Improving Thermal Comfort in the Outdoor Spaces of Universities through Planning: Corridors of the University of Al-Farahidi, Iraq

Hala Hussein Musa[1], Huda Sabah Fakhreddine[2], Fareeq Tawfeeq Najah[3] & Haitham Jameel Abd[4]
Department of Architecture, The Engineering College, University of Baghdad. Iraq.
Construction and Project Department, University of Baghdad. Iraq
hala.musa@uobaghdad.edu.iq
huda.sabbah@coeng.uobaghdad.edu.iq
fareeq.najah@uobaghdad.edu.iq
haitham.abid@uobaghdad.edu.Iq

Received	Reviewed	Revised	Published
03.09.2023	14.10.2023	23.10.2023	31.10.2023

https://doi.org/10.61275/ISVSej-2023-10-10-28

Abstract

As a result of the changing and large climatic variations occurring around the world, recent academic research has focused on climate and its most important aspects: how the communities maintain their existence in the climatic conditions, which affect thermal comfort. Similarly, this research focuses on "how to realize thermal comfort in the outer spaces of universities in general, and the outer spaces of the University of Al-Farahidi in particular".

It presents the idea in a four-step process. It first introduces thermal comfort and climatic variables that affect it. It then examines the determinants that affect people, and presents the options available in hot dry climates. This is followed by an examination of the outside spaces of universities and methods of site design. It focuses on the University of Al-Farahidi in Iraq in particular, testing its outdoor spaces using the ENVI-met software. The site chart was drawn using AutoCad, and images were taken using the bitmap extension of the program. It produced a model of the exterior spaces of the University of Al- Farahidi which introduced the ENVI-met program in the form of three options (three models). The variables were input, tested, analyzed, and the results of the three models were compared.

The research concludes that it is possible to achieve thermal comfort in the outdoor spaces in university complexes by adopting a number of treatments in the proposed models, The study led to an improvement of thermal comfort of the exterior spaces of the University of Al-Farahidi in Iraq.

Keywords: Thermal comfort, PMV, TMRT, Air temperature, ENVI-met simulation.

Introduction

One of the primary objectives of designing buildings with an open space is to provide thermal comfort for people. Thermal comfort research serves the standards used in the evaluation process, and they are considered references for a wide array of the functional problems which may arise, without specifying the design treatments to achieve thermal comfort, especially within the university complexes. As a result of this knowledge gap in how to achieve thermal comfort in the outer spaces of universities, this research aims to improve the sense of thermal comfort in such places. For this purpose, it examines the designs of ways of the outer spaces of the universities. Its objective is to identify their most important components and methods of planning, by using modern technical techniques (ENVI-met software). The study examined the case of the outer spaces of Al-Farahidi University tested by model's produced in the ENVI-met program, assessing the findings in order to link the indicators while choosing the best thermal zone. In turn, it will serve as a basis for designing of outer spaces of local universities in general.

Theoretical Framework

The Concept of Thermal Comfort

20th century witnessed a 0.74 °C increase in global temperature, a 40% decrease in worldwide glacial covers, an increase in acid rains, and a 27cm rise in sea levels. From these numbers, one can imagine the great pressure that natural environment faces now; due to industrial and technological developments in human activity and production (Shaheen & Abd alteif,2016).

This is precisely what led to the emergence of the concept of thermal comfort Since 1930s. The topic of thermal comfort has been discussed quite widely (Taleghani et al. 2012). Thermal comfort is usually defined as “that condition of mind that expresses satisfaction with the thermal environment” Najah et al. (2022). It is the ability of a person to live in changing climatic conditions, which is part of each individual's distinct behavioral and physiological makeup. Such ability is heavily correlated with the amount of environmental comfort or lack thereof, and human beings in general "maintain their existence by trying to adapt to and control their environmental conditions" Muttif (1995; Shaheen, 1988). Thermal comfort is also defined as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (Wei,2014).

The predicted mean vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under various conditions (Floriberta et al. 2020).

Climatic Variables Affecting Thermal Comfort

Air temperature, radiation, air movement, and relative humidity of air are the primary climatic variables that are concerned with thermal comfort. All of these variables affect the people either individually or combined (Shaheen, 1988). There are six primary factors, when defining conditions for thermal comfort. They are: metabolic rate, insulation, air temperature, radiant temperature, air speed and personal factors (Wei,2014). Hot and humid are the main characteristics of humid tropical climates, which can also be found in humid subtropical climates during summer (Floriberta.et al.,2020).

The Impact of Climatic Factors on People

The impact of climatic conditions on people and how they are treated is discussed. In the first case, when a person "moves" in Nature, climatic factors will have a direct impact on him; in this case, the architect's work will be limited to his direct protection; he will try to provide him with appropriate shading in hot or climatically disturbing times, and full openness in moderate and appropriate times. This may require the limitation of treatments in the approach of movement areas (Musa et al., 2022).

When a perdson is inside a building, such as a residence, or a shop or in any other building for his daily activities or otherwise protection is directed primarily at the building itself, such as the protection of the construction structure, the roof, the walls, the floors, and the window openings to create an internal atmosphere carrying all the specifications of psychological and physical comfort for the person (Shaheen,1988). Differences in indoor and outdoor thermal comfort can be divided into three categories: psychological, thermo-physiological, and handed-balance indifference (Wei,2014).

