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Original Research Article

Examining the Impact of Thermal Comfort on the Desirability of Spatial Territorial Formation (Case Study: Saf (Sepahsalar) Pedestrian Street, Tehran)*

Elham Shahabi[1], Yaser Shahbazi[2**], Azita Balali Oskui[3]

1. Ph. D. Candidate, Department of Architecture, Faculty of Architecture and Urbanism, Tabriz Islamic Art University, Tabriz, Iran.
2. Associate Professor, Department of Architectural Technology, Faculty of Architecture and Urbanism, Tabriz Islamic Art University, Tabriz, Iran.
3. Full Professor, Department of Architecture, Faculty of Architecture and Urbanism, Tabriz Islamic Art University, Tabriz, Iran.

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Abstract:

Problem statement: Humans are inherently social and require personal space to maintain comfort, both individually and in groups. Territoriality is essential for structuring one's environment and expressing identity. Defining territorial boundaries is a key step in placemaking and spatial identity. Understanding how territoriality forms involves examining theoretical indicators. Among these, thermal discomfort can cause a sense of congestion and influence how people define their space. This research investigates how thermal comfort impacts spatial territoriality, using public space as the study context due to its limited options for personalization.

Research objective: The purpose of this research is to validate the hypothesis that thermal comfort, a territoriality prerequisite in human environments, is a determining factor of spatial territorial formation desirability. It also explores the underlying values of indicators of territorial formation in the case study environment.

Research method: The present research is based on an inductive methodology and adopts a mixed-methods research design. The metrics regarding territorial formation and the underlying theory were established through qualitative data collection and an extensive literature review. The research incorporates thermal comfort simulations based on the Universal Thermal Climate Index (UTCI) for identifying thermal comfort zones within given territories. In response to the research question of how people prefer thermally uncomfortable spaces as attractive territories, a comparative analysis was conducted using both direct tracking and saturation sampling approaches. The findings show that users interact with thermally uncomfortable areas. The research goes further beyond these findings by trying to uncover the underlying meaning of indicators of territorial construction through a one-sample T-test, and it also examines gender differences using an independent-sample T-test.

Conclusion: As opposed to the initial study hypothesis, the study findings reveal that the preferred areas of the case study participants are not thermally comfortable. The T-test also shows gender differences in relation to the perceived importance of signs of territorial formation.

Keywords: *Territoriality, Thermal Comfort, Public Space, Desirability Assessment, T-Test.*

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**Corresponding author: 09123084072, y.shahbazi@tabriziau.ac.ir.

Introduction

The existence of human beings and what individuals do are fundamentally connected with how they perceive spatial relationships. This perception is founded upon an integration of various sensory cues, such as visual, auditory, kinesthetic, olfactory, and thermal sensations (Hall, 1967,67). The urban environment is a living and dynamic phenomenon that continues to grow and change, with its physical form being the body, and its very nature being personified in its inhabitants and their social life. Since urbanization developed so rapidly over recent years, the way that public areas look has become even more significant. However, for some people, engaging in these spaces is associated with terms like "disorder," "disruption," and "chaos." It is therefore essential that urban planning takes serious heed of the spatial nature of these environments.

According to the "Theory of Spaces of Being," the built environment is an essential framework for the conception and meaning-making of environments and thus for advancing the full human comprehension of being (Norberg Shulz, 2010, 136). In the pursuit of making space a desirable place, it is essential to establish the most influential factors that shape spatial territoriality. To render a space desirable, it is first necessary to offer a properly demarcated and acceptable territorial framework, thereby alleviating the issue individuals have in delineating their own spaces.

Within the spatial roles and the interaction of individuals with their capacity to make their environment adaptable, public spaces provide minimal scope for changes initiated by the users. This suggests that the built environment, especially regarding public spaces, must be intrinsically human-accommodating and support the process of space turning into a valuable and interactive place. Moreover, public spaces play a significant role in determining the experience and interaction of individuals with the urban environment, both socially and physically. An improvement in the quality of public spaces not only stimulates human mobility but also results in additional psychological comfort experienced by individuals in such environments (Pakzad, 2007, 121). Since personal space and territorial behavior—fundamental mechanisms for attaining privacy—satisfy fundamental human requirements such as security, self-actualization, and self-esteem, the incorporation of territorial concerns in the design of public space is necessary to heighten their quality and facilitate users' sense of belonging.

Research Background

It has seen extensive research focused on experimental and field studies of human behavior, such as interaction patterns, space guarding, seating location, and personal space (Altman, 2003, 24). Work by Rapoport (Rapoport, 1977,69) and Altman and Chemers (1980) provides a comprehensive explanatory framework for privacy mechanisms, territoriality, and personal space across cultures and geographical locations (Esmaeili et al., 2019, 72). Individuals use verbal, nonverbal (body language), environmental, and cultural norms to achieve optimum privacy (Altman, 2003, 17). The groundbreaking research by Edward T. Hall (Hall, 2011) was derived from field observations and studies of human behavior with respect to interpersonal distances, developing the idea of psychological comfort. A few other researchers viewed privacy as a source of reflection, interpretation, and contemplation (Chapin, 1951; Chermayeff & Alexander, 1988). Privacy research can be explained in terms of three approaches: 1) human factors emphasis, 2) environmental factors emphasis, and 3) an emphasis on their interaction (Nakhjavani et al., 2021, 78). Privacy is influenced by human and environmental factors with some indicators for interaction in each. Personal variables include interpersonal skills, culture, age, and gender (Lang, 2002; Hall, 2011). Environmental factors include enclosure, semi-open spaces, lighting, etc. (Mohammadnia Qaraei et al., 2017, 32). Physical variables (such as scale, location, and climatic variations) can cause the sensation of overcrowding

(Asadpour, 2022,197). When the built environment fails to meet the need for optimum privacy, individuals exhibit verbal or nonverbal behavior (ibid , 206). Research shows that privacy needs are as fundamental as other physiological human needs, and their fulfillment leads to self-evaluation. Territoriality and personal space are the two most significant mechanisms for operationalizing privacy in static and dynamic environments (Shariatifar & Shakouri, 2020, 35). Although concepts like privacy, territoriality, personal space, and crowding have been widely discussed across various scientific fields, their analysis in urban settings is far from exhaustive. The literature review puts into perspective the significance of social and cultural contexts for user meanings and experiences of spaces (Daneshpour, & Charkhchian, 2007, 23).

Additionally, personal traits, personal tastes, levels of satisfaction, and interactions with others and with environmental attributes play an important role in territorial perception (Macedo et al., 2021, 667). Open urban spaces have several advantages for big city populations. As better thermal comfort in open spaces contributes to enhanced urban quality of life, several studies have attempted to advance knowledge on this topic (Lai et al., 2020, 145). With the complexity of outdoor thermal comfort influenced by a myriad of factors, prolific research has examined both direct influences (physical, physiological, and psychological factors) and indirect influences (behavioral, personal, social, cultural, thermal history, and site-specific factors). Most of the research has shown that radiation is a more important parameter than wind speed, even though work in temperate climates indicates that wind speed can sometimes have a more important role to play (ibid. 202). While microclimatic factors such as radiation and wind have dynamic directional characteristics, their impact on thermal comfort has not as yet been satisfactorily dealt with (Ouali et al., 2019 ,105). Culture has a profound impact on the behavior of residents and their subjective evaluations of open spaces. These effects are shaped through cultural norms and national characteristics.

Research Questions

The research questions are as follows: Are territories without thermal comfort also appealing to users? How are the main indicators' values for territorial formation defined for users?

Theoretical Foundations

This research applies content analysis with a library-based approach to derive the main indicators of territory creation from the environment. Thermal comfort is theorized, based on the literature review, to be a requirement for the production of a good territory by the users. The research will verify this hypothesis through simulation and thermal comfort analysis in the case study.

There has been an increase in the need for passive urban microclimates everywhere with urbanization. Consequently, there has been an increasing trend towards modeling and mapping these microclimates (Arens et al., 2015, 58). The relative lack of full-scale approaches to quantify outdoor comfort is because of the complexity of simulating several outdoor comfort factors. In particular, outdoor settings are defined by changing wind speeds with complex flow patterns that occasionally require computational fluid dynamics (CFD) simulation. The settings also require precise radiative transfer calculations due to the thermal heterogeneity of urban surfaces (Webb & Weber, 2003, 55). Moreover, macro-scale climatic parameters exert impacts such as the urban heat island (UHI) effect where urban surfaces are several degrees hotter than surrounding rural surfaces. These heat island phenomena are often not considered in indoor environment simulation but become very important when a region is exposed to the outside air (Bueno et al., 2013, 478).

Several outdoor thermal comfort criteria have been proposed during the last decades, most of them incorporating some climatic indicators such as humidity, wind speed, or direct sunlight.

Hence, the most appropriate and broadest outdoor comfort parameter to select in this study is of utmost importance. The Universal Thermal Climate Index (UTCI) was employed as the "perceived temperature" benchmark used by meteorologists all over the world (Jendritzky et al., 2007, 510). The first step in the formulation of thermal comfort conditions is the investigation of the climatic parameters of the study area. For studying urban-scale thermal comfort conditions, meteorological data—like sky radiation, solar radiation, air temperature, relative humidity, wind speed, and direction—were combined with urban data to formulate the UTCI index.

Here, meteorological data recorded by the Mehrabad Airport weather station in Tehran are utilized to estimate climatic indices. Tehran has been selected as the study region due to its high thermal comfort variation during the year. In addition, the heterogeneity of the urban area at the Saf (Sepahsalar) walkway corridor and its transformation into pedestrian areas resulted in heterogeneous urban microclimates (Ranjbar & Rais Esmaeili, 2010, 45). A geometric model of this place was produced with spatial data provided by Tehran Municipality in Rhinoceros 3D (version 7). To enhance modeling accuracy, particularly in the case of transparent building facades, field surveys were conducted.

