Thermal Comfort in Public Open Spaces: The Historical Core of Isfahan, Iran

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Abstract

The world is experiencing high urban growth, which has caused increased temperature in many cities. This 'urban heat island' effect increases the thermal discomfort, and air pollution among other adverse effects and endangers public health. Iran has seen these effects most seriously during the recent times.

This study examines the relationship between the morphological components and thermal comfort in the historic city of Isfahan. The historical urban fabric was classified in terms of morphological features, and a field study was performed in nine neighborhoods for four consecutive days in the winter. Environmental variables such as temperature, humidity, radiant temperature, and wind speed were measured using a data logger. The PET index was calculated using the Rayman software, and the comfort levels were analyzed in different places.

The results show that thermal comfort in the mixed organization areas is higher than in the areas with tributary organizations. Thermal performance is higher in the radial-tributary organization, grid-tributary, and tributary-tributary streets, respectively. Streets with Northeast-Southwest and Northwest-Southeast orientations have better performance than North-South and East-West, and the thermal conditions of the roads in the vicinity of old plots, mixed plots, and plots with new arrangements were better, respectively. The thermal stress on the streets with a lower aspect ratio was almost the same and slightly different, less than the higher aspect ratio.

Keywords: morphology, thermal comfort, urban microclimate, urban fabric, historical city, Isfahan.

Introduction

The world is experiencing the biggest developments in urbanism in its history. Since 2008, for the first time, more than half of the world's population has been living in cities and towns. By 2030, this population will reach 5 billion people (about 61 percent of the world population) (Erell et al., 2012). The increasing human activities have various impacts on bioclimatic aspects such as increasing the use of fossil fuels, a decrease in the thickness of the ozone layer, water and earth pollution, and the greenhouse situation of the planet (Pourdeihimi, 2001). Population growth and city areas have made their problems more extensive and complex. One of the problems the contemporary cities encounter is an urban heat island, i.e., the temperature of the central metropolitan area being significantly higher than its surrounding rural areas. This temperature rise not only disturbs people's thermal comfort, but its role in air pollution will severely impact public health and lead even to death (Khodakarami and Hatami, 2016).

Urban climatology is a practical, effective field in designing the spaces between buildings; this field helps to understand microclimates. Through this, one can manage the spaces between buildings to create better environments (Erell et al., 2012). People only do their necessary activities when the streets and other urban spaces have poor quality. Still, on the other hand, urban spaces with high quality encourage more social and selective activities (Gehl, 1987). Thermal comfort in open spaces increases the social presence and decreases people's presence in closed areas. If the principles related to climate are observed in open spaces, ease in closed areas will be facilitated, and a significant amount of energy will be saved (Tahbaz, 2017).

Although there is a high importance of research on thermal comfort in exterior spaces, such studies are less than those on interior spaces (Aghamolaei et al., 2020). Moreover, the streets in residential areas have a minor part in thermal comfort studies of exterior spaces. For example, Johansson et al. (2014) have pointed out that there have been few studies regarding the streets in residential areas in comparison to studies regarding thermal comfort in parks, squares, pedestrian streets, waterfronts, and sports fields.

In this context, this research focuses on the local public open spaces and streets in residential areas, which contribute to the literature of this field. In previous studies, thermal comfort has been examined through the morphological point of view, and they review one or two variables in one region or a city. However, in this study, the relation of comfort has been examined at three scales: urban plots, blocks, and urban fabric.

The morphological analysis of the historical region has been done using the Kropf model in analyzing urban morphology elements, and different forms with various organizations have been identified. Then it studies variables related to block organizations, organization of streets network, enclosure level, street orientation, and type of urban sections. It investigates their relations with thermal comfort.

This study aims to determine the connection of morphological elements with thermal comfort in Isfahan's historical urban fabric. Its objective is to help urban designers and planners to promote the quality of public spaces, especially in terms of heat.

1. Theoretical Basis

1.1. Thermal Comfort

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and assessed by subjective evaluation (ASHRAE 55,2017).). As it is known, the human body needs to be within a range of temperature to function well. If the surrounding temperature either rises or falls, the body reacts to maintain the necessary body temperature, either by sweating or by shivering. Different factors affect the rate of heat loss from the body when its temperature rises to ensure that it feels comfortable. These factors can be categorized into environmental and individual characteristics. The first group includes temperature, radiation, airflow, and relative humidity. The second group is the rate of metabolism of the body and resistance of clothes (Olgyay and Olgyay, 1963).

To evaluate thermal comfort in open spaces, there are various indexes. Predicted Mean Vote (PMV), Standard Effective Temperature (SET*), Effective Temperature (ET*), Perceived Temperature (PT), Psychologically Equivalent Temperature (PET), and Universal Thermal Climate (UTC) are some of them. The most used indexes in recent studies are PMV, SET*, and PET (Xi et al., 2012). German engineering guidelines VDI 3787 (2008), developed for exterior environments suggest using PMV, PT, and PET (Johansson et al., 2014). Matzarakis and Amelung (2008) have described the range of thermal comfort based on PET, as shown in the Table 1.