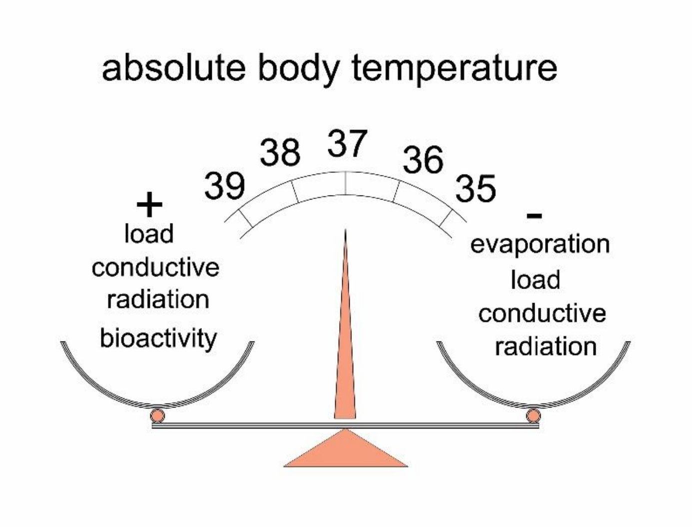


Fig. 2: Thermal comfort of the human body,
Source: Muttif,1995)

University External Spaces and Methods of Planning Within the Site:
Outdoor Spaces in Architecture, Landscape and Landscape Architecture

As mentioned by Marlowe, the definition of outdoor spaces is a built environment in any space which is located outside the buildings or between the buildings. Such spaces are linked to different human events such as the ones mentioned by Marlowe and the architecture of outer spaces: It is a tissue environment in its relationship with the physical environment (natural or man-made), or it is a functionally and "environmentally" an environment in on itself, or, in Motloch's words, it is a profession that deals with the uses of the land and external design, as well as the use of social behavior in the re-installation of outdoor spaces according to the available possibilities (Rahim, 2014).

Campus Landscape Architecture

The street canyon landscape is considered important to improving the thermal environment and has become a key research topic in landscape architecture. so, land scape is defined as the art of planning the numerous layers of university outdoor spaces that overlap with one another and is the key to establishing a green environment that has visible effects on university attendants. In fact, university outdoor spaces can give symbols to higher education (Rahim,2014; Hassan,2014). It has a role in conducting the movement of people through the different sectors of the university, including the green areas, roads, and lecture halls (Rahim, 2014). All land within the area, outdoor spaces and buildings, and the services that are carried out within them need to be concerned with the physical forms of higher education institutions in such a way that both planning and design are defined as a dynamic, cultural, and social units which are referred to as landmarks (Khanjar,2015).

Components of University Structures

1. Main buildings which represent the core of the university structure.
2. The vital components of the campus structure like roads and recreational spaces.
3. Auxiliary areas, such as transportation services, movements through and between the various campus structures is facilitated by such areas (Hassan,2014).

Components of University Outdoor Spaces

According to Motloch, the components of the university outdoor space can be identified by categorizing them into:

1. The lower horizontal layer: this represents the space floor, which is the layer where the buildings on the site meet and the movement through and between them it facilitates.
2. Upper horizontal layer: this represents the roof and sky and is rarely considered when designing such spaces. Its functions include providing shelter and environmental protection, as well as providing diversity in the features of outdoor space and creating a sense of excitement by manipulating shadow and light as its heights can be manipulated to create a variety of sub-spaces.
3. Vertical layer: Represents the boundaries and borders of space, which are usually meant to promote the efficiency of usage, and act to direct movement and attention towards intended targets. Its size can vary from case to case, and it can be measured in proportion from one another.
4. Objects within the spaces and sub-spaces: like seats, lighting structures and segment barriers, and other examples of what would usually be called space furniture. Their inclusion is important as if they did exist, the spaces would be empty, devoid of the contours of life (Rahim,2014; Motloch,2000).

A list of twelve necessary variables regarding the design of university spaces include location, accessibility, boundaries, limits, density, compactness, distribution, landmarks, green elements and air circulation (Khalil,1999).

Standards of University Design

According to our model, following are the most significant factors to consider when planning and designing a university or a similar structure:

I) Environmental considerations in university building planning and design, such as the process of land assessment.
II) Making better use of local technology by incorporating natural elements into planning and design solutions.
III) By depending on convergent planning and openness to the interior, it is necessary to evaluate the directions of the chilly winds and avoid the unfavorable directions. (Khanjar,2015; Najah,2016).