The Universal Thermal Climate Index (UTCI) is used in this research as the primary factor for evaluating outdoor thermal comfort. Since UTCI takes into account climatic factors (temperature, humidity, wind, radiation) and human factors (metabolic activity, clothing) simultaneously, it is a suitable tool for analyzing urban microclimates. In the current research, as shown in Fig. 1, the initial step consisted of a simulation-based analysis for examining the thermal comfort spatial zones. In the second step, through direct tracking and saturation sampling approaches, a comparative study was carried out between the zones pointed out by the participants as preferential areas and the zones that were found to be thermally comfortable through simulation. Having determined the advantageous areas that are devoid of thermal comfort, the research went ahead and determined the relative importance of each environmental factor in those areas by performing the T-test. A one-sample T-test was applied with a view to testing the concealed significance and impact of the factors on territorial development. An independent samples T-test was employed when testing differences by gender.

Theoretical Foundations

- **Spatial Territory**

Human beings, as natural beings, establish territories and boundaries to separate themselves from the rest and, in the process, establish a comfortable space for themselves. Territorial behavior is one of the mechanisms through which the borders between oneself and other individuals are kept in check, social relationships are permitted to occur through controlling social contact, and conflict and miscommunication are prevented. Territory also encompasses a broad

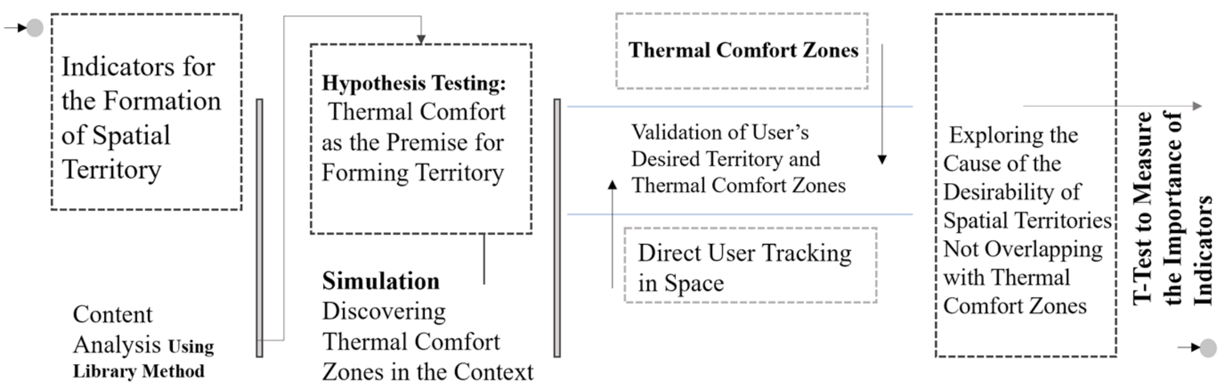


Fig. 1. Conceptual Diagram of the Research. Source: Authors.

range and must utilize the space and objects within the environment. Territorial behavior becomes increasingly complex in the process of time and space and mixes with other behaviors to create more complex action patterns (Altman, 2003, 129-130). What must be noted is that while the "need for territory is innate, so is the need to defend it. Individuals learn to mark off the area and boundaries of the territory, though.". When a human shares a territory with a partner or with a group, he or she learns who to accept and who to exclude from his territory" (ibid. 136). The concepts proposed by Hall have been studied and criticized, and years after, the results of proxemic research were developed further by Irwin Altman. Altman, psychosocially, relied on four terms—privacy, personal space, territory, and crowding—on which he based individual and social behavior toward the environment. He identified the terms from many experiments conducted by Edward T. Hall and created proxemics as a fundamental discipline to comprehend human environmental behavior (Aliawder & El Wakeel, 2022, 197). Here, we provide a brief definition of these concepts to set the stage for the development of common territory. Privacy, personal space, and territoriality are all human universals, and they are linked to the fulfillment of other needs such as security, self-actualization, and self-esteem (Lang, 2002, 415). The spatial relationship of man with the environment is framed by the concept of territory by its dimensions which are illustrated in Fig. 2. The major six factors on which the definition of territory largely depends are physical, functional, social, perceptual/psychological, cultural, and temporal. There exist some factors associated with the mental space and other factors related to the physical space. The role of all such factors is not the same. The geographical/cultural aspect is the background for the other aspects, while time, not only due to the duration of the establishment of the territory, has the greatest impact, but also serves as a background for the other factors that influence (Eieni Far & Agha Latif, 2011, 14).

• Spatial territory formation; environment-dependent indicators

Altman defined personal space and territory as two mechanisms for providing the user's optimal privacy in space, as depicted in Fig. 3. Personal space and territory vary mainly on the grounds that, first, "personal space" is mobile and accompanies the person from one place to another. This space unfolds around the person in both rest and movement and is idea-based, whereas territory is relatively more fixed. Second, a human or animal regularly marks out their (territory) and makes it something that others can feel and know. In other words, the individual places him/herself in a clearly demarcated "territory" and is fully present to others (Bannerman & Orasch, 2020, 22). In contrast, the boundaries of "personal space" are unperceivable and intangible, and influence individuals' interactions in a non-verbal manner. Thirdly, "personal space" revolves around the individual's body, whereas territory does not depend on the presence of the body. Whether or not the individual is present, the territory

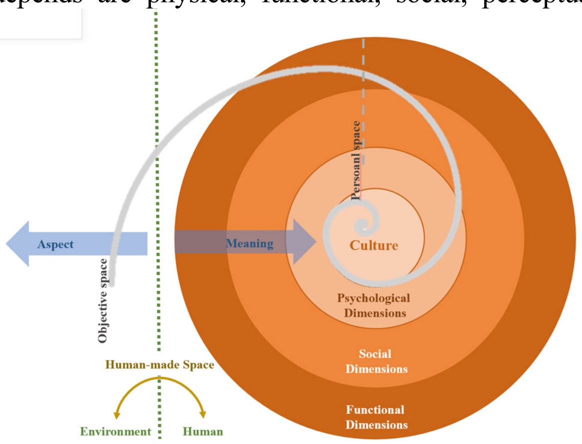


Fig. 2. Dimensions of Territory and the Impact of Space Nature on the Indicators of Territory Formation. Source: Authors.

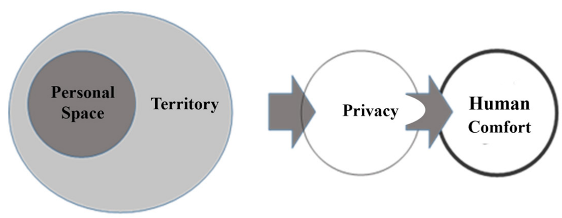


Fig. 3. Psychological Comfort Attained through the Privacy Index. Source: Authors based on Altman.

remains intact (Bahraini & Tajbakhsh, 1999, 25). Therefore, territory depends on physical space and immovable, while personal space depends on the user and dynamic.

Observing human conduct in spatial scenarios, it has been observed that individuals display non-verbal indications to mark out their territory in different ways (such as arranging the body to avoid eye contact or engaging in acts like reading a book or looking at a mobile phone) (Hall, 1997, 97). For territory, we have two types: territory as a product of the environment and territorial behavior as the user's reaction to the environment. Fig. 4 indicates that in public space design, spaces allocated for short- and long-term stays of users, where the user remains stationary in space, are considered spatial territory.

To analyze the environmental indicators of the construction of spatial territory, the indicators related to the environment have been elicited in Table 1 by going through the literature. According to the research findings, the significance of each of the elicited indicators is shown in Fig. 4.

Table 1. Extracted Parameters Derived from Scholars' Perspectives in This Field. Source: Authors.

Variables	Parameter source	Researcher
Distance	Six Defined Distances in Urban and Public Spaces	Sadahiro (2008)
	Four Types of Distance in Social Relations by T. Hall	Hall (1966)
	Iranians like to be farther away from strangers and superiors (e.g., their boss) and closer to acquaintances and inferiors.	Mortazavi (2001)
	T. Hall's research demonstrates that Arabs would find it insulting to stand at a great distance from one another.	Hall (1966)
	Due to the high population, the Japanese are tolerant of bodily proximity despite a desire for greater space.	Hall (1966)
	Creation of territory through physical markers and signs (e.g., walls, fences, dividers, etc.) or by demonstrating conceptual moves (e.g., backing off, etc.) is one way in which crowding can be overcome. Each individual naturally and instinctively moulds this in accordance with his or her own individual motivation and frame of mind.	Shahcheraghi & Bandar Abadi (2023)
	Territorial boundaries among people vary immensely in size and place.	Lang (1970)
	Individuals attain interpersonal balance in terms of distances by adjusting their individual optimal spatial boundaries with others.	Edney (1979) Shahcheraghi & Bandar Abadi (2023)
Degree of Enclosure	The Japanese always try to place the view of foreigners within their patterns.	Hall (1966)
	Research on the adjacency model in Germany indicates that stares and eye contact from strangers are not defined for Germans and can be interpreted as intrusive.	ibid (1966)
	Efforts to monitor a space.	Lyman & Scott (1967)
	The need for territory has been explained in terms of mechanisms for regulating one's own boundary and others' boundaries.	Sommer (2008) Ardrey (1966) Altman (1972)
	Territory is a frontier that one, a family, or other societies own.	Sommer (2008)
	Reactions to encroachment and efforts at space defense vary in intensity. These reactions comprise complete alertness, creation of aggressive and pointed signs, verbal and non-verbal cues, departure from the place, or establishment of markers in the environment for physical boundary and separation.	Altman (2003)
Angle of Orientation	The presence of individuals and their eyes and looks are acceptable to Arabs and increase their sense of control over space.	Hall (1966)
	The introduction of unfamiliar faces in the Germans' country disturbs and perturbs their state of tranquility.	Hall (1966)
	The presence of strangers annoys the English, yet knowing that they can see what is going on around them reassures them.	Hall (1966)
	Americans require a controlled and delicate form of gazing.	Hall (1966)

