Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Impact of Urban Formation on Outdoor Thermal Comfort in Campuses (The Campus of University of Baghdad as a Model)

Zainalabideen Abdulabass Yaseen 1*, Zaynab Radi Abass 2.
1Department of Architectural Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq.
2Department of Architectural Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq.
*Email: :zainalabideen.yaseen2204m@coeng.uobaghdad.edu.iq

ARTICLE INFO

Received: 29 Dec 2024

Revised: 12 Feb 2025

Accepted: 27 Feb 2025

ABSTRACT

Thermal comfort in university outdoor spaces is considered a fundamental requirement for achieving sustainable and livable environments that support the diversity of student activities and events through the effective influence of the physical and morphological structures of the university environment. The research problem emerged from the lack of knowledge about the impact of urban formation on thermal comfort in outdoor university spaces. The research hypothesized that changes in urban formation have a significant impact on the levels of thermal sensation experienced by campus users. The research aims to develop a theoretical framework that clarifies the relationship between urban formation and outdoor thermal comfort. The research adopted a descriptive approach and an analytical study to explore the relationship between urban formative indicators and the levels of thermal sensation. These factors were analyzed through a comparative evaluation of the values of the predicted mean vote (PMV) index between 1989 and 2024, using environmental simulation (ENVI-met v.5.7.1) to measure the impact of formation changes over time. The results confirmed that the decrease in green coverage and open spaces, along with the increase in paving and external wall areas, contributes to increased heat stress in university outdoor spaces.

Keywords: Campus, Environmental Simulation, Outdoor Thermal Comfort, Urban Formation.

1. INTRODUCTION

The term "campus" appeared in the mid-eighteenth century, and the first American universities were located outside cities in scenic landscapes (Hebbert, 2018). In 1774, Princeton University was the first to call itself a campus, which initially contained only educational and residential components, but later also acquired recreational infrastructure (Goloshubin & Pavlova, 2022). The term "campus" is used to define the types of physical components (mass components and outdoor spaces related to higher education). Buildings and spaces integrate with boundaries and green spaces to delight the viewer and give a physical definition and a special sense of place (Dober, 2000). While idealists define the campus as a small city containing an urban environment (Ar-Rifai, 1983), the campus is also described as a model of a small city. Among the ideas that considered the university a miniature part of the city are those of Oscar Newman and Louis Sert (Frey, 1964). Urban formation has been defined as a branch of "urban morphology" that deals with the form and structure of settlements and studies complex types of forms (Kristjánsdóttir, 2019). In this way, urban morphology studies the formation of urban form as well as the relationship between individual forms and the city as a whole, starting from the city's formative years to its subsequent transformations (Al-Saaidy, 2020). Thus, the campus plan, in reference to the elements of urban morphology, includes three main components: buildings, landscape, and movement paths.

Thermal comfort is defined by the LEED rating system for green and sustainable buildings as "the mental state experienced by building occupants expressing their satisfaction with the surrounding thermal environment" (Kamoona, 2016). While studies on indoor thermal comfort are numerous, measuring outdoor thermal comfort remains elusive. However, several studies conducted at the beginning of the current century began with the use of indoor thermal comfort assessment tools and then adapted them, especially since the factors affecting indoor thermal comfort are the same as those affecting outdoor thermal comfort, but they vary more over time and space, in addition to the multiple human activities in various urban areas such as streets, squares, playgrounds, and parks (Givoni, 2003). From the above, we find that there is great interest in providing enjoyable, stimulating, and comfortable outdoor environments in the outdoor spaces of university campuses, as they are an essential component of the university environment, contributing effectively to achieving psychological comfort for users by meeting thermal comfort requirements. Many of these scientific studies and research have addressed the factors affecting thermal comfort in university outdoor spaces, including urban heat islands, landscapes, landscape architecture, urban engineering, and others. They have also addressed the engineering and environmental solutions that must be provided in outdoor environments in order to achieve the required levels of thermal comfort in these environments (Wang et al., 2017; Yu et al., 2020; Eslamirad et al., 2022; Zhang et al., 2023; Guo et al., 2024; Qi et al., 2025a). Some studies have investigated the impact of different types of design elements on the outdoor thermal environment around university campuses in subtropical urban areas (Xi et al., 2012). Another study evaluated a sustainable urban solution as a prototype using the physiological equivalent temperature (PET) index by creating a neutral outdoor thermal comfort zone suitable for social gatherings while reducing local heat stress (Abaas & Khalid, 2023). Some have focused on studying outdoor thermal comfort in the urban environment of the Mustansiriyah district in Baghdad through the impact of a network of green infrastructure and the expansion of green vegetation cover (Ibraheem, 2023). The application of three outdoor thermal comfort indices, namely, physiologically equivalent temperature (PET), standard effective temperature (SET), and universal thermal climate index (UTCI), was evaluated in different outdoor environments on the campus of Xi'an University, China (Jing et al., 2024). The analysis of outdoor thermal comfort conditions and thermal sensation was addressed by determining the relationship between the predicted mean vote (PMV), the PET, and the actual thermal sensation of users in the university environment (Khalili et al., 2022). The effect of increased urban surface reflectance on outdoor thermal comfort was studied using PET as an indicator of outdoor thermal comfort on campus (Taleghani, 2018). Some studies have focused on calculating spatial measures of outdoor thermal comfort by using the Eddy3D tool to model and analyze outdoor thermal comfort for a specific area around the campus (Kastner, 2020). Another study addressed the effect of urban morphology, vegetation, and surface albedo on outdoor university environments and thermal comfort, using urban environmental simulation and measuring outdoor thermal comfort using PET (Yang et al., 2022). Another study addressed the role of urban engineering in reducing the effects of urban heat islands and achieving outdoor thermal comfort in Baghdad using urban environmental simulation (Abaas, 2020). Some discussed the importance of flexible, environmentally and socially sustainable urban planning for Baghdad, both in the past and present (Abaas, 2021). According to the aforementioned studies, studies related to human thermal comfort in outdoor university environments are still limited, especially in the area of its direct relationship to the urban planning of the university environment, especially since many previous studies have addressed outdoor thermal comfort and urban planning in Baghdad, and few studies have addressed the relationship between them in university environments such as the University of Baghdad campus. Accordingly, this research will measure, through a practical experimental study, the impact of urban planning (physical and formal structures) of university buildings and outdoor spaces and its impact on the outdoor thermal comfort of University of Baghdad users. The study was divided into three parts, the first and second of which were descriptive. The first described the most important previous studies in the field of outdoor thermal comfort of the university environment and identified the knowledge gap in the research field. The second part described the research sample historically and geographically, defined the urban components of the sample, and described the measurement method and mechanism used in the research. While the third part focused on calculating the values of the formative indicators of the University of Baghdad campus for the years 1989 and 2024, and measuring the thermal comfort in the external spaces of the university campus by using the environmental simulation program (Envi-met v.5.7) and comparing and analyzing the results quantitatively and qualitatively.