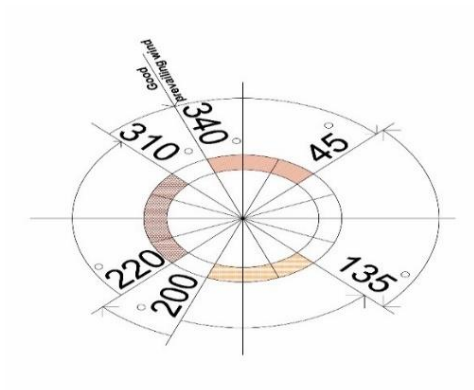


Fig. 3: Optimal guidance of university building spaces and exceptional guidance maneuver for Iraqi circumstances
Source: Khalil,1999

Environmental Determinants of University Buildings

1. Guidance: In dry hot areas, thermal comfort is determined by location, general orientation, and micro-manageable variables of the interior space of the building, such as the presence of a river or lake. Ideal guidance of educational spaces is considered the southern orientation and confined between the angle (135-200) degree, but in this case will take the building length and increase the area of its external faces (70-7%). Other educational spaces determine the least optimal guidance from educational spaces (25%-30%). Others rely on two primary directions, which are evenly distributed to educational spaces and are considered cost-effective and climate-friendly in hot climates where the depth of the structure increases while the area of the exterior walls decreases Khalil (1999;Najah,2016).
   There is also an effect of sunshine on parts of university buildings, which are influenced by guidance, and the effect of shading on the materials utilized (Hassan,2014; Najah 2016).
2. Lighting and color: Sunlight vehicles (natural lighting) are intended to complement industrial lighting as well as the colors of the exterior and interior floors, exterior and interior walls, ceilings, and roofs. Khalil (1999), and the material's impact on the thermal balance is obvious. Hassan (2014).

Following are the most essential environmental considerations for university buildings:

1- The number of buildings 2- the way of buildings constructing 3- the architectural style of buildings 4- buildings orientation 5- the relationships between buildings spaces (Rahim,2014).

Table 1: Climate Guide to additional requirements to improve sense of comfort of the city of Baghdad during the year for public buildings
Source: Shaheen, 1988

December January February	March November	April	May June September October	July august
We need solar rays Directly and widespread from 60-75 kilos /hour	We need to be exposed to the sun From 12-20 kilos /hour rays spread during the morning hours	shading	shading and air movement in the morning hours /the speed of the air move to a meter /second with moisturizing the atmosphere	We need a mechanical intervention in the air condition (It is preferable to cool for two meters for evaporation) with complete shading
Note: The requirements for complete shading within (62%) of the full annual period				

Environmental Characteristics of Outdoor Spaces Between University Buildings

1. The shape of university exterior spaces (completely closed outer space, corner-open outer space, centrally open outer space, open space surrounded by a specific building) has an environmental influence.
2. Orientation.
3. Extraterrestrial entrances.
4. Shading the university's outdoor spaces.
5. Materials for enclosing university outdoor spaces. (Rahim, 2014; Najah, 2016).

Importance of Environmental Considerations in the Design of University Outer Spaces are:

1- Connecting the internal and external spaces by consolidating and enhancing the presence of roofed walks.
2- Encourage the presence of green elements.
3- Avoiding wide open spaces.
4- Treatment of soil stability.
5- Using waterbodies when needed. Hassan. (2014), Najah. (2015).

Literature Review

Numerous studies show that green impacts play a vital role in the technique of environmental cooling in urban planning, as well as in conserving energy and improving human thermal comfort. The concept of thermal comfort has been thoroughly studied and many have focused on this aspect with various studies. These include Najah et al. (2022), Abdulateef, & Al-Alwan (2021), Musa et al. (2022), Suad Ridha (2017) and Rezaei et al. (2021).

Najah et al. (2022) examine how to apply the idea of thermal comfort in urban areas where streets, buildings, and infrastructure have taken the place of open spaces and green urban spaces. They aim to enhance the comprehension of an integrated approach to open green spaces through an examination of the urban environment, with a primary emphasis on thermal comfort and environmental sustainability. Three typical Baghdad regions in Zayouna have been chosen as the case study. These areas have been transformed into various buildings for various purposes with comparison and identification of the UHI effect in two scenarios such as the green zone and increased buildings.

Abdulateef & Al-Alwan (2021) assess how well green urban spaces mitigate the rise in urban heat islands (UHI) in Baghdad. Given the fact that Rusafa Municipality has a significant risk of urban heat island effect on thermal comfort, it has been chosen as a case study. They have evaluated the study area with two models, and have introduced green areas into this area. In these two models, surface temperature has been recorded at various places. The findings demonstrate that, in both models, green urban spaces play a significant part in the decrease of air temperature. This attests to the fact that such spaces significantly improve thermal comfort in the city of Baghdad.

On the other hand, Musa et al. (2022) examine the high temperatures in this area. They have focused on improving pedestrian thermal comfort in the area between the shrines of Imam Hussein and Imam Abbas in Karbala, Iraq. Thus, they examine how changes in architecture, both past and present, impact thermal comfort. They also figure out how vegetation affects thermal comfort outside. The findings suggest that in freshly designed metropolitan areas, trees with a medium density should be arranged in a compact manner next to the newly-constructed structures. The best strategy for existing urban plots they say, is to use vacant spaces like parking lots for medium-density tree plantings and to add agricultural land along the pedestrian routes.

Ridha (2017) have concentrated on practical strategies for lowering the urban heat island and improving pedestrians' outdoor thermal comfort. They have contrasted the old and modern areas with the construction design possibilities. By creating patterns of flora and shade, they argue, one can lessen the effects of urban heat island effects and enhance exterior thermal comfort. Four distinct scenarios have been created to evaluate the significance of vegetation components including trees, grass, and various shading patterns. The examination has been conducted during the hottest days of the summer. Air temperature, wind speed, specific humidity and average radiant temperature have been measured.