Variables	Parameter source	Researcher
Flexibility	The environment can have both a "gathering" and a "dispersing" quality, allowing for communication with others as one wishes, but also providing space for oneself when one does not wish to interact.	Shahcheraghi & Bandar Abadi (2023)
	T-Hall's research revealed that movable and adjustable chairs, used for distance control, are experienced by Germans as arrogance and rudeness that invade their psychological comfort. Americans value such flexibility highly, though, and find it pleasing.	Hall (1966)
	In spatial areas, the specified area briefly alters its status and is dependent on time.	Lang (2002)
Hierarchy and Zoning	This is a subtle remark to the effect that the environment could be "socializing," that is, making individuals feel compelled to be around others, or could be "anti-social," where individuals enjoy their own company.	Shahcheraghi & Bandar Abadi (2023)
	The boundaries and hierarchy between areas should be maintained. The joints between consecutive or adjacent areas, their degree of separation, and their precise interaction with each other should be clearly defined.	Shahcheraghi & Bandar Abadi (2023)
	There is a hierarchy of spatial structure, hierarchy of access, and hierarchy of space in public and private space to be considered.	Bahreini & Tajbakhsh (1999)
Thermal Comfort	Overcrowding is sometimes created by a surplus of sensory stimulation in the environment. (Heat, offensive noise, and air pollution may be contributors to the perceived surplus of people.)	Shahcheraghi & Bandar Abadi (2023)
	In different places, physical comfort is achieved by emphasizing privacy and territoriality.	Lang (2002)
	Changes in weather conditions and thermal discomfort could also lead to the perception of crowding in the user.	Asadpour (2022)
Form Quality	Attention to furniture design in establishing "territory" and "personal space" in urban planning, landscape architecture, architecture, and interior space is necessary.	Shahcheraghi & Bandar Abadi (2023)
	The Japanese prefer to use natural materials and trees to define the stranger's perspective in their architecture.	Hall (1966)
	The openness of space (open, semi-open, and closed) could influence the appeal of the spatial area.	Davy (2020) Shariatifar & Shakouri (2020)
	Variations in quality and preferred shape of space are purely a personal issue.	Lang (2002)
	Legibility, one of the most critical elements of responsive environments, is the characteristic that makes a whole space comprehensible. It becomes significant in both spatial arrangement and activity patterns, increasing the human perception of territoriality.	Bemanian et al. (2021)

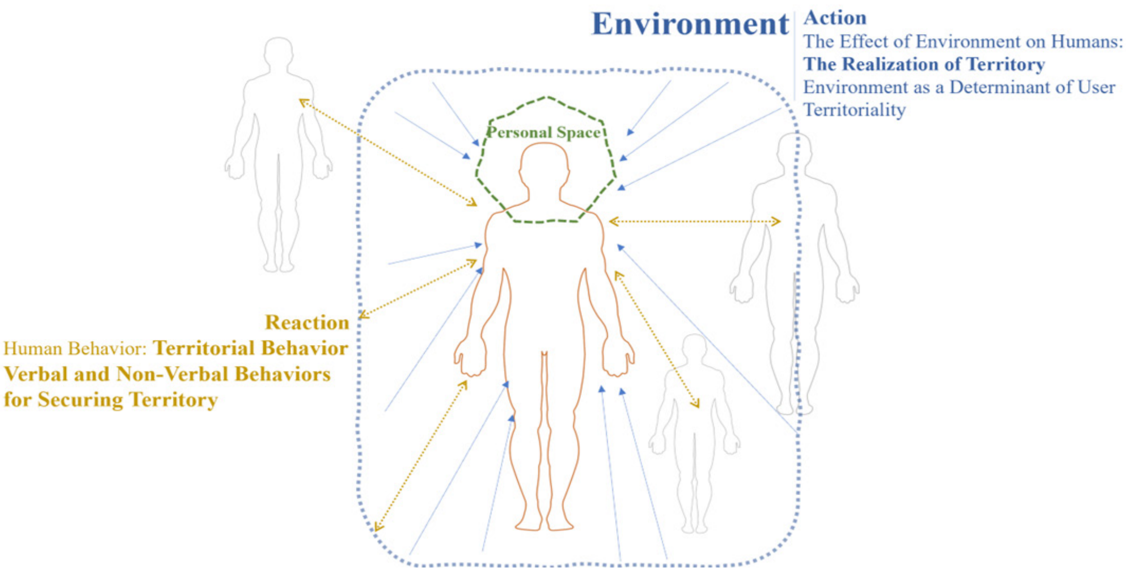


Fig. 4. Human-Environment Relationship Considering Territory and Territorial Behavior Concept. Source: Authors.

• Research Method First Step: Identifying Thermal Comfort Zones

The method proposed here for simulation within this research is a "hybrid" method, in which every urban thermal comfort parameter is simulated by an exclusive simulation engine. The current research employed the UTCI (Universal Thermal Climate Index) as the main reference for assessing outdoor thermal comfort. This index, given its factoring in both climatic variables (temperature, humidity, wind, radiation) and human (metabolic activity, clothing), is a good instrument for investigating the microclimate of cities.

The hybrid strategy used (i.e., combining the simulation environments EnergyPlus and OpenFOAM) is designed to accurately capture the complex behavior of climatic and urban parameters. This approach ensures that output is internally consistent (e.g., the EnergyPlus surface temperature output is used as input to OpenFOAM). To use in comparison to similar studies (e.g., Coccolo et al., 2016), the use of reference station data for urban simulations is dominant. The climate datasets utilized in the current study were retrieved from Mehrabad Airport as a result of its geographical position close to the case study site (approximately 8 km distant from Sepahsalar Street) and a 10-year (2010-2020) time series at hourly intervals.

Case Study

The city of Tehran has been selected in this study as a location where outdoor thermal comfort is remarkable due to its temperature range throughout the year. Moreover, the heterogeneity of the urban environment in Sepah Street (Sepahsalar pedestrian way) and traffic conversion into pedestrians have led to the establishment of various microclimates in the urban space (Ranjbar & Raees Esmaili, 2010). A 3D geometric model of this area was created with the spatial data of Tehran municipality using Rhinoceros 3D software version 7. For getting the properties of the wall materials, the library of the simulation engine was used. Also, to have a more accurate modeling process, especially for the transparent building facades, field surveys were conducted. Factors such as vegetation cover (density of plants, plant height, and shading coefficient, as per Lin's research, 2020) and material characteristics (thermal absorption coefficient (α) and emissivity (ε) of floor and façade materials, as per ISO 6946 standards) were quantitatively integrated into the 3D modeling.

Climatic Data

•Dry temperature and relative humidity

Based on the hourly temperature graph of Tehran Fig. 6, the average air temperature in Tehran during a month is within the thermal comfort zone only for a few months of the year. According to this diagram, the average monthly air temperature in Tehran falls inside the thermal comfort zone for only May, June, and September. However, the average temperature within the comfort zone does not mean that the temperature in these months is within the comfort zone, as maximum and minimum temperatures, and even parts of the temperature range of each month, are beyond the thermal comfort zone. This is mainly due to the great temperature variation during the day, and the primary reason is the low relative humidity of this city. Fig. 5 demonstrates the fluctuation in relative humidity throughout the various months and hours of the day. The relative humidity of Tehran is as high as 79% in December and as low as 38% in July Fig. 7. To model urban surface temperatures, the Energy Plus simulation engine was used. More specifically, full external radiation with reflection was used to alter solar distribution. Additionally, to calculate accurately, a 15-minute time step was used to create a certain ratio of solar energy for every urban surface.

• Wind

According to Tehran's wind rose Fig. 8, the prevailing wind in Tehran is westerly. However, the simulated wind speed in the urban area is derived from the statistical analysis of the data from the meteorological stations, and the simulated speed is the average speed in that direction.

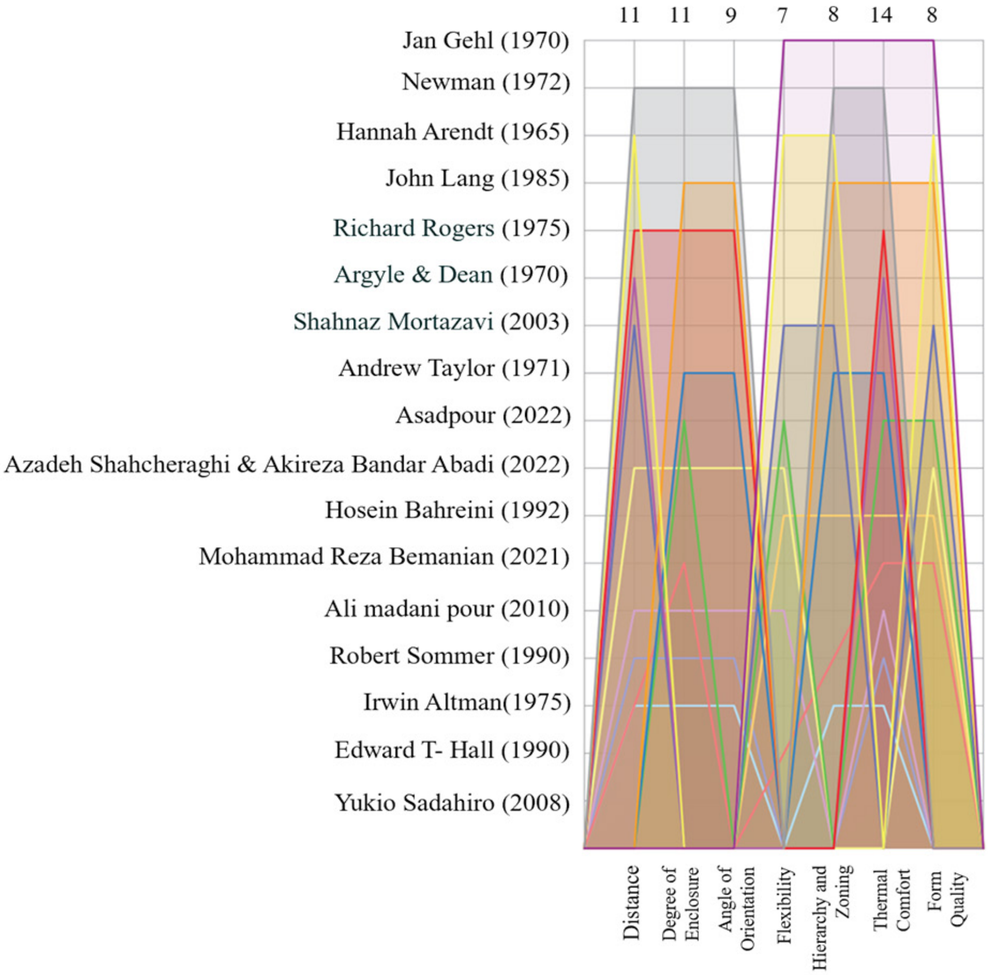


Fig. 5. Measuring the Importance of Parameters Based on Researchers' Theories. Source: Authors.