2. MATERIAL AND METHODS

The research adopted the descriptive methodology and an analytical study of the University of Baghdad campus, as a model for applying the measurement ruler to determine the effect of the urban formation of the university campus on the thermal comfort of users in the outdoor spaces. As shown in Fig. 1, the values of the urban formation indicators are calculated for the research sample models for the years 1989 and 2024, before and after the urban morphological changes that occurred on the university campus, especially after the addition of many buildings and spaces and the new expansion works that occurred in the university plan from the beginning of the nineties of the last century until now. Thermal comfort levels in the university environment are measured using the predicted mean vote index (PMV) through conducting environmental simulations of urban models and using the urban environmental simulation program (Envi-met V.5.7.1). The simulation is for the month of June, specifically the summer solstice (21/06), at 12:00 pm for a group of locations in the university's outdoor spaces that represent the gathering and movement

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

centers for campus users, as shown in Fig. 3 and Fig. 4. Conducting a comparative analysis of the achieved results using the descriptive method and statistical analysis (correlation analysis) to demonstrate the relationship and impact of urban formative indicators with the predicted heat sensation index.

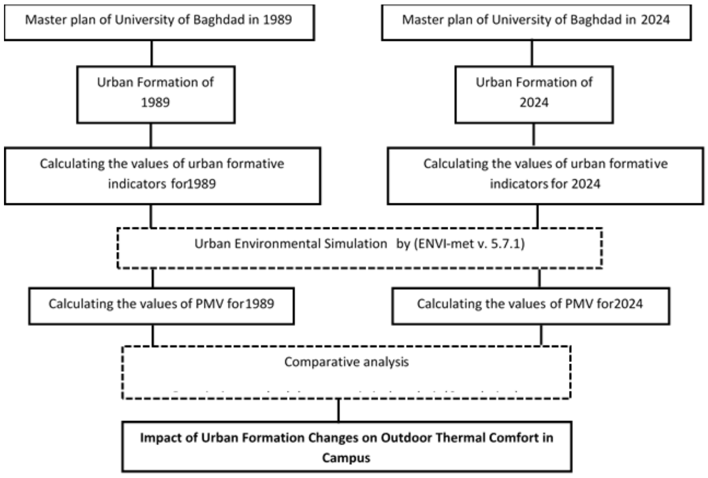


Figure 1. Framework of the study methodology

3. CASE STUDY (UNIVERSITY OF BAGHDAD CAMPUS)

3.1 Historical Background

The University of Baghdad campus is considered one of the most distinguished architectural landmarks in Iraq. The master plan of the University was developed in 1960 by the architects Collaborative (TAC), a consulting firm led by the renowned architect Walter Gropius, one of the most prominent architects of the 20th century, a global pioneer of the modernist movement, and the founder of the Bauhaus school. At the time, the University of Baghdad was regarded as the largest architectural project undertaken by Gropius during his lifetime, and one of the most of the impactful examples of the modernist architecture in the Middle East (Al-Alwan et al., 2022).

3.2 Geographical Location

The University of Baghdad is located in the Al-Jadriya district near the Tigris River, within the city of Baghdad, Iraq. It lies at the coordinates (44°22′54′′E 33°16′12′′N) and covers a total area of 346.23 hectares (Mahdi, 2024). The campus enjoys a strategic location, as it is surrounded by the river on three sides. Fig. 2 and Fig. 3 show the master plans of the University of Baghdad campus for the years 1989 and 2024.

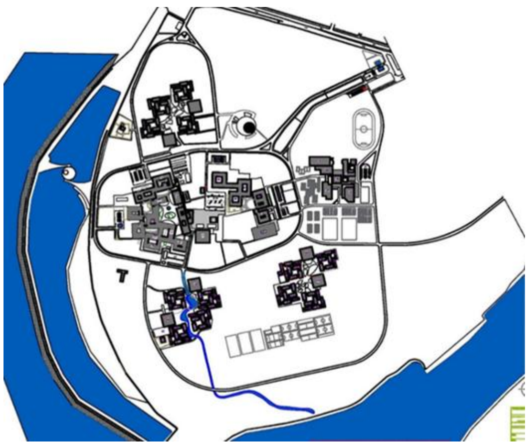


Figure 2. The Master Plan of The University of Baghdad in 1989

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

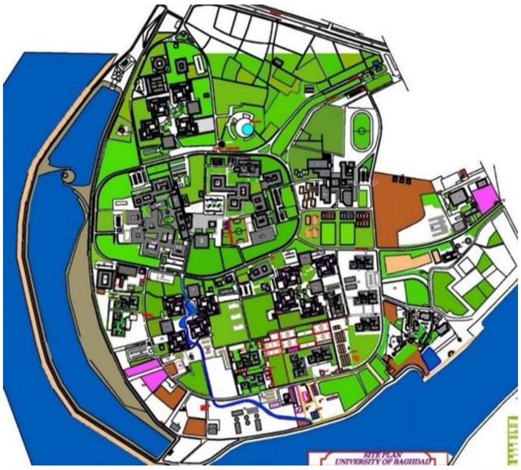


Figure 3. The Master Plan of The University of Baghdad in 2024.