Table 1: Ranges of the physiological equivalent temperature (*PET*) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo
Source: Matzarakis & Amelung, 2008

PET	Thermal Perception	Grade of Physiological Stress
<4°C	Very cold	Extreme cold stress
4.1- 8°C	cold	Strong cold stress
8.1- 13°C	Cool	Moderate cold stress
13.1 - 18°C	Slightly cool	Slight cold stress
18.1- 23°C	Comfortable	No thermal stress
23.1- 29°C	Slightly warm	Slight heat stress
29.1- 35°C	Warm	Moderate heat stress
35.1- 41°C	Hot	Strong heat stress
>41.1°C	Very hot	Extreme heat stress

1.2. Urban Morphology

Morphology involves the description of shape and form. Carmona et al. (2003) point out that studying urban morphology assists urban designers in becoming acquainted with local patterns of development and alteration procedures. Madanipour (1996) defines urban morphology as a systematic study of forms, shapes, plans, structures, and functions of the built fabric of towns and cities, as well as the origin and how this fabric has evolved. Kropf, points out the evolutionary characteristic of morphology. Kropf presents three main concepts for studying a built form's morphological features: pattern, process, type, and hierarchy. Repetitive patterns during time create varieties that are produced in a circle. Each class makes a series of prints connected through an order of related shapes (Kropf, 2017). Fig. 1 shows different levels in urban tissue, which can be studied from the Kropf's perspective.

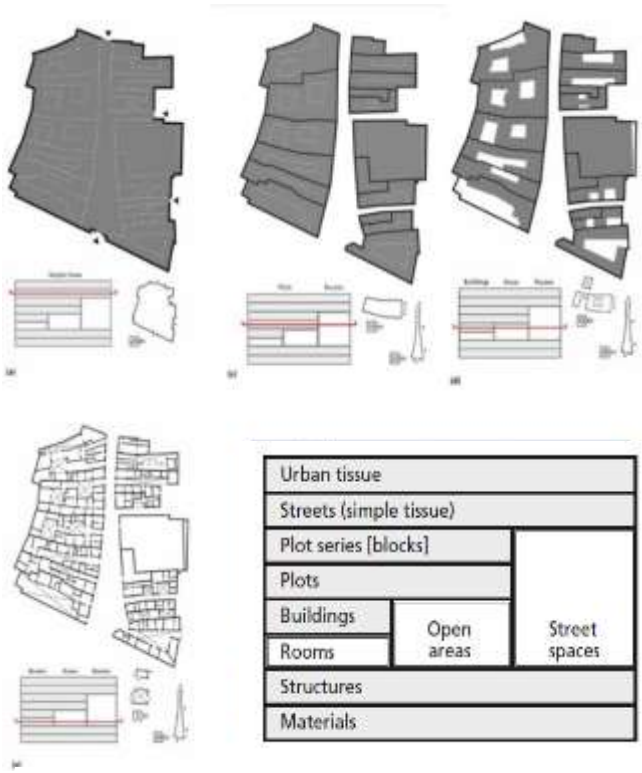


Fig. 1: The multi- level diagram for explaining the urban fabric
Source**:** kropf, 2017)

In hierarchical diagrams, the more we go down, the more details are presented. In each level, each element is defined based on three main features: position in a composition, outline, and internal structure. The place is determined by studying the plan view and identifying the relationship of adjacency with other elements of the same type within a distinct composition one level up the hierarchy. Outline, which is defined by the perimeter lines of each component determine shape (based on geometrical features), size (dimensions), proportions (dimensions ratio), and access points to that element. The internal structure shows the specific type of parts in each component the number of sorts, and their arrangements (Fig. 2).

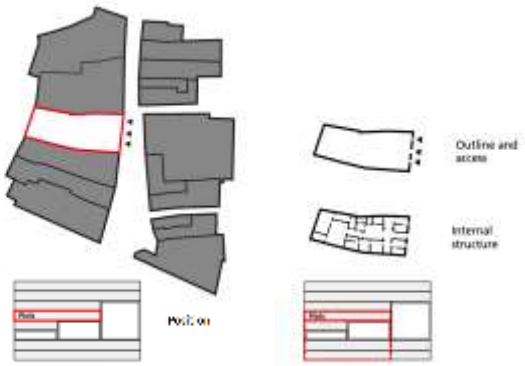


Fig. 1: The three different features for defining specific types of form.
Source: Kropf, 2017.