Rezaei et al. (2021) evaluate the changes in the level of thermal comfort in the open interior spaces of high-rise urban complexes. They show that the difference in building mass and shapes can affect thermal comfort rates and temperatures in the open interior spaces of urban complexes by adopting four different scenarios. The buildings have been shaped in the chosen location in the Gheytariyeh neighborhood of Tehran, using the first scenario with a three-sided block, the second scenario with a four-sided block, the third with an empty middle block, and the fourth with a rectangular block.

It is clear that most previous studies have dealt with the concept of thermal comfort at different urban levels. Some of them have dealt with it at the level of the residential area. Some of them have dealt with it at the level of an entire city, such as in Alwan’s study. Some of them have dealt with it at the level of historical centers, such as the study of Hala, while some of them have dealt with it at the level of residential complexes, such as Souad and Rezaei. However, no one has addressed ways to increase the feeling of thermal comfort of outdoor spaces in university complexes and the positive impact that has on improving the functional performance of these spaces. This study thus will shed light on this type of space and find appropriate environmental treatments for it to improve the feeling of thermal comfort in it.

Research Methodology

A lot of researches have been undertaken about university spaces from an architectural point of view, as to determine the effects of changes in the urban structure on the circulation of air flow velocity and other factors related to the environmental and thermal wellbeing of universities. However, little attention has been paid to the influence of the spatial distribution of blocks and buildings, as well as their orientation and ratio to open areas, and their effects on temperatures and thermal comfort zones as a result. the current study focuses on comparing three stages of Al-Farahidi University's architectural growth, representing them as a model, and providing solutions and treatments to obtain optimal values of thermal comfort regions to serve the university's biggest number of students and visitors.

The current study included a methodological approach that includes a review of the literature, data gathering, and simulation utilizing the ENVI-met program. The methodological approach used in the current investigation is schematically depicted in Figure:

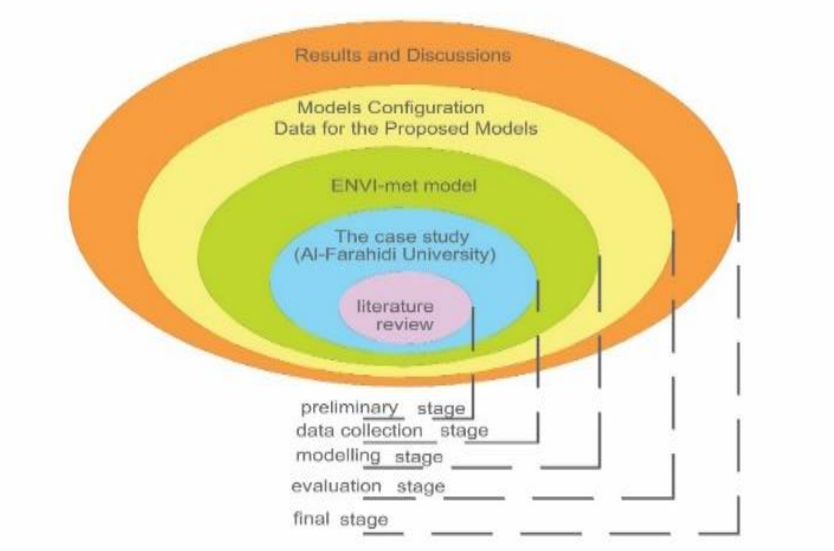


Fig.1: Schematic representation of the methodological approach followed in the current inquiry. Utilizing the ENVI-met program.
Source: Authors.

Geographical Location and its Climate of Iraq

Iraq's geographical location between the two districts of width 29-37 north of the equator, as it is located within the northern temperate region of the globe, which is characterized by its long hot summer, short cold winter, and heavy, rains during the winter. The location of Iraq in particular "relative to longitude and latitude circles is located at the latitude of 33 degrees north", and the longitude of 44 degrees east, and the length line 44 degrees east" and the climate in Iraq varies according to "the region is moderate in the northern, subtropical regions in the east and southeast, but in the eastern and south-eastern regions.

Fig. 4: Photos of al-Farahidi University's website for Iraq and Baghdad
Source: Authors & www. Google Earth.com.

South and southwest, the climate is continental desert, and there are two major climate zones in Iraq: lowlands, arid and high northern and eastern lands, each with a special climate in high areas and winters longer and colder in general, the summer in the organization of all parts of Iraq is hot dry, and the high humidity of the weather in the summer.

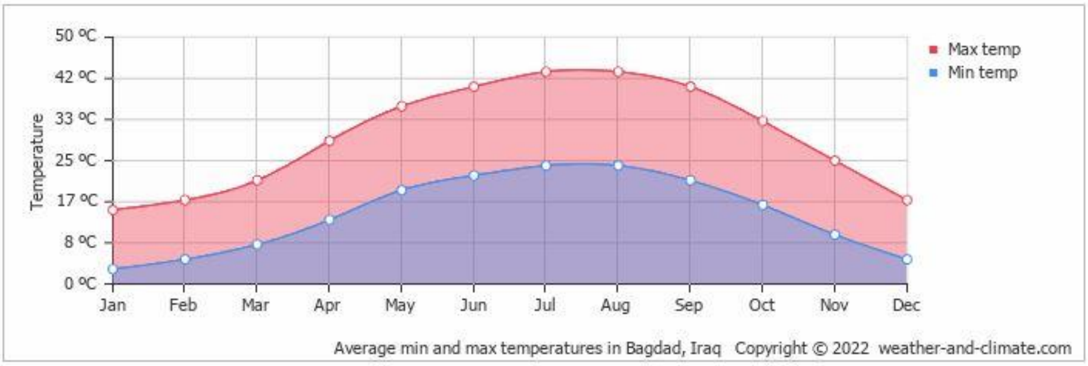


Fig. 5: Climate summary of the study area,
Source: weather-and-climate.com, 2022.