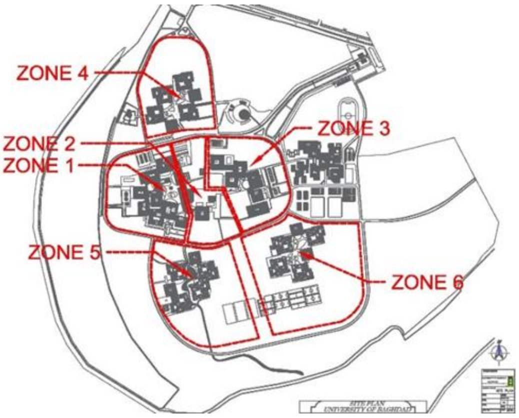


Figure 4. Measurement Locations for the Master Plan of University of Baghdad in 1989.

Figure 5. Measurement Locations for the Master Plan of University of Baghdad in 2024.

4. Urban Formative Indicators

Urban formation is a complex subject in terms of its spatial characteristics and interrelationships. It is measured using a variety of indicators, which quantify numerous morphological relationships-such as numbers, dimensions, sizes, areas, directions, and percentages-observed among the various elements of urban form. These indicators are used to describe, classify and understand the built environment and its spatial structure in recent years, most studies and research have become increasingly interested in the environmental approach, to investigate the various basic

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

structures that embody the relationship between urban factors and different climatic conditions (elzeni et al., 2021). There have been numerous studies on the local patterns of urban development in Iraq (Hemer 2014) (Khalid, Abaas, and Fadhil 2021) (Khalid and Radi Abaas 2021) (Kadhim and Abaas 2023).Some of them even specialize in developing local patterns for different urban forms and researching ecological and environmental variables and their impact (Khalid and Radi Abaas 2021) (Abdul-Sahib, Abaas, and Al-Shammaa 2021) (Salih & Abaas, 2022) (Al-Azzawi and Abaas 2023) (Al-Azzawi and Abaas 2023). However, there is an absence of research-identified local campus patterns. Table 1 below indicates the most important urban formation indicators related to environmental aspects and thermal comfort in outdoor spaces, and the methods of measuring and describing them, which include:

UGS area represents the area of each urban green space cover, **Urban area** refers to the area of each urban area. **F** is the building area; **A** is the total area of the urban area; **Fx** is the total floor area of the building, **Ax** is the area of the general site; **Havg** is the average of building height; and **BD** is a building density.

5. Environmental Modeling

The formative model of the University of Baghdad campus was developed for the year 1989 Fig. 6, and for the year 2024 Fig. 7, based on the master plans of the university campus and using the environmental simulation program (ENVI-met v.5.7.1). Table 2 present the data entered in the environmental modeling process.

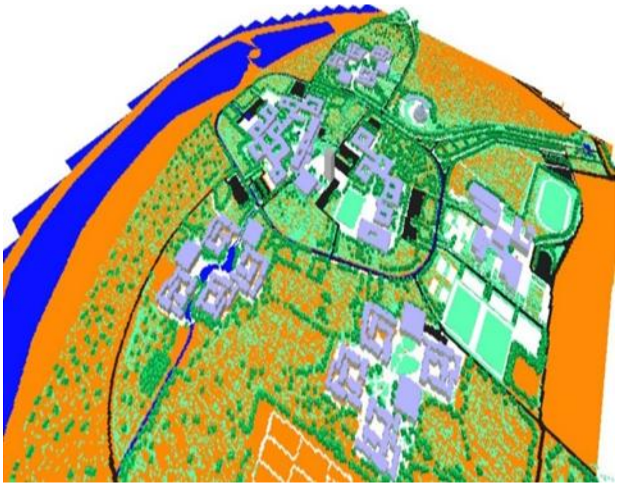


Figure 6. The Formative model of the University of Baghdad campus in 1989.

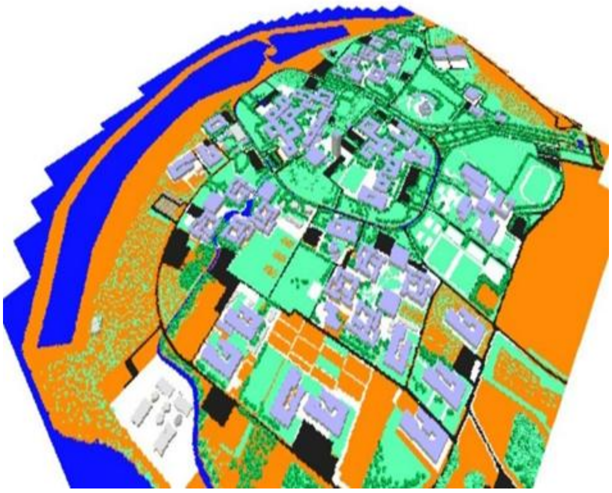


Figure 7. The Formative model of the University of Baghdad campus in 2024.

Table 1. Urban Formative Indicators, Measurement Method, Units, Description, and References.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Indicators	Measurement method	Units	Description	References
Green Coverage Ratio (UGSC)	$UGSC = \frac{UGS\ area}{URBAN\ area}$ (1)	%	Describes the percentage of areas covered by trees, shrubs, or grass within urban boundaries.	[38]
Building coverage ratio (BCR)	$BCR = \frac{\Sigma F}{A}$ (2)	%	Describes the percentage of total building area to the total area of the urban area.	[39]
Open Space Ratio (OSR)	GIS	%	Describes the percentage of open space to the total land area within an urban area.	[40]
Wall Building Area (WALL)	3D Model	M2	Describes the total surface area of a building's exterior walls.	[41]
Floor Area Ratio (FAR)	$FAR = \frac{Fx}{Ax}$ (3)	%	Describes the ratio of ground floor area to overall site area. It is used to measure land development density.	[42]