Street forms can be determined by street network patterns using Stephen Marshall's concept of macroscopic and microscopic street networks as shown in Fig. 3. The Macro-level or Citywide Street network distinguishes streets that are generally continuous over a substantial portion of the city that likely service travel from one part of the city to another and, in many cases, trips to or from the city. The Micro-level or Neighborhood Street network generally serves residential neighborhood travel because these streets are on routes not continuous over a significant portion of the city. Marshall defines four types of Citywide Street network types: linear, tributary, radial, and grid; he then combines this with two Neighborhood Street network types: tree and grid (Marshall and Garrick, 2011).

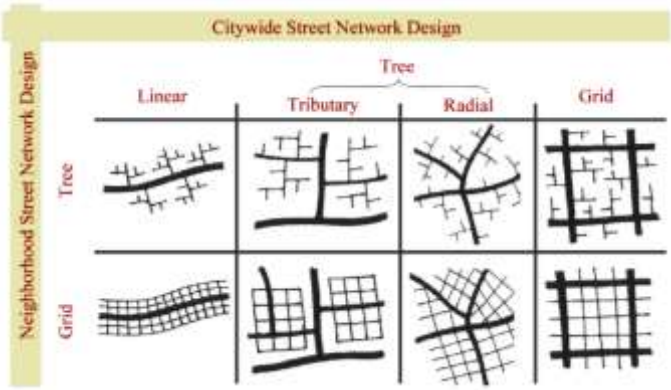


Fig. 3: Street network classification.
Source: Marshall, 2004.

1.3. The Impact of Morphological Elements on Urban Thermal Characteristics

The first impact of urban geometry on the urban thermal environment is a change in radiant heat exchange and convection in space. Urban canyons capture short and long waves, and the heat produced by human activities and their devices increases the temperature of the areas between the buildings (Lee et al.,2017). Urban canyons are one of the most widely used models for describing quantifiable urban features which affect its micro-scale climate (Erell, 2012). Oke (1992) describes an urban canyon street as a basic geometrical unit that can be defined approximately with a two-dimensional section, neglecting street junctions, assuming that buildings along the canyon axis are semi-infinite in length. Erell (2012) describes the geometry of urban canyons with three main features: The first feature is defined as height to width ratio (H/W), which is the ratio of the average size of the adjacent vertical elements (such as building facades) and the average width of the space (i.e., the wall-to-wall distance across the street).). The second feature is the direction of the street axis (urban canyon) which is often described by the closest cardinal rule. The third feature is the Sky View Factor (SVF), which is closely related to an urban canyon's aspect ratio (H/W). Kropf method (2017) was used to describe the morphological features of the study region. This method emphasizes on investigation scale of the city and resolution level in studying position, outline, and the internal arrangement.

2. Review of literature

Many studies have been conducted to explain outdoor thermal comfort. Aghamolaei et al., (2020) has pointed out that the number of research related to interior thermal comfort are more than twice in comparison with exterior thermal comfort in 2018. According to Johansson, the research in local public spaces in residential urban areas is less than research in parks, squares, and pedestrian streets (Johansson et al., 2014).

Different features of urban spaces are studied that effects thermal comfort in these areas. Lee et al. (2017) explains the impact of urban geometry on the building exposure to the sunlight and affect urban thermal environment. Erell (2012) discusses the urban canyons and their geometry that can be defined by three features including height to width ratio, direction of

streets, and the sky view factor. Oke's arguments (1992) have similarity to Erell, that describes an urban canyon street as a basic geometrical feature. Despite remarkable achievement of previous research, these studies explain relations between urban canyon features than urban fabric form with thermal comfort.
In this study, Kropf method is utilized to describe the morphological urban fabric in different scales and find integrated analysis for exploring thermal comfort in open public spaces.

3. Research Methods

3.1. The Research site

Isfahan (51°39' N, 32°38' E) has a dry climate according to Koppen-Geiger's climate classification. The main characteristics of this type are a dry climate and little rainfall in which the maximum temperature is 40.6°C, the minimum temperature is -10.6°C, and the average annual temperature is 16.7°C, as recorded. The number of frost days is 76 days, and the average annual precipitation is 116.9 mm (Kottek et al., 2006). The data taken from Isfahan Weather Station implies that during 64 years (1951 – 2015), January and February have been the coldest months in Isfahan (Isfahan Weather Forecast Organization, 2015). Hashemi Nasab and Ataee (2013) have investigated Isfahan's climate and have identified that cold stress was very high in January. Since most human activities in winter occur during sunlight, data has been collected from 9 a.m. to 5 p.m.

The selected site is the region of Seljuk Isfahan (Fig. 4) which is considered a historical region in today's Isfahan. In this part, there still exists the reminiscent of the ancient city, which has identifiable morphological features related to the traditional city. The changes that have occurred and the formation of new features are observable next to the old city. This provides the possibility of comparing the thermal characteristics of the city with the morphologically different features in the same microclimate.