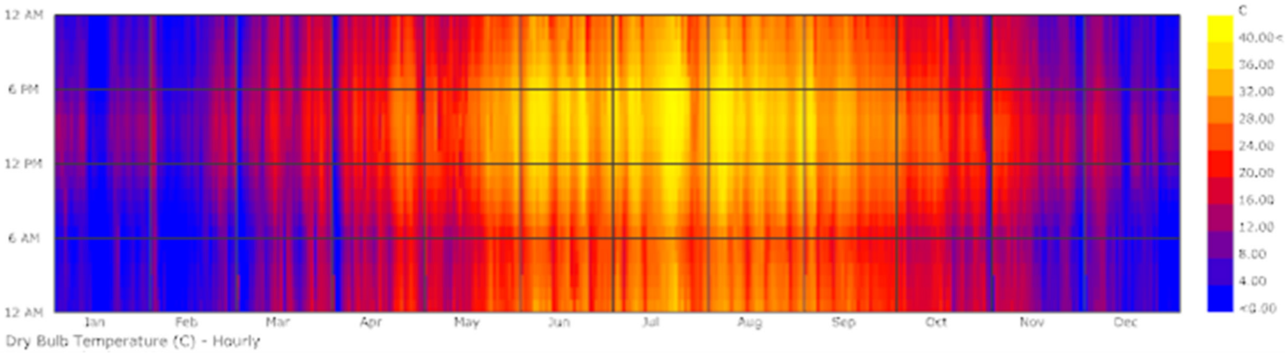


Fig. 6. Dry Air Temperature of Tehran. Source: Mehrabad Airport Climatic Data: Ladybug Tools.

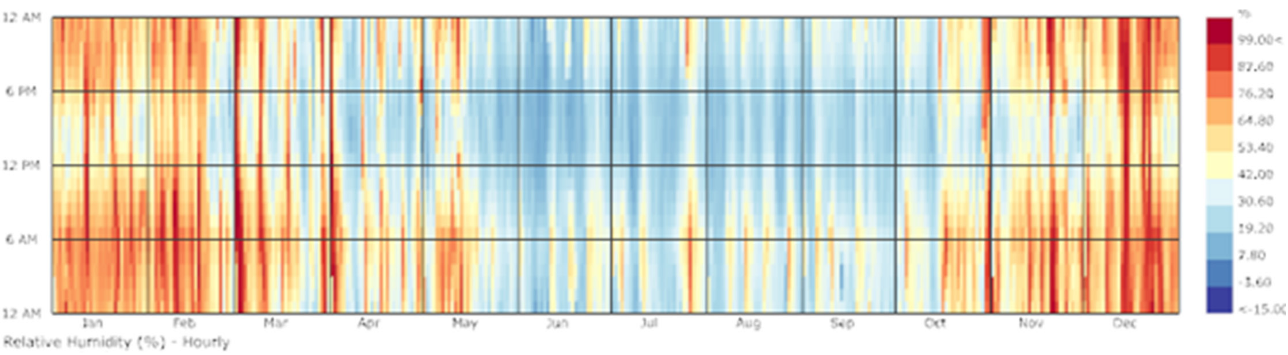


Fig. 7. Relative Humidity of Tehran. Source: Mehrabad Airport Climatic Data: Ladybug Tools.

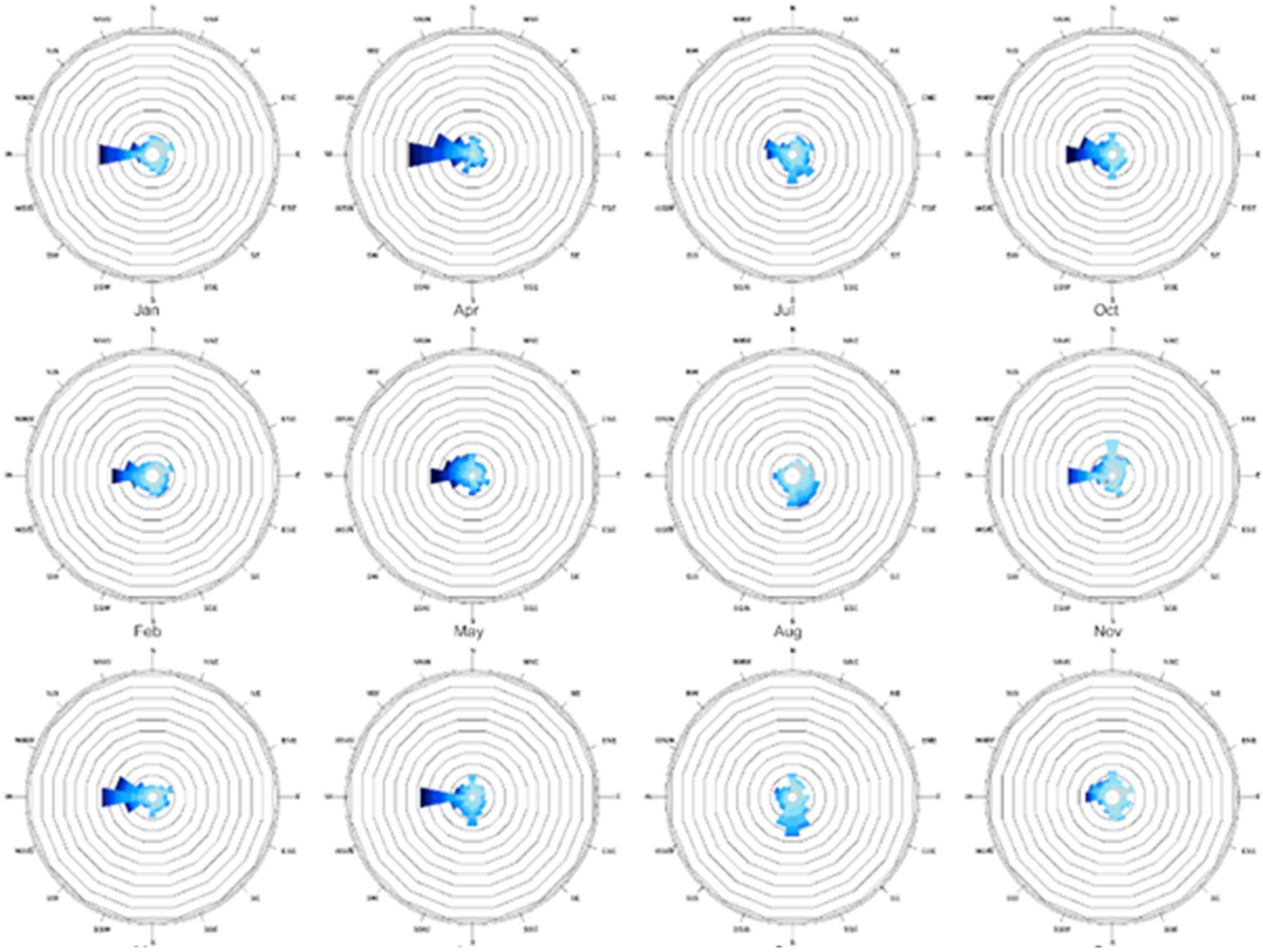


Fig. 8. Wind Rose of Tehran. Source: Mehrabad Airport Climatic Data: Ladybug Tools.

• Sky and Sun conditions

Solar diagrams of Tehran Fig. 9 indicate when shading devices are necessary within the climate of the city. The highest solar altitude angle during Tehran's long summer days is approximately 78 degrees, which is a high angle for solar radiation. Under this high solar altitude, the sun's rays hit the horizontal building surfaces almost vertically at noon in summer. Furthermore, the simulated sky dome conditions of Tehran Fig. 10 show that the peak amount of radiation in Tehran is 62. 11 kWh per square meter. However, the peak direct solar radiation is only 44/ 94 kWh per square meter. Ladybug Tools software suite was employed for the simulation of solar radiation in the urban environment. • Thermal Comfort: After the simulation of climatic data in the urban environment for 8760 hours of the year, data were combined using the Ladybug Tools suite to derive the Universal Thermal Climate Index (UTCI).

• Thermal comfort

With the simulated climatic data available in the urban environment for 8760 hours of the year, the data were combined with the Ladybug Tools suite to derive the Universal Thermal Climate Index (UTCI). These data were classified for the final analysis between the ranges of very hot and very cold. According to the outdoor thermal comfort chart Fig. 11, in the selected urban area, about 26% of the year, the temperature is within the thermal comfort zone. Additionally, about 41% of the year, the temperature in the area is below the lower boundary of the thermal comfort zone, while in 33% of the year, the temperature is higher than the upper boundary of the thermal comfort zone.