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Total Building Scale (BS)	$BS = \frac{Havg}{BD}$ -4	-	Describes the ratio of the average building height to the building's building density.	[43]
Paving ratio (PAVE)	GIS	%	Paving ratio refers to the proportion of the hard surface portion within a circle of a given radius.	[44]

Table 2. Data input into the environmental modeling process

Simulation Date and Time	(05 Am-05 Pm) -2024- 1989\06\21
Model Dimensions	60 x 620 x550
Grid Cell Dimensions	dx=3 dy=3 dz=3
Model Building Materials	[0200LO] Loamy Soil [0200ST] Asphalt Road [0200PG] Concrete Pavement Gray [0200WW] Deep Water [0200XX] Grass 25 cm aver. Dense Palm, Large trunk, Dense Albizzia Tree [0200C4] Concrete Wall Block [0200WR] Concrete Roof
Maximum Temperature (C)	42.76
Minimum Temperature (C)	24.87
% Relative Humidity	17.25
Wind Speed (m/s)	3.51
Wind Direction (degrees)	309

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

6. OUTDOOR THERMAL COMFORT

The Predicted Mean Vote (PMV) is used to assess levels of thermal comfort in outdoor spaces. PMV is a thermal sensation indicator that predicts the average sensation vote, on a numerical scale, for a group of people for any given combination of (air temperature, average radiant temperature, air velocity, humidity, activity, and clothing) (Fanger, 1970). It refers to a numerical scale as shown in Table 3. When the thermal comfort equation is met, the PMV value for a group of people equals zero. Therefore, thermoregulation (vasodilation, vasoconstriction, sweating, or shivering) can maintain thermal balance even outside the comfort limits. The PMV value is measured through the environmental simulation program (ENVI-met) after the simulation process is completed and through the BIOMET icon, as shown in Fig. 8.

Table 3. PMV value based on Fanger.

Cold	cool	Slightly cool	Natural	Slightly Warm	Warm	Hot
-3	-2	-1	0	1+	2+	3+

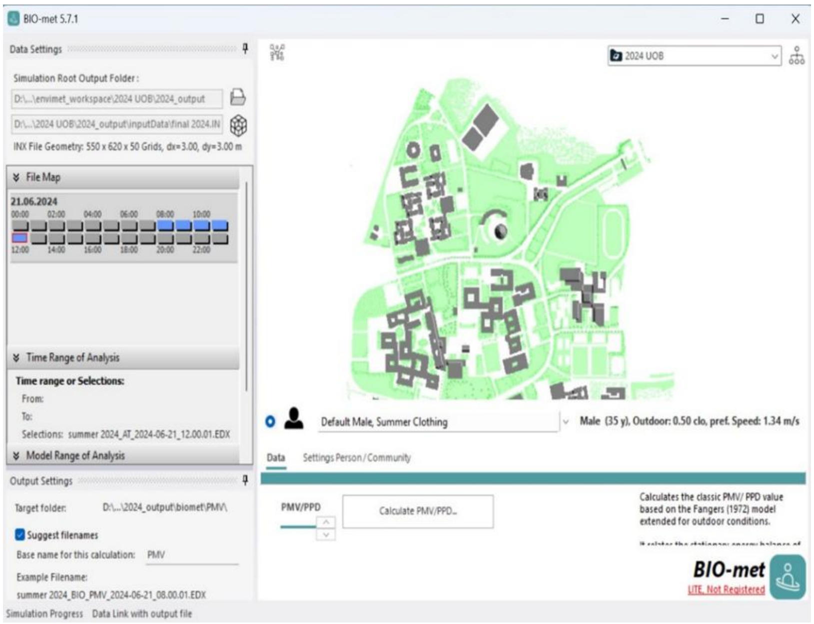


Figure 8. Method for Calculating PMV Through Environmental Simulation.

7. Results

7.1 Urban Formative Indicators Values

The values of the urban formative indicators mentioned previously in Table 1, were calculated in advance through the master plans of the University of Baghdad campus and using specialized engineering programs, as shown in Tables 4, and 5.

Table 4. Urban Formative Indicators Values for the year 1989.

Urban Formative Indicators	Zone1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Green Coverage Ratio (UGSC)	0.017	0.015	0.019	0.032	0.026	0.028

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Building coverage ratio (BCR)	0.023	0.013	0.015	0.018	0.018	0.018
Open Space Ratio (OSR)	0.034	0.028	0.030	0.041	0.040	0.038
Wall Building Area (WALL)	25593	11400	16100	19656	19656	19656
Floor Area Ratio (FAR)	0.010	0.007	0.007	0.006	0.006	0.006
Total Building Scale (BS)	456.5	1000	633.3	583.3	583.3	583.3
Paving ratio (PAVE)	0.011	0.009	0.004	0.012	0.012	0.012

Table 5. Urban Formative Indicators Values for the year 2024.

Urban Formative Indicators	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Green Coverage Ratio (UGSC)	0.017	0.015	0.009	0.020	0.024	0.026
Building coverage ratio (BCR)	0.023	0.013	0.021	0.025	0.019	0.020
Open Space Ratio (OSR)	0.034	0.028	0.026	0.038	0.039	0.034
Wall Building Area (WALL)	25593	11400	25600	29500	22608	29858
Floor Area Ratio (FAR)	0.011	0.007	0.009	0.009	0.009	0.009
Total Building Scale (BS)	456.5	1000	452	420	552.6	525
Paving ratio (PAVE)	0.011	0.009	0.005	0.017	0.016	0.019

A comparative analysis of these values reveals the following:

- **Zone 1:** No significant changes were observed in most urban formative indicators between 1989 and 2024. The values of the UGSC, BCR, OSR, WALL, BS, and PAVE remained stable, with the exception of a slight increase in the value of the FAR factor by 10%, which indicates a slight increase in the percentage of land use without any change in the shape of the urban mass.
- **Zone 2:** There is a remarkable stability in the values of most urban formative factors between 1989 and 2024.
- **Zone 3:** UGSC decreased by 52.63% for 2024. OSR decreased by 13.33%. BCR increased significantly to 40%. WALL increased by 59%. FAR increased by 28.57%. BS decreased by 28.63%. PAVE increased by 25%.
- **Zone 4:** There was a 37.5% decrease in UGSC. BCR increased by 38.89%. OSR decreased by 7.32%. WALL increased by 30%. FAR increased by 30%. BS decreased by 28%. PAVE increased by 41%.**Zone 5:** There was a 7.7% decrease in UGSC, a 5.6% increase in BCR, a 2.5% decrease in OSR, a 15% increase in WALL, a 50% increase in FAR, a 5.3% decrease in BS, and a 33.3% increase in PAVE**.**
- **Zone 6:** There was a 7.1% decrease in UGSC, an 11.1% increase in BCR, a 10.5% decrease in OSR, a 51% increase in WALL, a 50% increase in FAR, a 10% decrease in BS, and a 58.3% increase in PAVE.