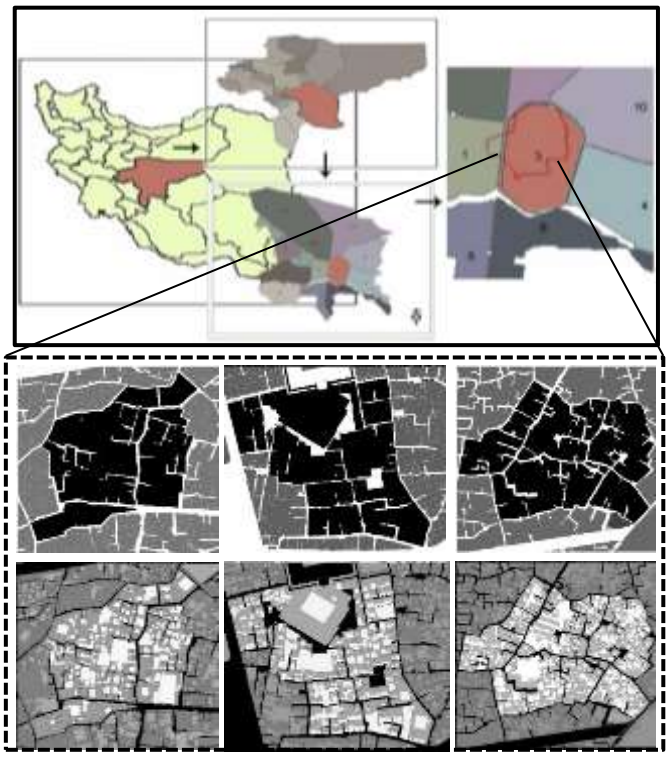


Fig. 4: Location of the study area in the district 3, city of Isfahan in Iran, and three neighbourhoods in this area
Source: Authors, 2022

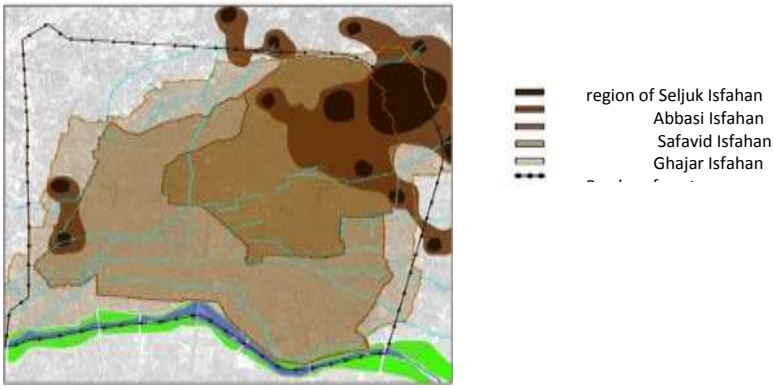


Fig. 2: Historical growth and development of city in Isfahan
Source: Bavand Consulting Engineers, 2003

3.2. Field Study

In this study, the morphological features of the historical core of Isfahan (Seljuk Era) were described using the Karl Kropf approach. As the table 4 shows, three street arrangements were identified. Then, three-zones were chosen in each region; the first zone included the neighborhood, which dominantly has plots with a new pattern. The second neighborhood consisted of plots with an old pattern (mostly courtyards), and the third was a mixture of plots with new and old patterns.

Air temperature, the temperature of the globe thermometer, humidity, and wind speed were measured to examine the impact of the physical characteristics of open urban areas. The field survey was taken in winter from 25th January, 2020; this continued for four days and three times from 9 am to 6 pm. WBGT meter was used to calculate the air temperature (Ta), the temperature of the globe thermometer (Tg), relative humidity (RH), and Humidity/Anemometer type k/j device was used to estimate the wind speed. In this study, streets were identified in four directions: North-South (N-S), East-West (E-W), Northwest-Southeast (NW-SE), and Northeast-Southwest (NE-SW).

To calculate the thermal comfort, Rayman Software 1.2 was used. Mean Radiant Temperature was calculated using the following equation; air temperature, relative humidity, wind speed, and mean radiant temperature were used as inputs in Rayman Software to calculate the PET thermal index. The conditions for estimating thermal comfort in Rayman Software are shown in the Table 1, and the specifications of the other two calculating devices and the measured variables are given in the Table 2.

$$\mathrm{MRT} = [(\mathrm{GT}+273)^4 + \frac{1.1*10^8*\mathrm{Va}^{0.6}}{\mathcal{E}*\mathrm{D}^{0.4}}(GT-Ta)]^{1/4} - 273 \qquad (1)$$

In this equation, MRT is the Mean Radiant Temperature, Va is the air velocity at the globe level, Ta is the air Temperature in centigrade, D is the Diameter of the globe thermometer, GT is the global temperature in centigrade and ε is the emissivity of the globe. This emissivity for the black copper ball is 0.95 (Ashrae, 2010).