Envi-Met Model

ENVI-met is a program that may be used for outdoor microclimate simulation in open areas, as well as wind turbulence, vegetation impact on the microclimate, pollutant dispersion, and bioclimatology input. The simulation model created by ENVI-met is according to a list of factors (e.g., clouds, structures, soil data, etc.). A daily and hourly time range is defined by the default basic settings, including the simulation's total duration, relative humidity, wind direction and speed, and external temperature, throughout the starting and end of the simulation. Many studies have shown the trustworthiness of ENVI-met findings for modeling outdoor thermal spaces. These examinations revealed that data collected at local meteorological sites appeared to match the predicted outcomes with accurate and reliable validation Ridha, (2022). http://www.model.envi-met.com

ENVI-met results could be recognized as accurate and effect of aspect ratio and symmetrical distribution on urban design in Baghdad city, and the impact of greenery strategies on improving outdoor thermal comfort ENVI-met is a prognostic model based on the fundamental laws of fluid dynamics and thermodynamics. It is a three-dimensional microclimate model designed to simulate the surface-plant-air interactions in an urban environment. This resolution allows the investigation of small-scale interactions between individual building outer surfaced plants. Wei (2014) Validation of ENVI-met has been attempted in several other studies. Alitoudert & Mayer used it to study a several orientations of streetscapes focusing on PET (physiologically equivalent temperature) and human thermal comfort. However, they found that the values predicted by the model were probably overstated due to higher-than-expected radiation fluxes and focused on wind speeds validation for ENVI-met's accuracy and found initial wind seeds, attempts to validate ENVI-met have been through air temperature comparisons. Initial simulations using ENVI-met showed average air temperatures and diurnal amplitude. Kerry Nice, (2011).

Data for the Proposed Models

Data of proposed models: it is calculated adopted the climatic conditions for the hottest day in the last 10 years where the highest temperature was recorded and the climatic data for the day which based on IMOS (Iraqi Meteorological Organization and Seismology), were as follows:

Table 2: Data for the Proposed Models.
Source: Authors.

Model domain	Model Location	Iraq/Baghdad, Latitude: 33, Longitude: 44	
settings	Model Geometry	Model Dimensions : x-Grids 50 / y-Grids 50 / z-Grids 30 Size of grid cell in meter, dx=4 / dy=2 / dz=1 (base height) Model rotation out of grid north: 44	
	Vegetation	Grass 25cm aver. dense	0100XX
		Palm, large trunk, dense, medium	01PLDM
		Sophora Japonica	0000s2
Simulation	Simulation cases study day	28 July 2020	
	Simulation starting time	00:00 AM	
	Simulation duration	24h	
Initial meteorological conditions	Wind speed measured in 10 m height (m/s)	3.9	
	Wind direction (deg)	315 (0=from North …180=from South)	
	Temperature of atmosphere	MIN 35 C at 06:00 AM, MAX 52 C at 16:00 PM	
	Relative humidity in 2m (%)	MIN 24 at 16:00 PM, MAX 36 at 06:00 AM.	

This chart was prepared with the help of AutoCAD and a picture was taken with a bitmap extension of the AutoCAD program so that it could be worked out and entered into ENVI -met, thus drawing the model. Adopt the scale based on ENVI-met pixels.

The Case Study: Al-Farahidi University, Baghdad, Iraq.

It is a private university located in the city of Baghdad, Airport Road, Al-Qadisiyah neighborhood, founded in 2012, formerly called Al-Farahidi University College, with three sections: Arabic, English, and media. Several years later in 2016-2017, seven new sections were developed: communication engineering, aeronautical engineering, medical equipment engineering, architecture, pathological analysis, accounting, sports science a, and physical education and in 2017-2018, four sections: dentistry, pharmacy, finance, and banking were added. Then in 2018, it became the Al-Farahidi University to include eight colleges: Faculty of Education, Faculty of Media, Faculty of Medical Technology, Faculty of Engineering Technology, Faculty of Management and Economics, Faculty of Pharmacy, Faculty of Dentistry, Faculty of Law. The number of employees of the university is 14,000 (interviews and statistics of the presidency of Al-Farahidi University).

If the University of Al-Farahidi is analyzed according to what was previously put forward in the research: according to spaces and blocks located by functional spaces, it has a first pattern central, in the center, the open spaces and sections are on the sides. It is a helicopter pattern. If depending on the place and its relationship with the surroundings, it is characterized by openness to the interior. According to the overall planning level, it is centrally and balanced similar. Depending on the structure of the university, it is radial. According to the campus, its main attribute is central. Four categories for universities exist: educational, research, productivity, and investment (Khanjar, 2015). Al-Farahidi University is considered according to this classification as an educational and investment university.