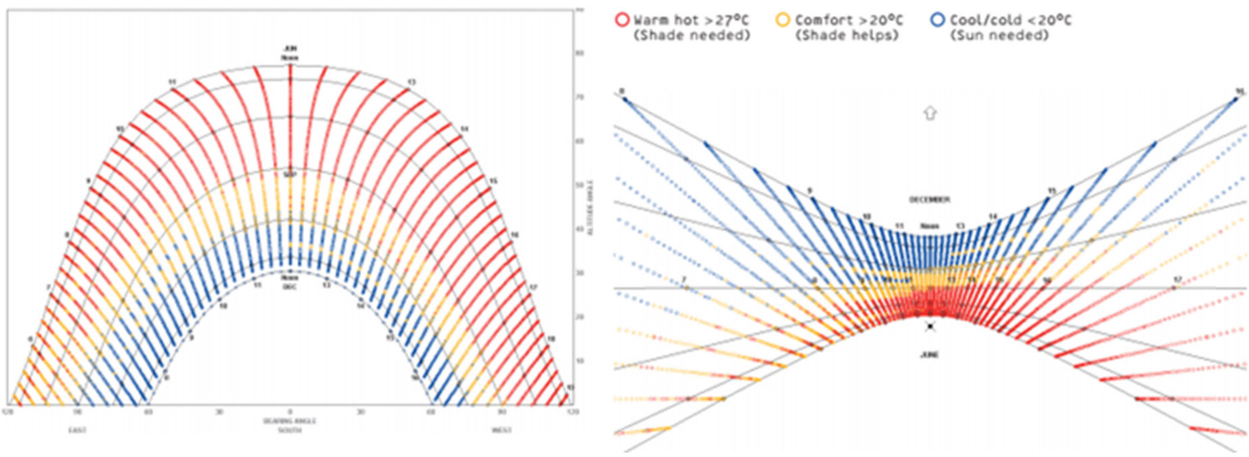


Fig. 9. Solar Diagrams (Source: Mehrabad Airport Climatic Data: Climate Consultant)

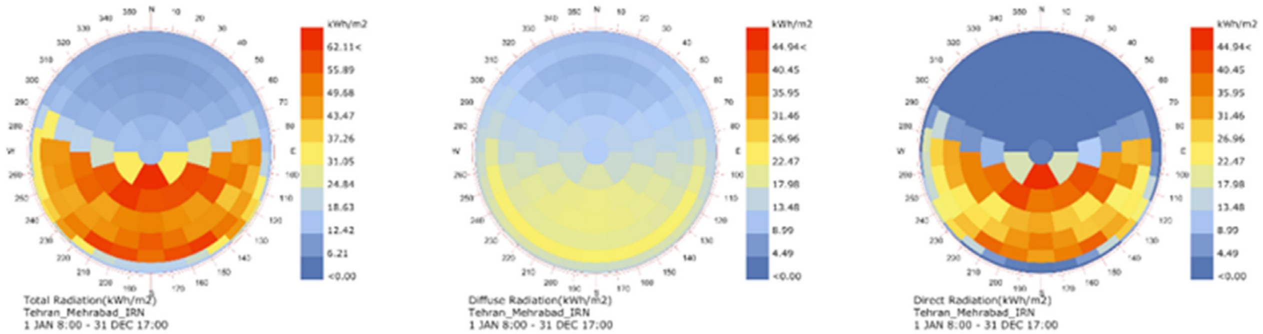


Fig. 10. Solar Radiation Dome. Source: Mehrabad Airport Climatic Data: Ladybug Tools.

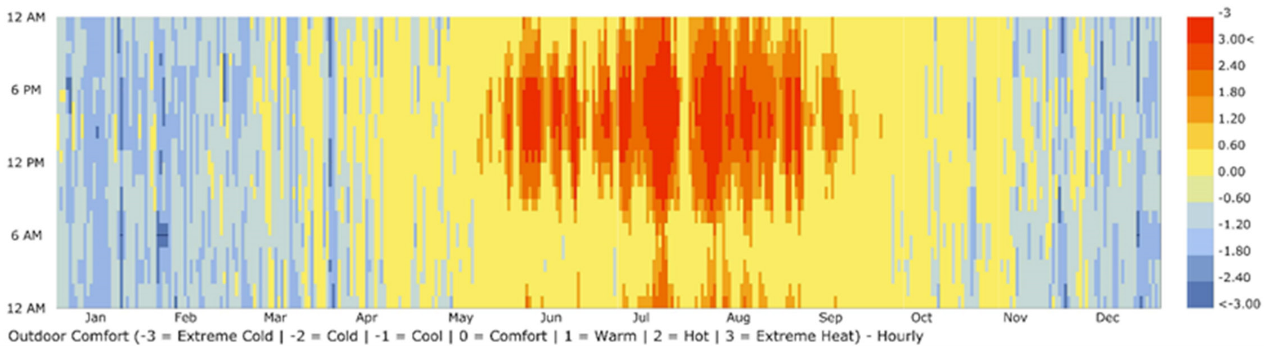


Fig. 11. Hourly-Annual Thermal Comfort Conditions. Source: Mehrabad Airport Climatic Data: Ladybug Tools.

Discussion

• Step 1: Identifying thermal comfort ranges

Based on the climatic data of Tehran, the time intervals from May 1 to 7 for spring, July 15 to 21 for summer, October 28 to November 4 for autumn, and February 21 to 27 for winter were selected as reference weeks to determine the average Universal Thermal Climate Index (UTCI). For qualitative analysis, the UTCI is aligned with human-perceived conditions. In this alignment, the UTCI values are interpreted as follows:

- UTCI < -13: Severe Cold Stress - Risk to Public Health
- UTCI between -13 and 0: Moderate Cold Stress
- UTCI between 0 and 9: Low Cold Stress
- UTCI between 9 and 26: Thermal Comfort Zone
- UTCI between 26 and 28: Low Heat Stress
- UTCI between 28 and 32: Moderate Heat Stress
- UTCI > 32: Severe Heat Stress - Risk to public health (CoccoloKämpf et al., 2016, 305).

Generally, considering the climate of Tehran, most of Saf Pedestrian Street in spring is not subjected to thermal stress. However, comparatively warmer microclimates in spring will occur in the middle of Saf Pedestrian Street, especially in low-rise adjacent building areas. This is due to reduced shading by adjacent buildings and a lack of thick vegetation cover in the middle zone. In addition, due to the openness of the facades and the inability to retain heat, combined with the shade effect from trees—particularly on the east facade—relatively cool microclimates are felt Fig. 12.

The crucial characteristic of the thermal comfort assessment in summer is the presence of microclimates with severe heat stress, posing a public health risk in the central part of Saf Pedestrian Street. In summer, vegetation and shading from commercial plots form thermally comfortable zones on the edges of the pedestrian street. This, coupled with seating areas around the plants, has led to the creation of pause spaces Fig. 13.

Due to the cooler conditions of autumn, low-cold stress areas co-exist with thermal comfort areas. With notable significance, solar reflection from commercial surfaces and leaf fall has made solar radiation reflection from commercial surfaces and leaf shedding decrease the intensity of cold microclimates for this season Fig. 14.

The areas forming cold microclimates in this season, similar to that of winter, are mainly found around plant cover. This largely occurs due to the shade of wind effect generated along the axis of such trees during this season. Mostly, the reduced solar radiation angle is also an important contributor to decreasing the Universal Thermal Climate Index (UTCI) during this season Fig. 15.

The findings indicate that in summer, there is extreme heat stress (UTCI > 32) in the middle of the pedestrian street due to a lack of shade and large heat-absorbing

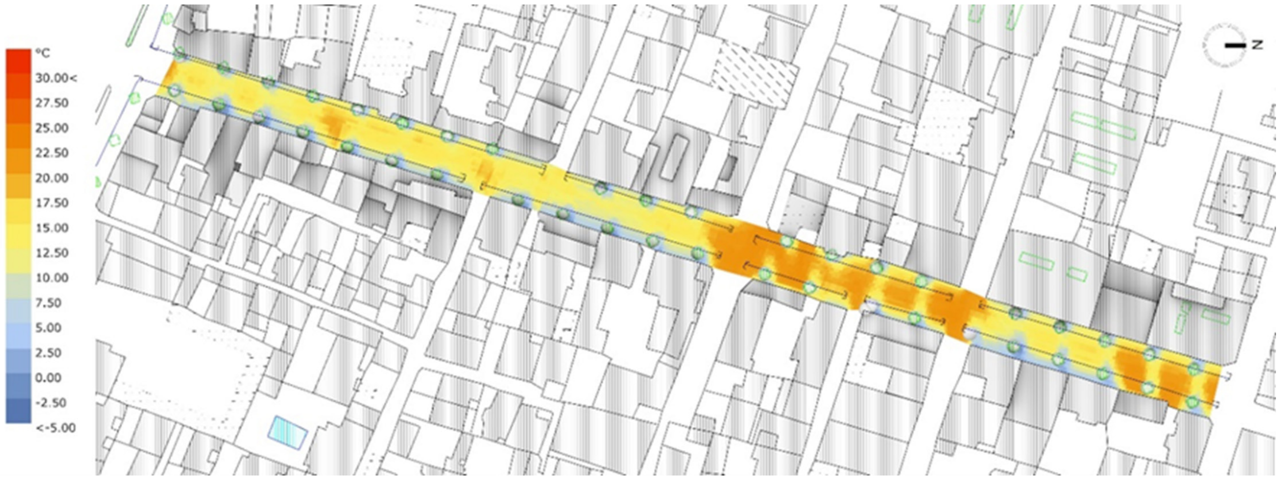


Fig. 12. Average Universal Thermal Climate Index (UTCI) of Saf Pedestrian Street in Spring. Source: Authors.

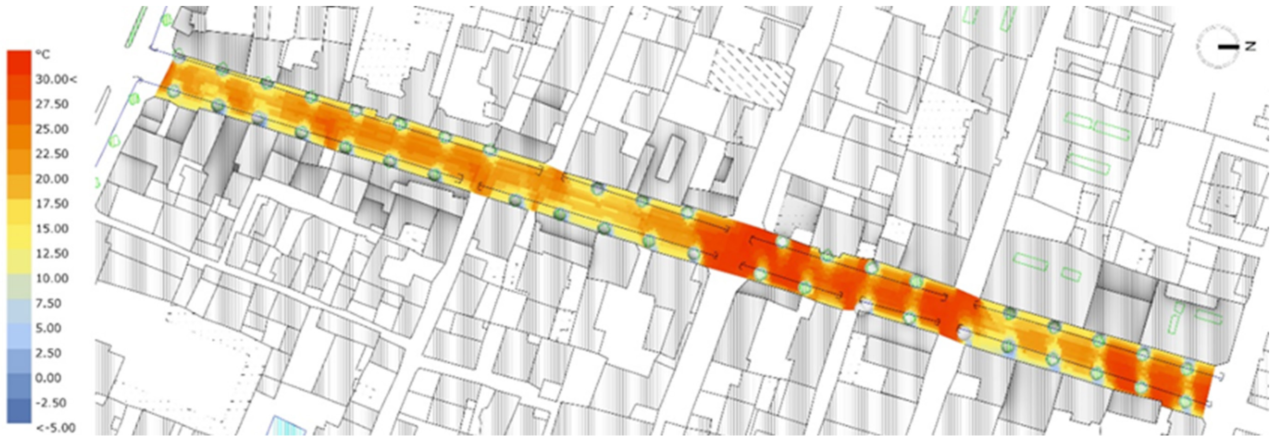


Fig. 13. Average Universal Thermal Climate Index (UTCI) of Saf Pedestrian Street in Summer. Source: Authors.

materials. In winter, cold stress (UTCI < -13) is felt near the vegetation due to wind shade and small radiation. Overall, the thermal comfort zones throughout the year are predominantly located at the edges of the pedestrian street, particularly the eastern frontage. This is primarily due to the impact of solar radiation and the formation of very hot microclimates in Tehran. Recorded images and field observations done by the researchers show that visitors like the sitting spaces at the sides of the pedestrian street and around the trees for pausing, even at night. However, inadequate shading in the middle of the pedestrian street has led to less thermal comfort, especially during warmer seasons. In general, there is an implicit connection between the thermal comfort zones and the spatial domains (seating areas) that are planned along the edges of the pedestrian street Fig. 16.