Table 2: Input data for calculating thermal comfort in Rayamansoftware
Source: Authors,2022

Place	ESFAHAN					
Georg. longitude	51°40'					
Georg. latitude	32°38'					
personal data	height	weight	age	sex	clothing	activity
	1.75 m	75.0 kg	35 a	m	1.2 clo	80.0 W

Table 3: Measuring variables and devices,
Source: Authors.2022

	Method of capturing data	Accuracy	Name	Unit	Variables
	Manual	0.6°C	Heat index WBGT meter 8778	°C	Ta(Air temperature)
		1.5°C		°C	Tg (Globe temperature)
		3%		%	)RH(Relative humidity)
		0.1 °C		°C	WBGT (Radiant temperature[1])
	Manual	0.1 °C	Humidity / Anemometer Type K/J TEMP Model: AM-4205A	°C	Ta(Air temperature)
		0.1 m/s		m/s	Wind speed

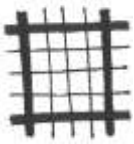
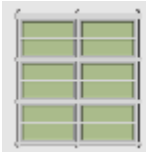
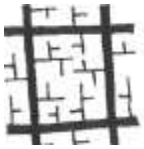
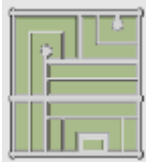
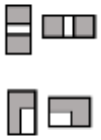
3. Results and Discussion

The field study of this research includes blocks with various dimensions. Parts of this area, especially the region Bazzar (area no. 12), has an integrated texture with large blocks. Smaller blocks can be found in newer regions; even parts of the historical city separated by the streets and next to the main roads. In areas 7 and 18 (near Naghsh-e-Jahan and Emam Ali Square), the blocks whose positions are in the depth of the neighborhood are more. The forms of the blocks in these areas are organic, while geometrical forms can be found in newer regions. Four directions (North–South, East-West, Northeast-Southwest, and Northwest-Southeast) can be found in the streets. Since the historical one, the dominant height in the area has been one and two-floor buildings. The organization's roads are either tributary or a combination of tributary and grid (Table 4).

According to the Marshall (2004) model for streets network configuration, four models can be found in the field study: GG (Grid-Grid), GT (Grid-Tributary), TT (Tributary-Tributary), and RT (Radial- Tributary). G stands for Grid, T for Tributary, and R for Radial. This model shows macro and micro-level of street network. For instance, GT shows that the macro-level street network is grid, and the micro-level is tributary. The first model (GG) is rare in the area studied, while the dominant models are the second and the third. The fourth model can also be found in older parts of the site (areas 6 & 7). The urban fabric pattern is also, categorized into three groups according to the streets pattern. Grid (G), Tributary (T), and mixture of both patterns (M) (table 4).

[1] Wet Bulb Globe Temperature

Table 4: City morphological features and patterns number 2-4 in the Isfahan historical core.
Source: Authors,2022

Number	Streets Arrangement		Urban fabric pattern		Streets Orientation	Plots Pattern
1		GG		G	N-S E-W	 New Pattern
2		GT		M	N-S E-W NE-SW NW-SE	
3		TT		T	N-S E-W	
4		RT		T	NE-SW NW-SE	 Old Patterns

After investigating the scale of block and the urban fabric, the study continued at the scale of plot and its identified points that remained from the older forms of the Isfahan historical core (courtyard pattern); points which had new patterns (with 60% built area) and points which were next to both forms (Table 4). Table 5 shows the specifications of the regions studied. The positions of these areas are depicted in Fig. 6.

Table 5: Morphological features of selected locations.
Source: Authors, 2022

Street orientation	City pattern	Street's arrangement pattern	Aspect ratio in the streets (H/W)			Number of zones
			The point of measuring data is next to the			
			Old plots	Old and new plots	New plots	
N-S	M	GT	1	0.99	0.15	18 (Mevdan)
N-S	M	GT	0.58	0.29	0.83	17 (Malek)
E-W			0.69	0.9	0.16	
N-S	T	TT	0.87	0.3	1.3	13(Ahmad abad)
E-W	T	TT	0.57	0.72		12 (Bazar)
E-W	T	TT	0.58	0.31	0.30	11 (Hakim)
NE-SW	T	RT	0.15	0.8	1	7 (Dardasht)
E-W	T	TT	1.3	1.1	0.36	2 (Ebne sina)
NE-SW	M	GT		0.5	0.36	4 (Kamal)
E-W			0.21			
NW-SE	T	RT	0.65	0.44	0.96	6 (Joubare)

To analyze the data, thermal comfort (which is evaluated by the PET index in this study) has been compared with the morphological elements. The Box and Whisker Diagram has been used for data analysis. This diagram provides more information than other charts and therefore increases the accuracy of the analysis.

