Street network	street width	
design pattern	Spatial configuration of buildings	
design pattern	Building Density	

As the above table shows, the indices of the street network element play a more significant role in the climatic comfort of urban blocks. According to the simulation, in cities with hot and dry climates, paying attention to the orientation of urban streets plays a significant role in the ventilation of the urban block and increasing climatic comfort in the face of threats caused by climate change (Table 10).

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