Fig. 9-15 below shows the amount of changes in urban formative indicators between 1989 and 2024.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

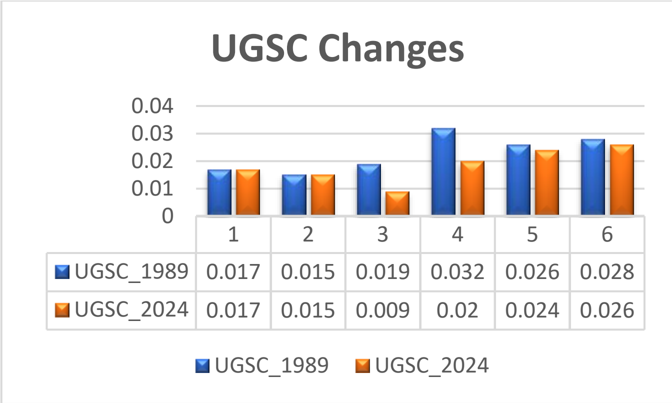


Figure 9. UGSC Changes between 1989-2024.

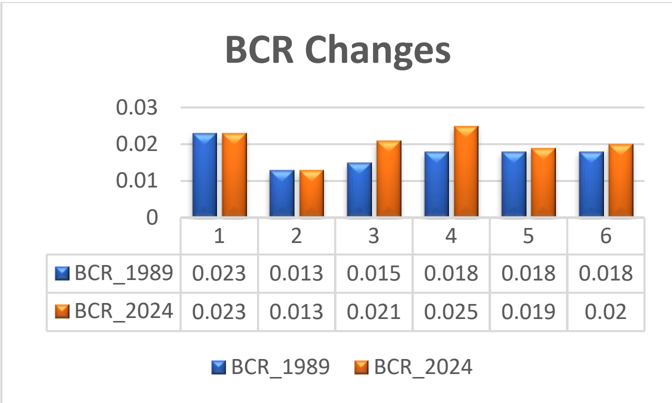


Figure 10. BCR Changes between 1989-2024.

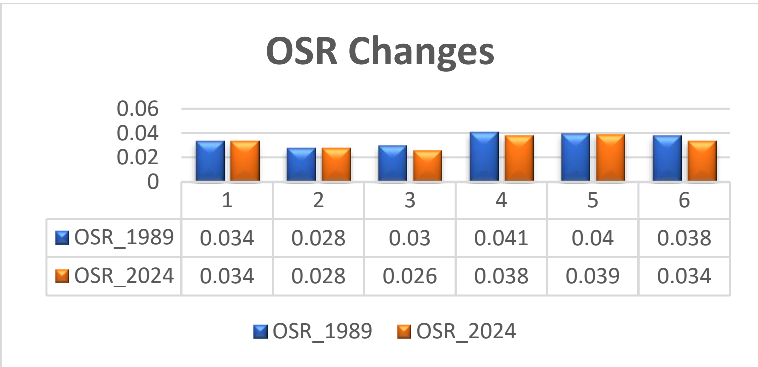


Figure 11. OCR Changes between 1989-2024.

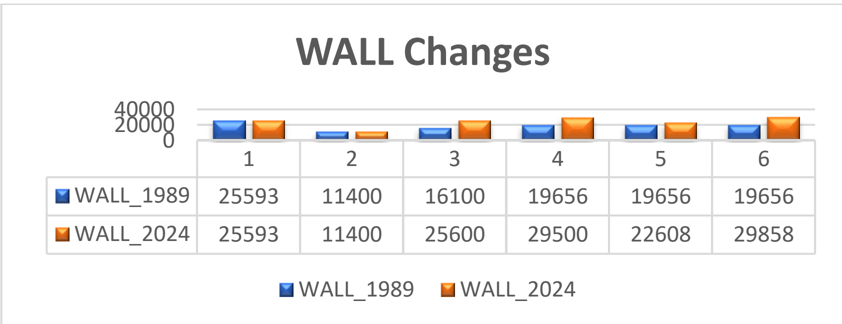


Figure 12. WALL Changes between 1989-2024.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

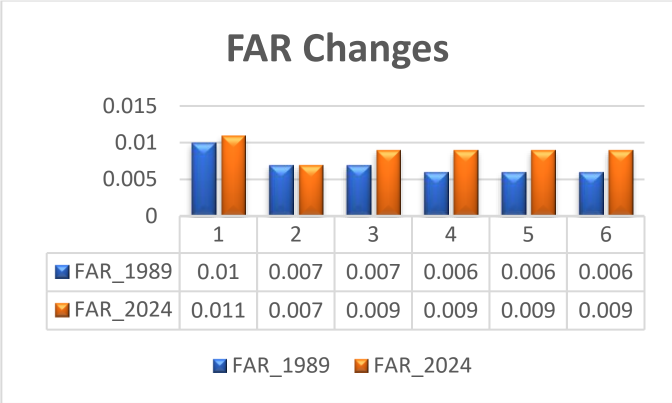


Figure 13. FAR Changes between 1989-2024.