Comparing PET in Mixed urban fabric and Tributary one shows that the maximum and minimum of temperature during the day are almost similar in these areas. Moreover, temperature changes are more significant for the Mixed urban fabric in the interquartile range. Thus, during some hours in the day, Mixed urban fabric experiences higher temperatures than the Tributary pattern. The data's median and the temperature average are higher for the Tributary pattern. Both patterns have a lower temperature than the comfort zone (Thermal comfort zone with no stress in PET is 18 to 23 °c according to table 1) (Diagram 1). Since a Mixed urban fabric is newer than a Tributary one, there exist some points in which the ratio of height to width for streets is higher, and as a result, more shadows are available. So colder points in Mixed urban fabrics are more than the Tributary ones. The higher changing range in the Mixed area originates from both the old and the new patterns. The ancient city is more compact and has a higher floor area ratio and lower height, while the new city has less floor area ratio and more open spaces (due to the higher width of the streets).

Perini and Magico (2014) show that a higher floor area ratio leads to a higher temperature. In this study, the Tributary urban fabric absorbs more radiation since it has a lower H/W ratio than the Mixed urban fabric and is expected to have a higher PET. Various studies have examined the relationship between thermal comfort, the mean radiant temperature, and sky view factor (Lai, 2019; Wang, 2014; Taleghani, 2015). From research which investigates the aspect ratio of the urban canyon in a hot and arid climate, it can be concluded that with an increase in height-to-width proportion and a decrease in sky view factor, the temperature decreases; on the other hand, an increase in the sky view factor and decrease in the aspect ratio the temperature will increase (Johansson, 2006).

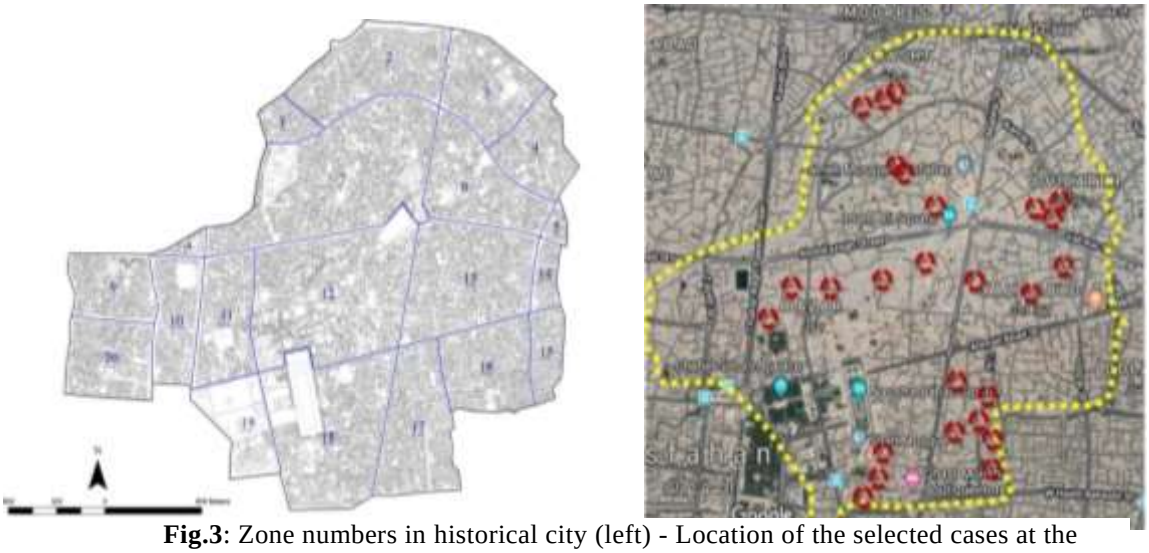


Fig.3: Zone numbers in historical city (left) - Location of the selected cases at the historical core of Isfahan (Right).
Source: Google map image

Analyzing the data captured from the streets in the blocks with old, new, and mixed pattern plots (diagram 2) shows that the temperature change range is higher in blocks with the older plots. This area has a minimum low temperature and a maximum high temperature during a day. Furthermore, the medium temperature and the median of the data are higher in the urban fabric with older plots, and the thermal status in these areas is better. Widening streets in the historical area decreases the aspect ratio in the area studied. On the other hand, where the historical city undergoes less transformation, streets are narrow, and the aspect ratio is higher. This confirms a higher change range in thermal comfort next to the old plots. In points where

the aspect ratio is higher, the shadowing time during the day is higher and the comfort level is lower, while in places with a lower proportion, surfaces absorb more radiation. As a result, the temperature median in blocks with old pattern plots is higher than blocks with the new and mixed paterns plots, thus the comfort level is higher.

Johansson (2006) has studied the geometry of urban canyons in the old and new parts of Morocco. The results show a 6-to-10-degree temperature difference between the deeper and shallow canyons in the hottest day of the year, while in the winter, the surface streets have better conditions since they absorb more sunlight. Diagram 2 shows that blocks with the new pattern plots have fewer temperature changes and higher minimum temperature than other patterns. Thermal comfort in three forms is in the moderate to extreme cold stress range according to ranges of the physiological equivalent temperature (Matzarakis & Amelung, 2008), and it is out of the comfort zone. Only some parts of the data related to the old form are in a comfort zone, and the maximum temperature in the mixed pattern is 19.5°C (diagram 2).