Model Configurations

A review has previously been carried out of the most important reasons for the selection of Al-Farahidi University to calculate thermal comfort and to choose the hottest days of the year in the hottest summer for the last 10 years. Accurate results were entered: following data that represent the explanation of the finished materials used in the first model.

1. The building finishing material for the side facades is brick and stone.
2. The material for finishing the facades of the front buildings is glass.
3. The material for the streets surrounding the buildings is asphalt.
4. Strip ends of walkways is the bonding stone.
5. The finishing material for surfaces is concrete tiles.
6. The material for the termination of vertical motion towers is concrete.
7. The trees on site are palms and herbs.
8. Buildings are height listed where they are 4-8-12-16-20 meters.

Three models have been developed for this study where the main goal was to reach the best thermal comfort in the movement paths within the outer spaces of the specific area of the University of Al-Farahidi.

1. Model I: a model of reality where part of the site plan of the university was identified as two buildings and surrounding streets, gardens, open spaces, and traffic paths.
2. Model II: In it, the sheds made of backed clay bricks were added along the movement path of the pedestrian at a height of 4.5 m to provide spatial shading as an attempt to improve the feeling of thermal comfort.
3. Model III: In addition to the sheds added to the second model, the sophora trees are added and the type of street tiling has been changed from asphalt to lightweight concrete to reduce the solar glare, especially in the hot summer months, due to the absence of trees and their leaves that absorb part of the falling solar rays that reflect the other part (Dhumad, & Khaza'al, 2018).

Analysis of Simulation Results for the Three Models

Analysis is based on the study of thermal comfort in movement paths of the pedestrian in the three models and the factor (PMV) has been adopted to evaluate thermal comfort in the study area. This standard is related to several other criteria taken into consideration in calculating the simulation result.:

1. TMRT: It represents the value of heat gained and radiated by bodies, streets, buildings, trees and everything present on-site. High value of the standard is a good indicator of increased thermal comfort.
2. SVF: The coverage rate in open spaces is an important indicator for calculating thermal comfort where the lower value of this standard means increasing in shaded area and thus increasing the sense of thermal comfort. (Ridha, 2022).
3. T means the degree of air temperature, where the lower value of it is an indicator to greater sense of thermal comfort. (Najah, et al., 2022).
4. W.S Means air speed on-site, a standard associated with feeling thermal comfort where in a hot dry climate, the lower airspeed means more thermal comfort.

Simulation Results for the Model I

From the review of the thermal maps of the model one can note the following.

1- The amount of TMRT in motion paths reaches 78 °C and not less than 73 °C.
2- The amount of W.S in motion paths reaches 1.8 m/ s.

3- T temperature up to 45°C and not less than 44°C in motion paths.
4- PMV amounts to 7.23 and is close to the maximum allowable for hot areas according to studies ranging from 4 to 8 for hot areas. The application of the PMV equation to external conditions in summer heat stress situations can certainly produce PMV values in excess of 4 (8 and higher). The result is numerically correct (Ridha, 2022; Najah et al. 2022; http://www.model.envi-met.com).

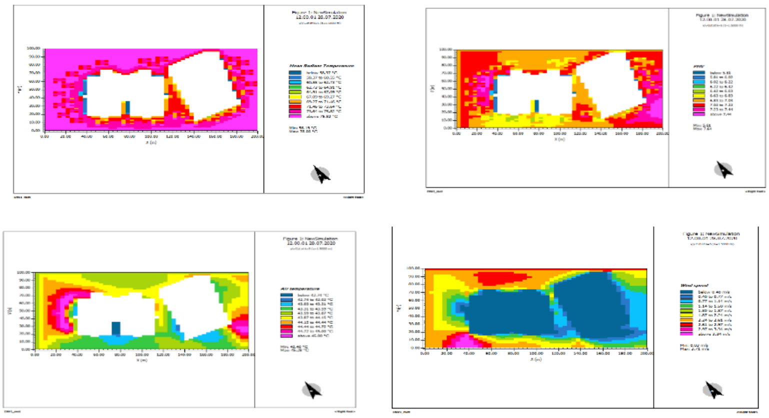
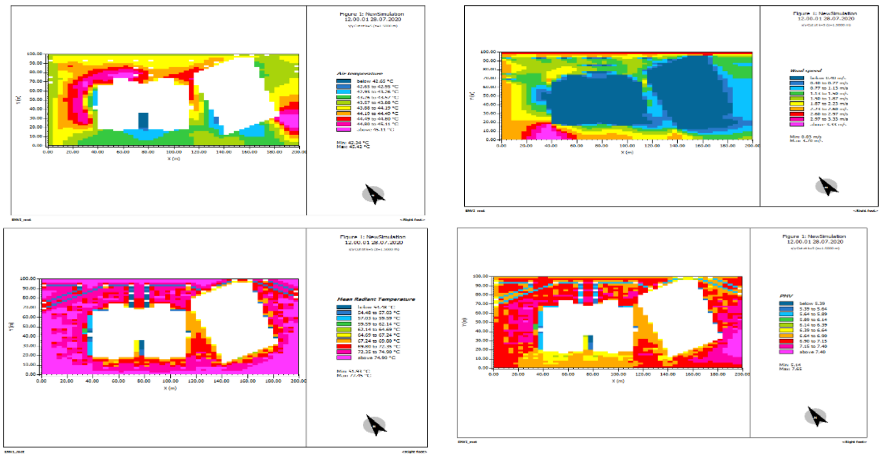


Fig. 6: Results charts showing simulation of the first model.
Source: Authors.