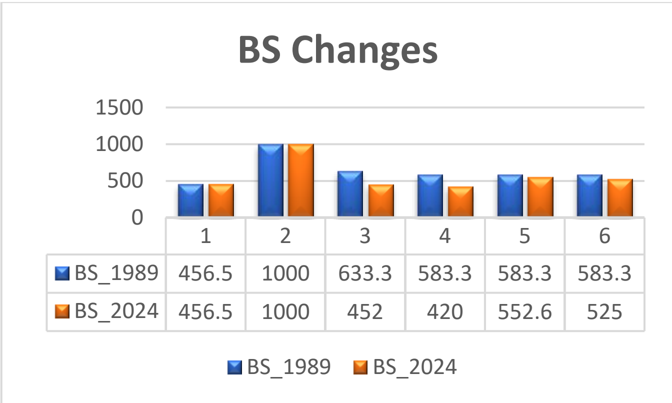


Figure 14. BS Changes between 1989-2024.

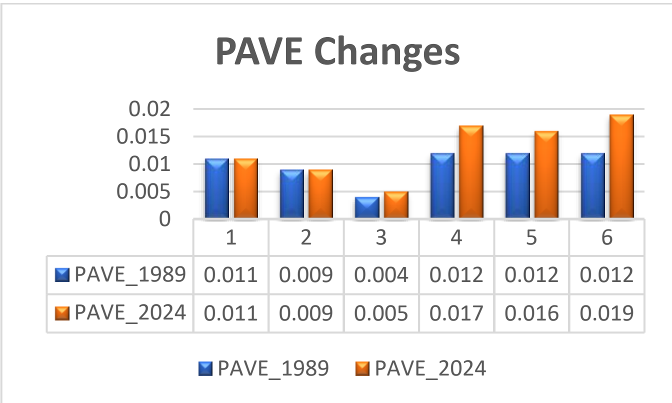


Figure 15. PAVE Changes between 1989-2024.

7.2 Environmental Simulation Values

7.2.1. 1989 Values:

The urban environmental simulation for the University of Baghdad campus model of 1989 was conducted using (ENVI-met v.5.7.1) to evaluate thermal comfort levels in outdoor university's spaces. The results of the predicted mean vote index (PMV) for the outdoor thermal sensation were shown in Fig. 16 and shown in Table 6 for all the specified zones at 12:00 pm. It is noted that the lowest value of the average voting was recorded in zone 5, where it was 4.5, and it indicates a very hot average thermal sensation based on Fanger.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Table 6. PMV values of 1989.

Time	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
12:00 PM	4.9	4.9	4.8	5.2	4.5	5.2

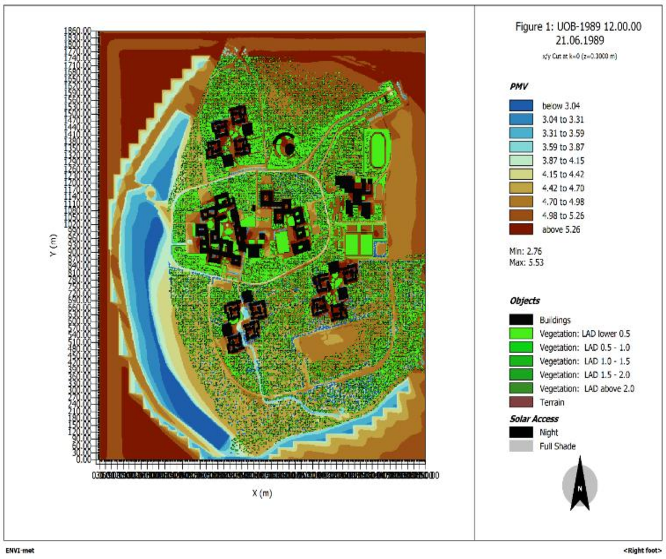


Figure 16. Simulation Values of 1989.

7.2.2. 2024 Values:

The urban environmental simulation for the University of Baghdad campus model of 2024 was conducted using (ENVI-met v.5.7.1) to evaluate thermal comfort levels in outdoor university's spaces. The results of the predicted mean vote index (PMV) for the outdoor thermal sensation were shown in Fig. 17, and shown in Table 7 for all the specified zones at 12:00 pm. It is noted that the lowest value of the average voting was recorded in zone 5, where it was 6.9, indicating a very hot average thermal sensation based on Fanger.

Table 7. PMV values of 2024.

Time	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
12:00 pm	7.5	7.5	8.1	8.0	6.9	**8.1**

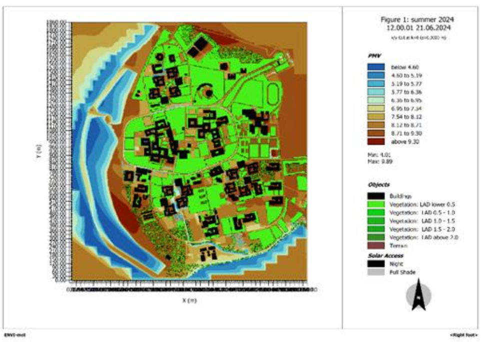


Figure 17. Simulation Values of 2024.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

7.3 Discussion of Results

7.3.1. Descriptive Analysis of Results:

The results of comparing the PMV values between 1989 and 2024, as shown in Fig. 18, reveal a significant increase in the levels of thermal sensation in the outdoor spaces of the University of Baghdad campus. The PMV average rose from a less severe level in 1989 to a severe thermal level in 2024, reflecting numerous changes in the structure of the outdoor spaces and their climatic behavior, as follows:

Vegetation coverage at zones (3, 5, and 6) declined slightly to moderately, with the average UGSC declining from a relatively high value in 1989 to a lower value in 2024. Although the quantitative difference appears small, its qualitative impact is profound. Afforestation—even in small amounts—improves thermal comfort by reducing direct solar radiation, providing shaded areas, and enhancing moisture evaporation. As these elements decreased, the average of PMV increased due to increased surface heat absorption by pavements and walls. Therefore, the decline in vegetation cover was a major factor in increasing the average thermal sensation values at all zones.