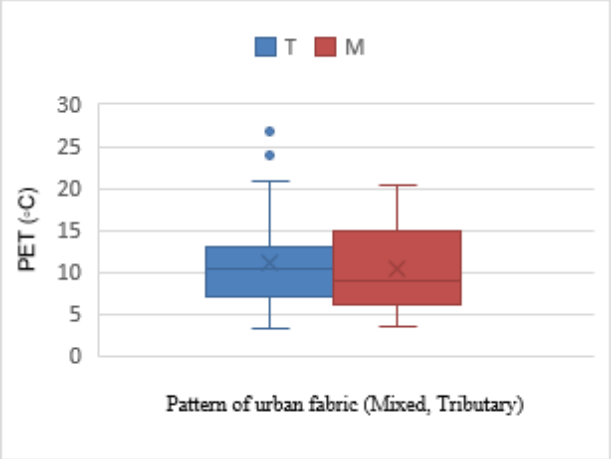
The diagram 3 shows the PET in GT, TT, and RT arrangement. Comparing these data indicates that the change range is higher in the RT organizations. The minimum temperature in GT and TT is lower, and the maximum is in RT. The higher medium and median of the data related to PET in RT organization can be due to street direction, which results in having full sunlight during some hours. In this organization, streets mostly have NE-SW or SE-NW directions which have a full casting shadow in the morning and full sunlight in the afternoon. This fact confirms various temperature ranges in RT organization. NW-SE or NE-SW has the most suitable shadow-casting in summer and winter (Knowles, 1980). In a hot and dry climate with cold winters and warm summers, having shadow and sunlight simultaneously in an urban canyon can fulfill thermal comfort during some hours. Although diagram 3 shows better thermal comfort conditions for RT organizations, the majority of the data in the three organizations are lower than 18° C which indicates low thermal comfort according to the table1.

Comparing PET of streets with different directions in the diagram 4 shows that changes in temperature range are more in N-E and NS-SW directions than E-W and NW-SE ones. Medium and median temperatures are lower in E-W and N-S directions than in others. This fact is also confirmed in other studies (Knowles, 1980). N-S streets cast a shadow on one side during warm seasons, and S-W streets have the least shadow-casting in summer and the most in winter, which can directly impact temperature and create undesirable conditions.

The diagram 4 shows that thermal status is better in the NE-SW streets. The medium and median of the data are higher in these streets, and part of the data is in the comfort zone. However, most data for other directions are out of their comfort zone and in the moderate to extreme cold stress range.

The impact of the streets aspect ratio on PET, has been categorized into two groups: 0-0.5 and 0.5-1 (diagram 5). The data comparison shows that both groups have similar max, min, and medium temperatures. Roads with an aspect ratio of 0.5-1 experience more changes between the first and third quartiles. This means that they have lower temperatures during the cold hours and higher temperatures during the warmer hours. In spaces with a proportion of 0-0.5, the median of temperature is 0.5 degrees lower than the streets with a proportion of 0.5-1 (against what is expected from the spaces with a lower aspect ratio); regarding the low height of these spaces, this can be the impact of wind flow which is more in the areas more open to the sky. The H/W ratio in streets can be considered the main factor in wind flow and ventilation (Ali-toudert and Mayer, 2006; Nakamura and Oke, 1988).

Taleghani (2015) points out that the increase in space openness will increase wind flow. Similarly, Wang and Akbari (2014), using a simulation method in Canada, concluded that the wind speed in shallow street canyon (SVF=0.85) is 2.5 m/s, while in a deep street canyon (SVF= 0.3), it is 0.5 m/s.



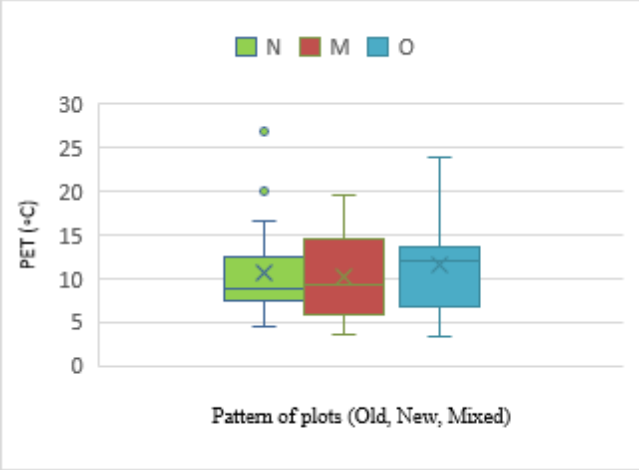
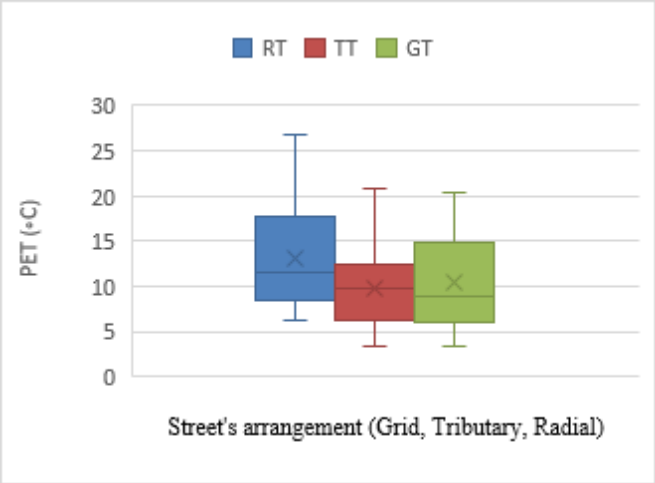