Simulation Results for the Model II

The thermal maps attached to the model show the following- :

1. The amount of TMRT in the movement paths decreases due to the presence of roofs to 54°C where the shading rate increases and the heat gained and radiated decreases.
2. The amount of W.S. in the movement paths is 1.13 m/s, where it scores low due to the existence of sheds that are considered breakers of air movement.
3. The air temperature T in the movement paths drops to 43°C, 2 degrees lower than the first model.
4. The amount of PMV registers a marked decrease from the first model to 5.6.



Thermal maps showed the following:

Simulation Results for the Model III

1- The amount of TMRT in movement paths up to 56°C that rise is an indicator of increased feeling of thermal comfort.
2- The amount of W.S. in the movement paths is up to 0.4 m/s, where it registers a significant decrease due to the presence of shady trees as well as roofs.
3- Air temperature T in paved traffic paths drops to 43°C.

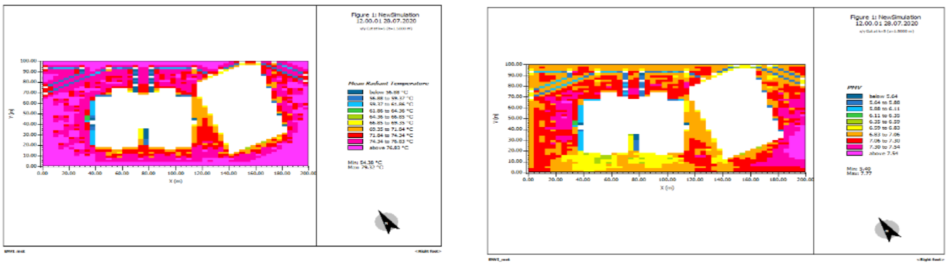


Fig. 8: Results charts showing simulation of the third model. Source: Authors.

The research aims to reach the highest thermal comfort rate in the pedestrian movement paths. The following table shows the variation in the amounts of the three models.

Analysis of the results in the three models:

Table 3: A comparison table between the results of the three models.
Source: Authors.

factor	model of reality	model of the sheds	model of sheds + tiling
PMV	6.8 – 7.2	5.6 – 7.1	5.6 – 6.5 With an increase in space
T	43.5°C – 44.15°C	43.5°C – 44.8°C	43.2°C – 44.6°C drop in temperature of the light tiling area and coverage of the entire area
TMRT	73.6°C – 78°C	57°C – 77.4°C	56.8°C – 79°C TMRT rise in light tiling area
W.S	2.2 m/s – 2.9 m/s	0.7 m/s – 1.8 m/s	0.7 m/s – 1.8 m/s The wind speed is reduced by the sheds in the pedestrian paths

Receptors Analysis

Several receptors (R) have been placed in specific locations within the pedestrian movement paths to accurately record SVF values and to see the coverage provided by the sheds and sophora trees and the effect on increase the sense of thermal comfort.

Table 3: The table shows a decrease in SVF values due to increased shading of roofs and trees and this contributes to an increased sense of thermal comfort.
Source: Authors.

R	MODEL I	MODEL II	MODEL III
1	0.85	0.71	0.71
2	0.9	0.71	0.71
3	0.9	0.8	0.8
4	0.9	0.8	0.8
5	0.93	0.8	0.78
6	0.9	0.78	0.78
7	0.95	0.67	0.67

Conclusions

In its theoretical framework, the research dealt with the design standards for universities based on a set of determinants that did not take into account the standard of thermal comfort in outdoor spaces, which constituted a major problem for the users of these spaces, especially in a hot, dry climate such as that of Iraq, which necessitated an attempt to find solutions to these growing problems. Through the use of a simulation model for the site plan of a university in

Baghdad city, the model was processed with suggested treatments, and the results were successful in improving the feeling of thermal comfort as follows:

1. The wind speed decreased when the sheds were placed in the pedestrian movement paths, reaching 2.9 km/h and were reduced to 0.7 km/h.
2. The temperature decreased in the areas of the pedestrian path movement when putting the sheds and changing the type of tiling and adding the sophora tree in the model. In reality, it reached 44.15°C while it decreased to 43°C when the temperature decreased by 9°C from the maximum degree recorded.
3. The value of radioactive heat increased in the model of sheds and light tiling in pedestrian path movement from the model of reality where it reached 78 while reaching 79 in the modified model. It gained radiated heat in shaded areas and decreased due to the increased shading rate.
4. Reducing the wind speed and temperature while increasing the radiant temperature of the streets adjacent to the movement paths contributed to increasing the feeling of thermal comfort within the pedestrian movement path for the modified model, as it changed from 7.23 to 5.6.
5. Based on the above, the proposed Model 3 is considered successful as it is PMV in hot areas ranging from 4 to 8.