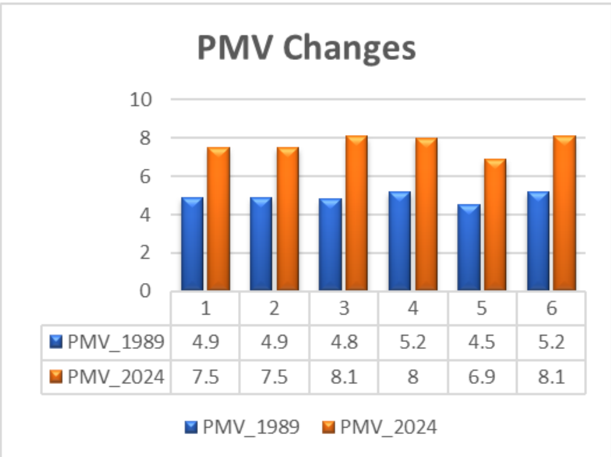
There is an increase in the area of building walls in zones (3, 4, 5, 6), which means that there is an increase in the amount of building mass exposed to solar radiation. This mass stores heat during the day and radiates it later, which leads to the heat remaining even after midday, which leads to higher PMV values, especially during the midday hours. Therefore, the increase in building mass causes an increase in the negative impact on the average external thermal comfort.

There is a slightly decrease in the values of the total building scale (BS) in zones (3, 4, 5, 6), which reflects a slight imbalance in the size of the built mass, which leads to a weak urban balance between mass and space, and consequently affects natural ventilation and increases in external temperatures and thermal sensation levels.

The increased values of the building coverage ratio (BCR) at zones (3, 4, 5, and 6), and the floor area ratio (FAR) at zones (1, 3, 4, 5, and 6), reflect the increased building density, which has contributed to the reduction of areas subject to natural cooling or shading. Even a small increase in these ratios leads to the narrowing of open spaces, restricting air dynamics and thus raising the air temperature in outdoor spaces.

There is a significant decrease in the open space ratio (OSR) in zones (3, 4, 5, and 6), which represent the primary breathing space for the urban environment. With the decrease in vegetation cover and the increase in the proportion of paved surfaces, these areas become hot surfaces that absorb and re-radiate heat. Therefore, reducing the proportion of these spaces increases the intensity of use and thus doubles the external thermal sensation.

There was a significant increase in the percentage of PAVE pavement at zones (3, 4, 5, and 6), as the increased proportion of external surface materials (such as asphalt and concrete tiles) led to a significant increase in surface temperature, due to the reduced ability of these materials to reflect solar radiation or absorb moisture. Accordingly, this increased proportion contributed to an increase in the external air temperature and the average thermal rating.



	1	2	3	4	5	6
PMV_1989	4.9	4.9	4.8	5.2	4.5	5.2
PMV_2024	7.5	7.5	8.1	8	6.9	8.1

Figure 18. PMV Changes Between 1989-2024.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

7.3.2. Correlation Analysis Between Urban Formative Indicators and PMV Index:

A correlation analysis was conducted between the values of changes in urban formative indicators and the values of change in the predicted mean vote index PMV between the years 1989 and 2024 for the University of Baghdad campus, in order to determine the effects of these factors on the expected thermal sensation and the strength and direction of the relationship between them. Table 8 below shows the results of the analysis, as also shown in Fig. 19.

Table 8. Results of the Correlation Analysis Between the Formative Indicators and the PMV Index.

Urban Formative Indicators	Correlation Factor	Interpretation of the Relationship
UGSC	-0.624	**A moderate negative correlation indicates that increased green coverage leads to a lower PMV, which enhances thermal comfort.**
BCR	0.688	**A strong positive correlation indicates that increased structural coverage is associated with a higher PMV, which means increased perception of heat.**
OSR	-0.911	**A strong negative correlation, indicating that increasing open spaces significantly reduces the PMV index, contributing to improved thermal comfort.**
WALL	0.803	**Strong positive correlation, as increased wall area is associated with higher temperature, resulting in higher PMV.**
FAR	-0.093	**Very weak correlation, indicating that changes in floor area ratio have no significant effect on PMV.**
BS	-0.046	**Weak and negative correlation, indicating that change in the construct measure does not significantly contribute to change in the PMV index.**
PVAE	0.652	**A moderate positive correlation indicates that increased paving volume contributes to a higher PMV index, enhancing the heat island effect.**

The results of the correlation analysis achieved in Table 8 and shown in Fig. 19-25 can be interpreted as follows:

- The relationship between UGSC-PMV is moderately inverse, with green cover acting as a natural thermal insulator through its ability to cool by evaporation, absorb direct and reflected solar radiation, and provide shade. Therefore, increasing green cover leads to lower temperatures and a reduction in the average thermal sensation in outdoor spaces.
- The relationship between BCR and PMV is moderately direct, as construction materials such as concrete and others have a high capacity to absorb heat during the day and radiate it at night. This leads to higher temperatures in outdoor spaces and, consequently, a higher average thermal sensation.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

- The relationship between OSR and PMV is strongly inverse, as open outdoor spaces allow for better airflow, which enhances natural ventilation and reduces heat buildup in urban environments. This, in turn, results in lower temperatures and a feeling of thermal comfort.
- The relationship between WALL-PMV is strongly positive, as the exterior walls of buildings absorb and store large amounts of heat during the day and re-radiate and release it back into the urban environment at night. An increase in this relationship leads to higher air temperatures and an increase in the average thermal sensation value.
- There is a very weak correlation between the floor area ratio (FAR) and the building envelope (BS) with the predicted mean vote (PMV). This is due to the poor ability of these ratios to represent the physical composition of the urban environment and, consequently, their poor ability to convey thermal comfort in outdoor spaces.
- The relationship between PAVE and PMV is moderately direct, as exterior surfaces paved with asphalt or concrete absorb large amounts of solar radiation and re-radiate it as heat. Therefore, increasing its percentage leads to higher temperatures and an increase in the average thermal sensation in outdoor spaces.