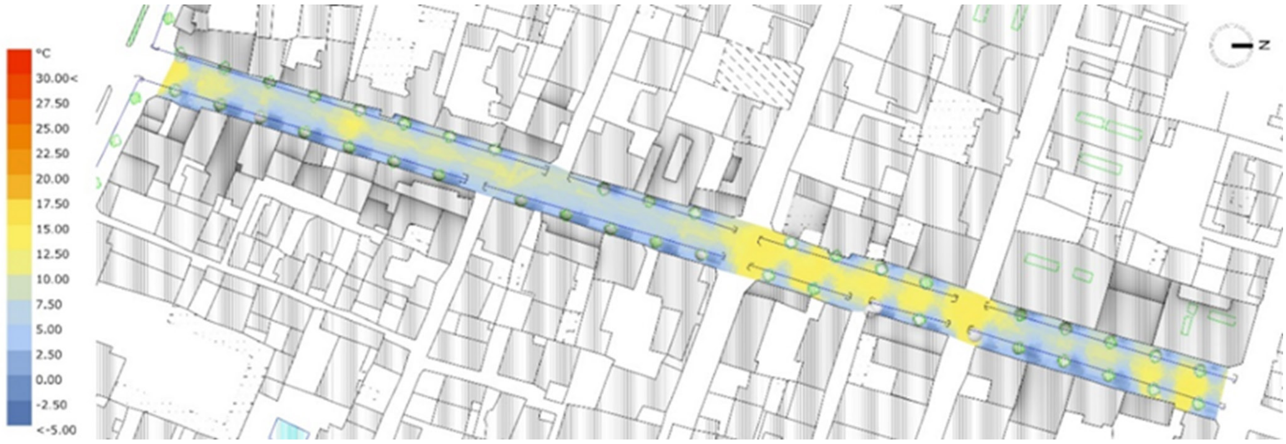


Fig. 14. Average Universal Thermal Climate Index (UTCI) of Saf Pedestrian Street in Autumn. Source: Authors.

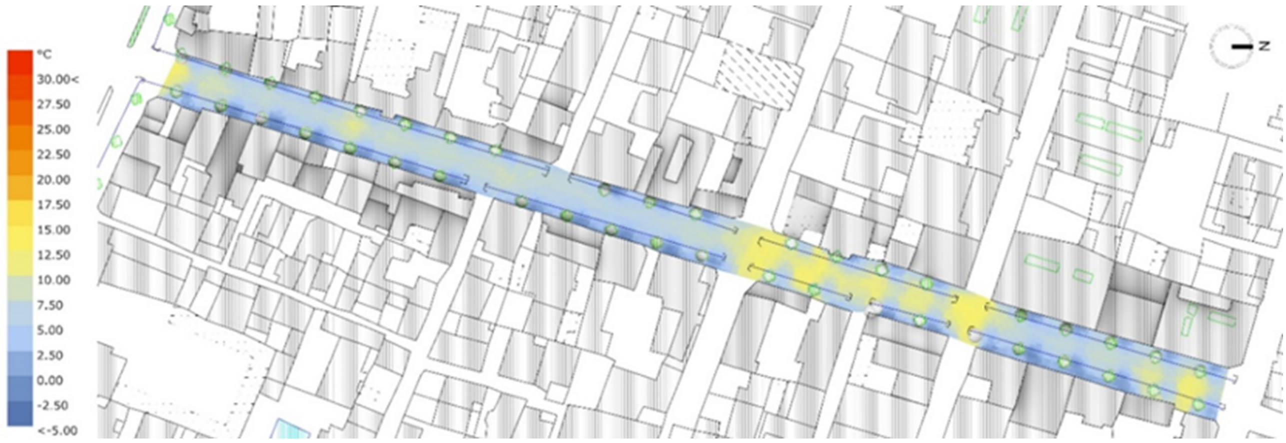


Fig. 15. Average Universal Thermal Climate Index (UTCI) of Saf Pedestrian Street in Winter. Source: Authors.

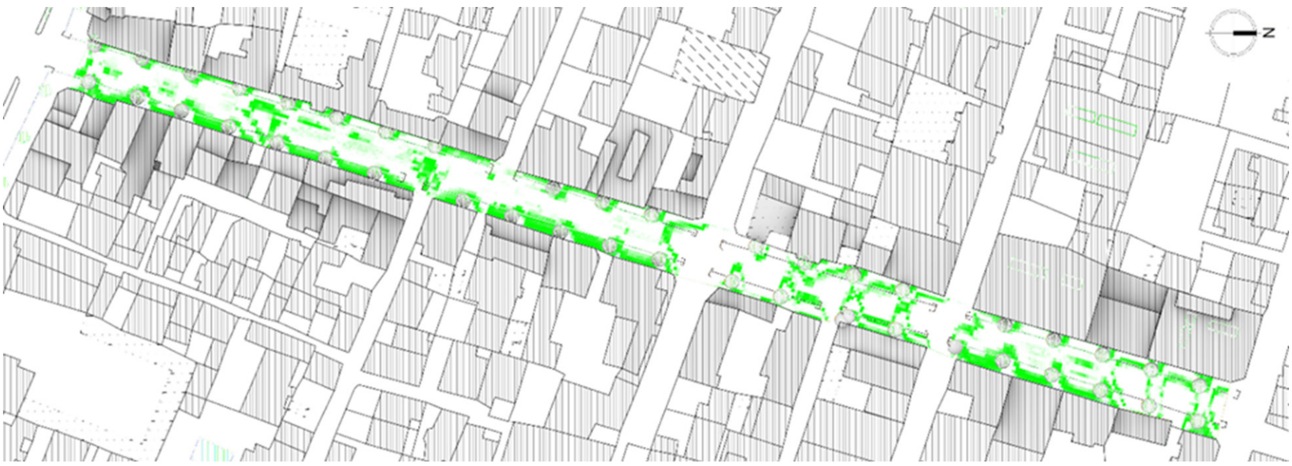


Fig. 16. Cumulative Annual Thermal Comfort Zones of Saf Pedestrian Street. Source: Authors.

- **Step 2 . Comparative analysis of user territories and thermal comfort zones**

Spatial territories are shaped by various factors, and one of the most frequent indicators of their formation, based on previous studies, is thermal comfort. By using climatic data, spatial information, and the Universal Thermal Climate Index (UTCI), we can identify urban spaces that have the potential to form spatial territories. As observed in the case study of Saf Pedestrian Street, one of the factors contributing to the formation of spatial territories in this urban area was the alignment of thermal comfort conditions with urban furniture. The results of the simulation of the average Universal Thermal Climate Index in Saf Pedestrian Street Fig. 16 show areas with lower thermal stress around the trees in this area. The placement of seating areas adjacent to these vegetation covers has resulted in the creation of pause spaces in these zones. On the other hand, the lack of proper shade in the middle of the pedestrian street has reduced thermal comfort, especially during warmer seasons.

In general, there is an implicit correlation between thermal comfort zones and certain spatial territories, where the maximum use of these zones by users of the pedestrian street indicates the desirability of these territories and the necessity and importance of thermal comfort in them. This study seeks to align user behavior with the spatial territories that offer suitable thermal comfort Fig.16. For this purpose, climatic data of Tehran were used, with the following time periods chosen as benchmark weeks to determine the average UTCI:

- Spring: April 20– 26
- Summer: July 6– 12
- Autumn: October 20– 27
- Winter: February 10– 16

These weeks in autumn and spring were selected to align the results with direct user tracking and observation in the field (Fig. 17). For the comparative analysis of the results and user behavior, theoretical saturation sampling was employed. In this sampling method, data are gathered from individuals, events, spaces, and situations with sufficient knowledge of the subject matter. According to this approach, the number of interviews, or the sample size, depends on theoretical saturation (the point at which new data stops being collected due to repeated responses). This method is especially used in qualitative research (Mohammadpoor, & Rezaei, 2008).

Thus, the sample for this study was selected from specialists among architecture and urban planning graduates and graduate students who had not yet used Saf Pedestrian Street, aged between 25 and 35 years Table 2. To record the territories used by users, they were asked to walk around the pedestrian street for 20 minutes and choose the areas they found suitable for pausing. They were free to select multiple points or zones for pausing, which was facilitated by the existing urban furniture. For direct user tracking, using the method of Winkel and Sassanoff (1966), specialists were instructed to mark the pause points of the samples on the existing plan, without the users being aware of the tracking process.

As shown in Fig. 18, the comparative analysis of user behavior in thermal comfort zones is depicted using red and green areas. Three points where users chose to pause, despite being outside thermal comfort zones, were identified through an average of 120 samples.

Based on fundamental research conducted to date, thermal comfort and distance are identified as two determining parameters in forming an optimal territory for users. This study tests the hypothesis of

Table 2. Sample information. Source: Authors.