Recommendations

The most important of these design factors, which were used in improving the feeling of thermal comfort of outside space for university campuses are as follows:

1. The usage of shaders in highly used roads.
2. Increasing green spaces and the usage of short, green and umbral plants instead of ones that are tall and have little shadow like palms.
3. The replacement of end-materials in movement roads to sun-reflecting and non-heat-absorbing materials.
4. Using more light colors which aid in the decrease of heat gain for surfaces.
5. The awareness of all the former and the care of outside spaces from busy roads to student gathering places to campus users actively aids the functional performance of the university.

References

Abdulateef, M. & Al-Alwan, H. A. S. (2022) The Effectiveness of Urban Green Infrastructure in Rreducing Surface Urban Heat Island. *Ain Shams Engineering Journal*, 13(1). Available at: https://doi.org/10.1016/j.asej.2021.06.012.

Dhumad, K. & Khaza'al, Sh. (2018) The Effect of Urban Land Use Changing on Green Area Neighborhoods No. 336 & 338 in Baghdad –Case Study uob. *J. Eng. Univ. Baghdad*, 24(12), pp. 1–20. Available at: https://joe.uobaghdad.edu.iq/index.php/main/article/view/j.eng.2018.12.09

Floriberta, M. et al. (2020) A review of outdoor thermal comfort indices and neutral ranges for hot-humid regions. *journal of urban-climate*, 31.

Guanghao, Li. Et. al.(2019) Sky View Factor-Based Correlation of Landscape Morphology and the Thermal Environment of Street Canyons: A Case Study of Harbin, China, *Journal Pre-proof*, pp. 1-41.

Motloch, J. (2000), Introduction to Landscape Design, *John Wily & Sons Inc. New York, U.S.A.* 2, pp. 202-205.

Musa, H. et al .(2022) Phases of Urban Development Impact on the Assessment of Thermal Comfort: A Comparative Environmental Study, *Civil Engineering Journal*, 5(8), pp.951–966. Available at: https://www.civilejournal.org/index.php/cej/article/view/3424

Muttif, S. (1995) Architecture and climate environment theoretical and applied foundations, *Abadi Center for Studies and Publishing, Sana'a, Republic of Yemen*. pp. 46

Najah, F. et al. (2022) Urban Land Use Changes: Effect of Green Urban Spaces Transformation on Urban Heat Islands in Baghdad, *Alexandria Engineering Journal*, 66, pp. 555-571. Available at: https://www.sciencedirect.com/science/article/pii/S1110016822007384

Ridha,S. (2022) The Impact of Various Patterns of Residential Building Design to Confront the Challenges in Climate Changes in an Arid Environment, Baghdad City-Case Study, *Journal Of Engineering Science And Technology*.

Rezaei, H. et al. (2021) The quantitative assessment of the effects of the morphology of urban complexes on the thermal comfort using the PMV/PPD model (a case study of Gheytariyeh neighborhood in Tehran), *International Journal of Low-Carbon Technologies*, 16, pp. 672–682.

Rizko, N. & Abdel Wahab, K. (2017) Urban agriculture as one of the ecological applications of the regenerative city. *J. Eng. Univ. Baghdad*, 23(9), pp. 64–81. Available at: https://joe.uobaghdad.edu.iq/index.php/main/article/view/89

Shaheen, B. (1988) Architecture and Climate Lecture Group in Dry Hot Areas, Courses of the Center for Continuing Education, Faculty of Engineering, University of Baghdad,. pp.3-19.

Shaheen, B. & Abd alteif (2016) Environment Friendly Eco - City. *J. Eng. Univ. Baghdad*, 22(2). Available at: https://joe.uobaghdad.edu.iq/index.php/main/article/view/264/232

Taleghani, M. et. al. (2012). Environmental Impact of Courtyards-A review and Comparison of Residential Courtyard Buildings in Different Climates. *Journal of Green Building*, 7 (2),PP. Available at: 113-136. https://doi.org/10.3992/jgb.7.2.113.

Hassan,H. (2014) Planning and Design Considerations on a SustainablCampusus, Unpublished master's Letter, Faculty of Engineering, University of Technology, pp. 6-14.

Kerry, (2011) The micro-climate of a mixed urban parkland environment , School of Geography and Environmental Science, Unpublished master's Letter, Monash University, pp. 12.

Khalil, L. (1999) Building of University Buildings Analysis in The Origins of Planning and Integrative Design, Unpublished master's Letter, Faculty of Engineering, University of Baghdad, pp. 52, pp.83-86.

Khanjar, A. (2015) Architecture of Higher Education and The Data of the Age (The Learning-Friendly Campus), Unpublished master's Letter, Faculty of Engineering, University of Baghdad, pp.23-40.

Najah, F. (2016) The Planning and Design Basics of The Universities Educational Spaces, Unpublished master's Letter, Faculty of Engineering, University of Baghdad, p. 80-83.

Ridha, S. (2017) Urban Heat Island Mitigation Strategies in an Arid Climate is Outdoor Thermal Comfort Reachable, Unpublished Ph.D. Thesis, Department of Building.

Wei, Y. (2014) Outdoor Thermal Comfort in Urban Spaces in Singapore, Unpublished Ph.D. Thesis, Department of Building, National University of Singapore.