Diagram 1: Thermal comfort according to the type of urban fabric (Mixed and Tributary) (Left), Diagram 2 Thermal comfort according to the pattern of urban plots at each point of capturing data (New, Old, Mixed) (Right),
Source: Authors,2022



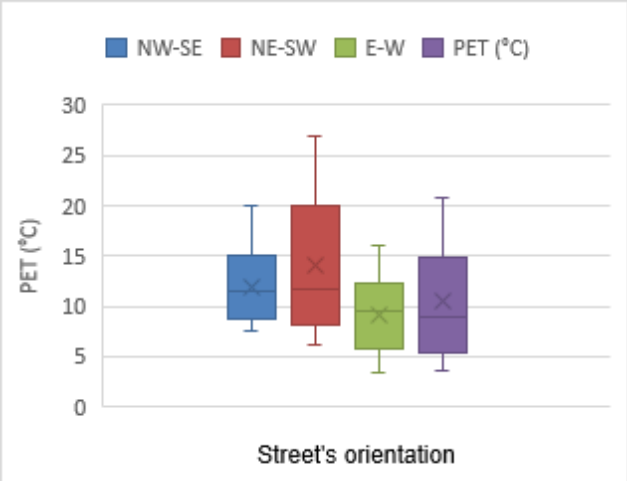


Diagram 3: Thermal comfort according to the type of streets arrangement (Radial-Tributary, Tributary-Tributary, Grid- Tributary) (Left), Diagram 4 Thermal comfort according to the street's orientation (Right), Source: Authors,2022

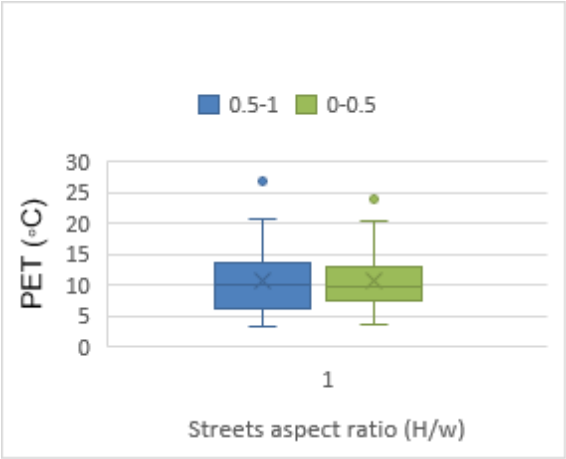


Diagram 5: Thermal comfort according to the street's ratio
Source:Authors,2022

Conclusions

This research shows that thermal comfort can increase the quality of local public open spaces and help them become more vital. Isfahan's historical urban fabric has a different morphological character than the new parts of the town. It helped this research to assess thermal comfort in the same microclimate with different morphological features. patterns of urban plots related to blocks and urban fabric features such as urban fabric patterns, streets organization and direction, and aspect ratio in the streets have been studied to investigate the relationship between urban morphological features and thermal comfort in Isfahan's historical core. The Kropf hierarchical structure method helped to evaluate the field study's urban morphology.

The research shows that the morphological elements impact casting shadows on the streets, increase the level of exposure to direct sun, and result in thermal comfort. The data showed that thermal comfort was better in the urban fabric with a mixed organization than in a tributary organization. The thermal status of the streets next to the old plots was better than the streets next to the mixed plots and mixed plots had better thermal status than plots with new patterns. Thermal comfort is higher in RT than GT and TT arrangements. In NE-SW, NW-SE, N-S, and E-W directions, thermal comfort has better conditions, respectively. Thermal stress on the streets with an aspect ratio of 0.5-1 was lower than 0.5-1.

The results of this study indicate that the temperature for the three organizations of the urban fabric in the field study is lower than the comfort zone, and it is located in a moderate to extreme cold stress zone. Although providing a solution for the hot and dry climate, which has cold winters and warm summers, seems to be a difficult task, considering the local public spaces, which have various morphological features, there is a need to provide more flexibility and adaptability with climate during both the seasons.

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