Sample information							
25 October	23 October	21 October	26 April	24 April	22 April		
35	34	32	32	38	33	Theoretical Saturation	
19	18	15	16	24	17	Female	Gender
16	16	17	16	14	16	Male	

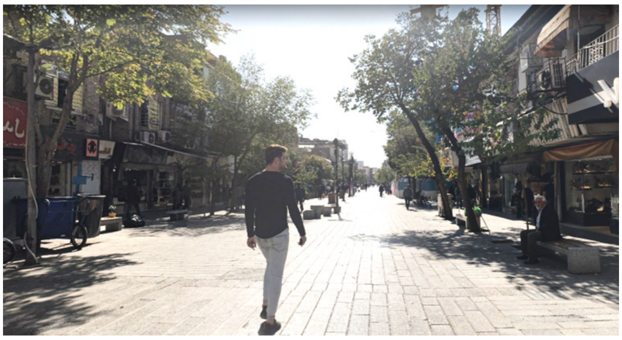
this multivariable longitudinal equation for forming an optimal territory. The research framework is based on the distance index at the points where territories are formed through the environment (urban furniture and pause spaces), which are equally valued. According to Fig 18, the thermal comfort levels in the territories defined by the designer differ. The use of red zones by the average users indicates that there is no prioritization or hierarchy for forming an optimal territory based on the desirability of predefined parameters, meaning that the importance of providing thermal comfort in forming a spatial territory for users is not established. This reflects a hidden relationship between the parameters forming spatial territories for humans.

As shown in Figs. 19 & 20, a comparison of the focus maps of female and male users in the field shows a significant difference. This difference indicates that, among women, selecting territories within the thermal comfort zones was a higher priority than for men. The selected zones by the users within the thermal comfort zone almost overlap.

Step Three: Examining the Importance of Indicators in the Formation of Spatial Territory

The conducted analyses have identified certain areas as the user's preferred territory, despite lacking thermal comfort. This indicates that the significance of indicators, as emphasized by researchers, is not easily distinguishable and must be further explored to determine their role in spatial territory formation. To assess the importance of these indicators, a survey was conducted in three areas within the research field. Participants from the previous step were asked to complete a questionnaire, and the significance of each indicator was determined using a t-test. This study is applied in nature and follows a descriptive survey approach

a



b

Fig. 17. Images of Sepahsalar Pedestrian Street. a) Saf Pedestrian Street at the Corner of Diba Alley, July 5, 202. b) Saf Pedestrian Street at the Corner of Mosadeghi Alley, October 14, 2020 Source: Author's archive.

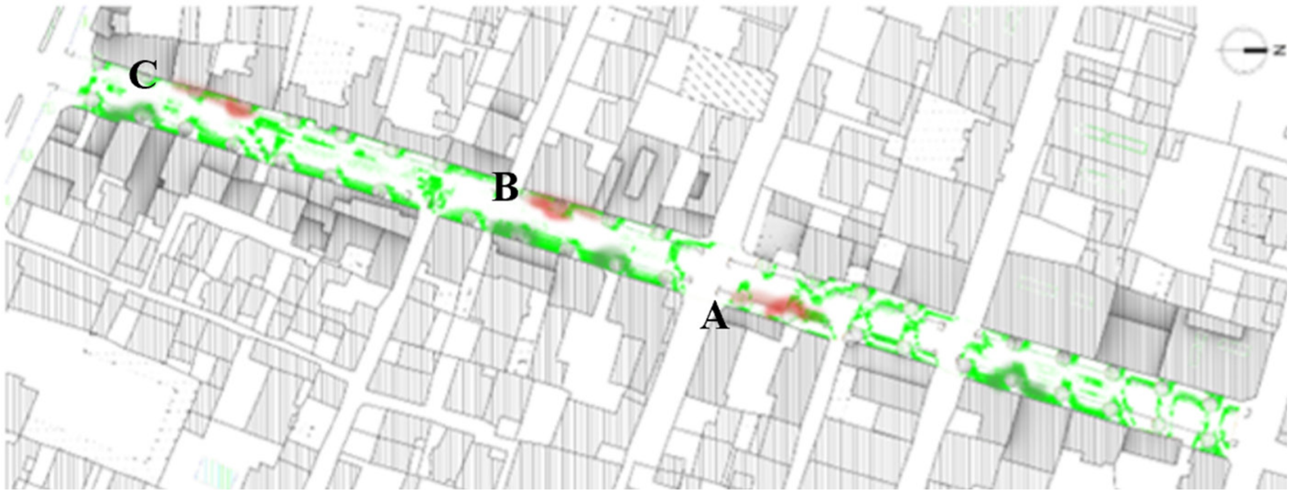


Fig. 18. Alignment of Selected Territories by the Sample and Thermal Comfort Zones of Saf Pedestrian Street – Cumulative Annual Analysis. In the red points, the user has selected their territory outside the thermal comfort zones. Source: Authors.

for data collection. A one-sample t-test, the simplest form of t-tests, was employed to determine whether the observed sample mean—randomly selected from the population—is equal to the hypothesized population mean. The assumption in this test is that a sample of size n with a mean m is drawn from a population, and we seek to determine whether this sample can be considered a random representation of a population with a mean of μ (Mansourfar, 2005, 200) Fig. 21. presents the sample distribution, while Tables 3 to 5 display the results of the t-test at points A, B, and C Fig. 18.

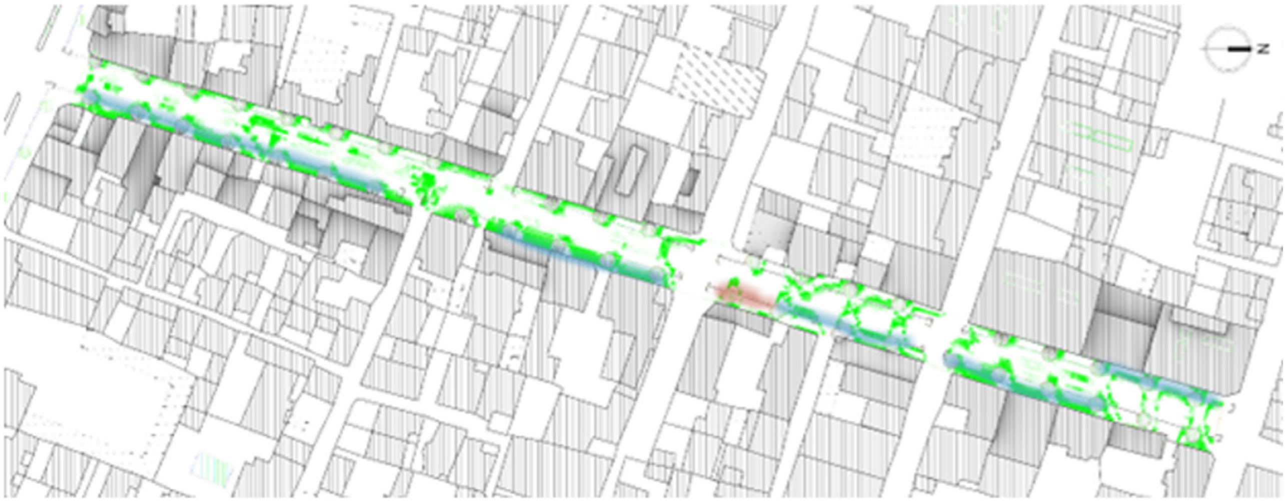


Fig. 19. Alignment of Selected Territories by Female Samples and Thermal Comfort Zones of Saf Pedestrian Street – Cumulative Annual Analysis. In the red points, the user has selected their territory outside the thermal comfort zones. Source: Authors.

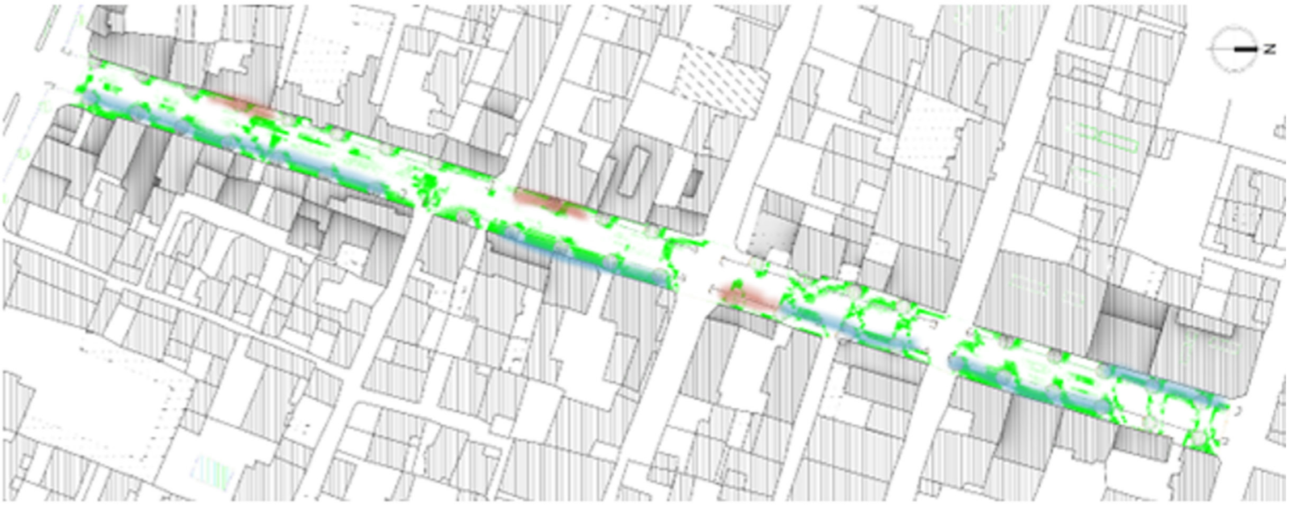


Fig. 20. Alignment of Selected Territories by Male Samples and Thermal Comfort Zones of Saf Pedestrian Street – Cumulative Annual Analysis. In the red points, the user has selected their territory outside the thermal comfort zones. Source: Authors.

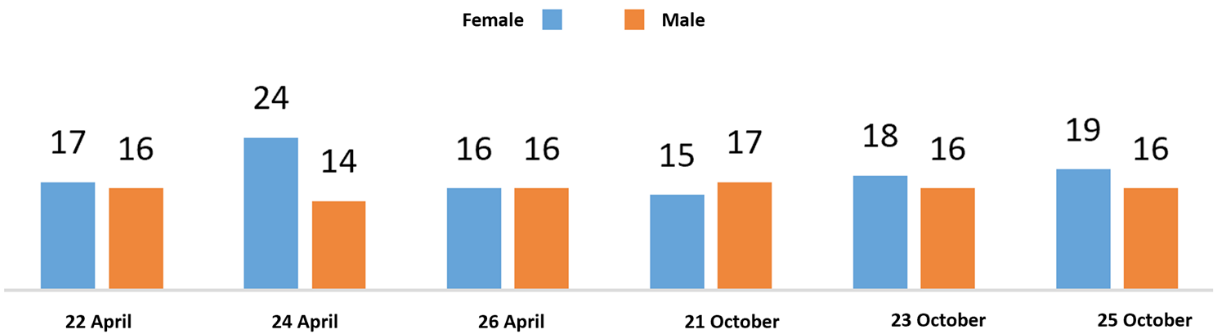


Fig. 21. Frequency Distribution Chart of Sampled Individuals. Source: Authors.

For assessing the importance of indicators at point A, a one-sample t-test was conducted. The findings indicated that the empirical mean for the parameters of distance, enclosure level, and flexibility was higher than the expected mean (3). The t-value was significant at an error level of less than 0. 01 [P-Value≤ 0.01]. Given that the t-value was significant at this level, it can be concluded that the observed mean significantly differs from the theoretical mean. Since the empirical mean was higher than the theoretical mean, it can be inferred that distance, enclosure level, and flexibility are highly desirable parameters at point A.

The findings also showed that the empirical mean for visibility, domain, thermal comfort, and formal quality was lower than the expected mean (3). The t-value was significant at an error level of less than 0. 01 [P-Value≤ 0.01]. Given that the t-value was significant, it can be concluded that the observed mean significantly differs from the theoretical mean. Therefore, it can be stated that visibility, domain, thermal comfort, and formal quality are not highly desirable parameters at point A.

To assess the significance of parameters at point B, a one-sample t-test was conducted. The findings indicated that the empirical mean for the parameters of visibility, enclosure level, and

Table 3. Results of One-Sample t-Test for Assessing the Importance of Parameters at Point A. Source: Authors.

Variables	Empirical Mean	Theoretical Mean	Paired Difference: Mean Difference	Confidence Interval Difference: Lower Bound	Confidence Interval Difference: Upper Bound	t	df	Sig
Distance	3.4242	3	0.424	0.675	0.477	11.444	428	0.000
Degree of Enclosure	3.5804	3	0.580	0.5105	0.329	9.075	428	0.000
Angle of vision	2.3263	3	0.674	-0.767	-0.580	-14.182	428	0.000
Flexibility	3.3240	3	0.324	0.764	0.588	15.060	428	0.000
Hierarchy and Zoning	2.6480	3	0.352	-0.447	-0.257	-7.292	428	0.000
Thermal Comfort	2.4942	3	-0.506	-0.597	-0.415	-10.902	428	0.000
Form Quality	2.0117	3	-0.988	-1.067	-0.910	-24.744	428	0.000

Table 4. Results of One-Sample t-Test for Assessing the Importance of Parameters at Point B. Source: Authors.

Variables	Empirical Mean	Theoretical Mean	Paired Difference: Mean Difference	Confidence Interval Difference: Lower Bound	Confidence Interval Difference: Upper Bound	t	df	Sig
Distance	3.1000	3	0.1000	0.3846	0.6154	8.517	428	0.052
Degree of Enclosure	3.6075	3	0.6075	0.0866	0.3284	13.374	428	0.001
Angle of vision	3.5225	3	0.5225	0.0035	0.2415	12.023	428	0.044
Flexibility	3.6900	3	0.6900	0.2759	0.5041	14.722	428	0.000
Hierarchy and Zoning	3.1575	3	0.1575	0.0379	0.2771	2.588	428	0.050
Thermal Comfort	3.0450	3	0.0450	-0.0738	0.1638	0.744	428	0.457
Form Quality	2.9925	3	-0.0075	-.1222	0.1072	-0.129	428	0.898

flexibility was higher than the expected mean (3). The t-value was significant at an error level of less than 0. 01 [P-Value≤ 0.01]. Given that the t-value was significant at this level, it can be concluded that the observed mean significantly differs from the theoretical mean. Since the empirical mean was higher than the theoretical mean, it can be inferred that visibility, enclosure level, and flexibility are highly desirable parameters at point B.

The findings also showed that the empirical mean for distance, domain, thermal comfort, and formal quality was around the expected mean (3). The t-value was not significant at an error level of less than 0. 01 [P-Value≤ 0.01]. Given that the t-value was not significant, it can be concluded that the observed mean does not significantly differ from the theoretical mean. Therefore, it can be stated that distance, domain, thermal comfort, and formal quality have a moderate level of desirability at point B.

To assess the significance of parameters at point C, a one-sample t-test was conducted. The findings indicated that the empirical mean for all parameters was higher than the expected mean (3). The t-value was significant at an error level of less than 0. 01[P-Value≤ 0.01]. Given that the t-value was significant at this level, it can be concluded that the observed mean significantly differs from the theoretical mean. Since the empirical mean was higher than the theoretical mean, it can be inferred that visibility, enclosure level, and flexibility are highly desirable parameters at point C. A comparison of the empirical means of the parameters showed that the three parameters distance, enclosure level, and visibility had a better status at point C compared to the other parameters.

Considering Figs. 19 & 20 from the previous step of the study, which illustrate the differences in spatial preferences between men and women, an independent samples t-test was conducted to examine the significance of parameter importance in shaping a desirable spatial territory for men and women. This test compares the means of two groups of respondents. It is used to calculate the confidence interval or test the hypothesis of the mean difference between two populations (when the standard deviation is unknown and the samples are independent). The results are presented in Table 6.

To examine whether there is a significant difference between men and women in the importance of parameters, an independent samples t-test was conducted. Based on the results shown in the table, it was found that the significance level of the Levene test was greater than 0.05. Therefore, the results from the first row, assuming equality of variances for the two groups, were used for interpretation. Since the t-value was significant at the 0. 05 level

Table 5. Results of One-Sample t-Test for Assessing the Importance of Parameters at Point C. Source: Authors.

Variables	Paired Difference					t	df	Sig
	Empirical Mean	Theoretical Mean	Mean Difference	Confidence Interval Difference				
				Lower Bound	Upper Bound			
Distance	3.7475	3	0.74750	0.3703	0.1347	14.212	428	0.000
Degree of Enclosure	3.5325	3	0.33250	0.2137	0.4513	5.502	428	0.000
Angle of vision	3.5275	3	0.32750	0.2117	0.4433	5.558	428	0.000
Flexibility	3.3650	3	0.36500	0.2481	0.4819	6.136	428	0.000
Hierarchy and Zoning	3.3700	3	0.37000	0.2590	0.4810	6.550	428	0.000
Thermal Comfort	3.3850	3	0.38500	0.2751	0.4949	6.887	428	0.000
Form Quality	3.2475	3	0.24750	0.1376	0.3574	4.429	428	0.000

Table 6. Results of the t-test for Independent Samples to Assess the Importance of Parameters. Source: Authors.

Variables	Category	Mean	Levene's test		t	DF	level of significance
			F	Sig			
Distance	Male	3.1346	7.334	0.007	4.674	107	0.000
	Female	3.4494					
Degree of Enclosure	Male	3.5192	0.738	0.391	4.155	107	0.000
	Female	3.1370					
Angle of vision	Male	3.3269	0.138	0.710	2.002	107	0.000
	Female	3.1272					
Flexibility	Male	3.0115	1.114	0.124	-3.421	107	0.000
	Female	3.3951					
Hierarchy and Zoning	Male	3.3628	1.936	0.165	2.814	107	0.900
	Female	3.0580					
Thermal Comfort	Male	2.9551	0.123	0.726	-3.458	107	0.000
	Female	3.3605					
Form Quality	Male	2.9410	1.398	0.122	-2.597	107	0.000
	Female	3.2222					

(P-value $\leq$ 0.05), it can be concluded that there is a significant difference between men and women in the importance of the parameters. The comparison of the observed means revealed that the average scores for enclosure, view, and zoning were higher among men than women, while the average scores for distance, flexibility, thermal comfort, and formal qualities were higher among women than men.

Conclusion

Architecture is the organization of space. Such space only has value if humans are present. To obtain human presence in space, one should find out the requirements of humans in space. So, how is this space to be to meet human needs? According to the "spaces of being" theory, architectural spaces can provide a solid basis for the perceptions and assumptions regarding the environment that constitute an integral part of the overall explanation of human existence or the world in general. From an anthropological point of view of this phenomenon, the concept of space finds articulation in various structural manifestations, depending on cultural environments or even specific subcultures. However, each form of spatial ordering has an order of its own, one that may have its origin in symbolic, mythological, religious, political, economic, or social convictions but is never once characterized by randomness or lack of rule. The allure of space that is at the root of human architecture becomes self-evident once the spatial desires and needs are understood. This research attempts to explore the appeal of spatial areas that are fundamental in explaining human interaction across various environments by identifying context-sensitive indicators that shape them. The indicators indicated through both data compilation and a study of the existing literature are: distance, enclosure, view, flexibility, hierarchy, spatial zoning, thermal comfort, and the formal properties of the built environment.

In light of the theoretical significance given to thermal comfort, it was contended to be a necessary condition for the realization of spatial realms. Therefore, a hypothesis test was carried out to examine if the users would accept the space as their spatial realm or not if it lacked thermal comfort. The conducted hypothesis test, which included the simulation of boundaries of spatial areas and thermal comfort zones while, at the same time, the user was being monitored, revealed that the hierarchical relationship according to the significance of indicators in defining spatial areas is not subjectively perceived by the user. In shared environments where individuals have little control and customization, a highly notable difference appeared regarding the interpretation of each metric in the context of gender, more specifically between females and males. Most significant among these metrics were measures explaining the "distance" between the different realms, their "sight" of one another, patterns of movement, and the quality of "enclosure" surrounding the realms, all of which carried substantial implications on how to gauge the realm's attractiveness to users. Hence, when pause spaces and pre-defined domains are being designed, it is necessary to give varying degrees of significance to every parameter so that the equation to calculate an optimal domain for the users can be resolved based on factors such as usage type, culture, gender, and social and individual factors.

The variations in the preferences shown by men and women reveal that the identification of the gender of the individual's utilizing space is a fundamental element in augmenting both the spatial quality and its functionality. The comparison of the observed means revealed that the enclosure, view, and zoning factors are more significant for males compared to females. Conversely, the distance, flexibility, thermal comfort, and formal qualities factors are deemed more significant for females compared to males in creating desired spatial zones.

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