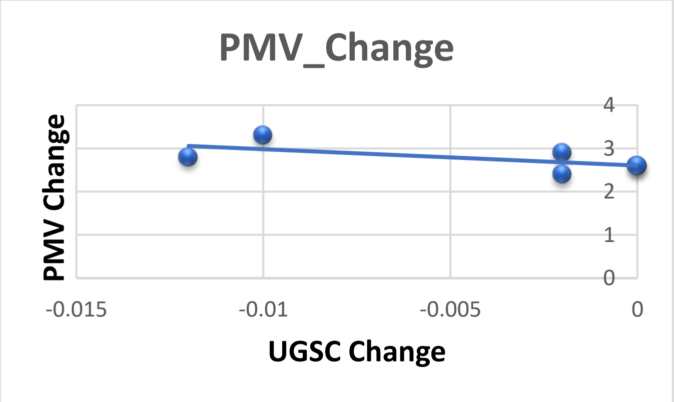


Figure 19. Correlation Between UGSC-PMV.

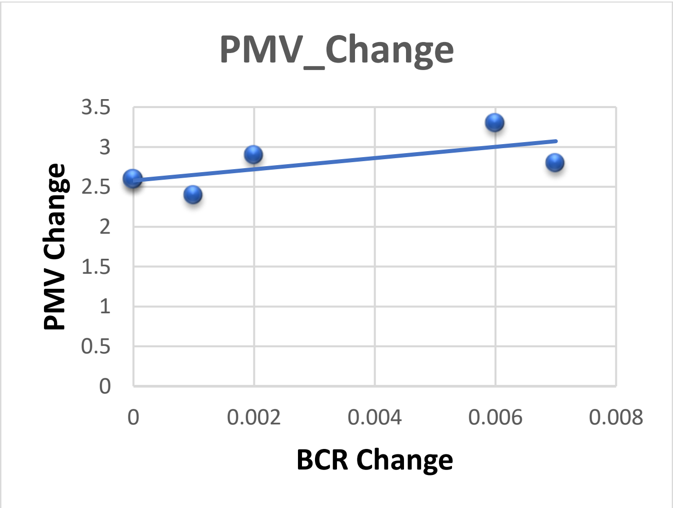


Figure 20. Correlation Between BCR-PMV.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

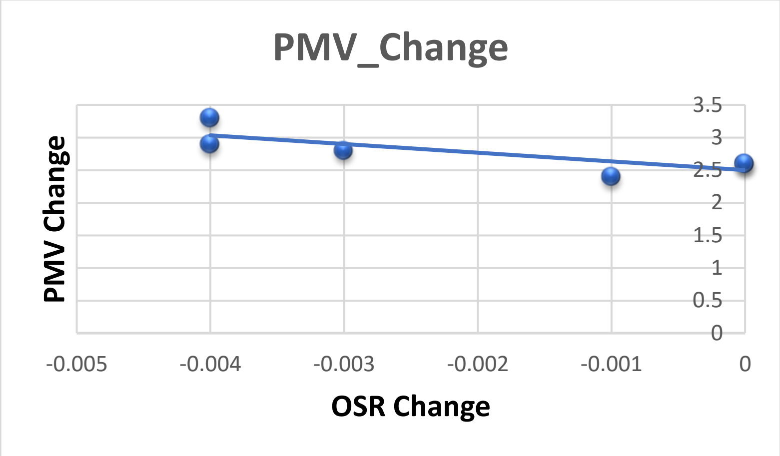


Figure 21. Correlation Between OSR-PMV.

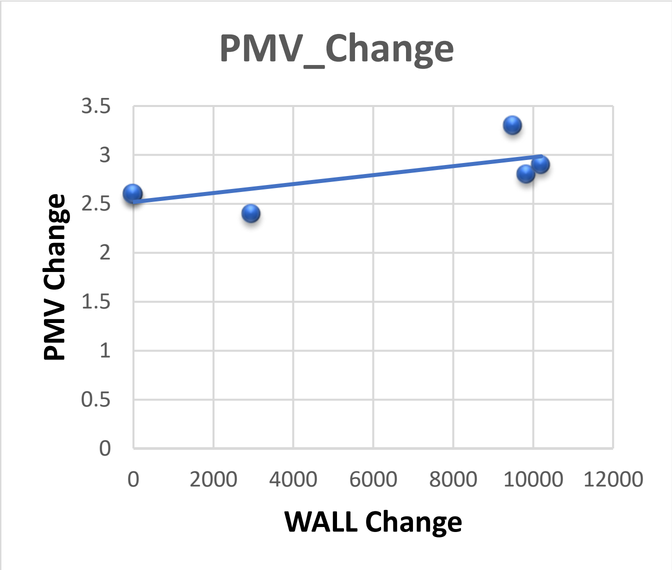


Figure 22. Correlation Between WALL-PMV.

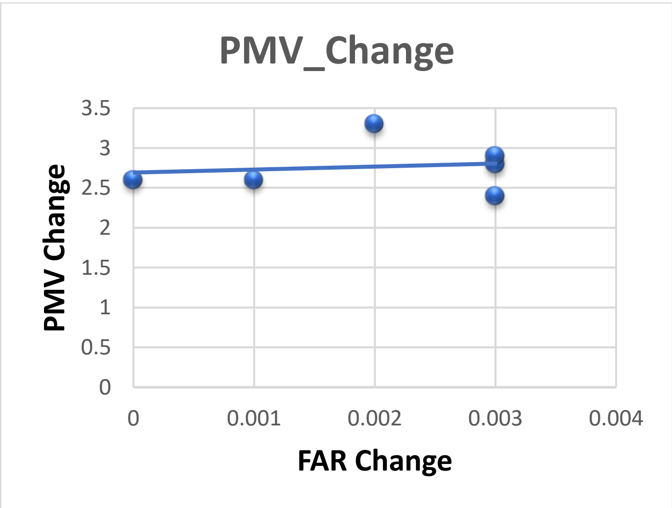


Figure 23. Correlation Between FAR-PMV.

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

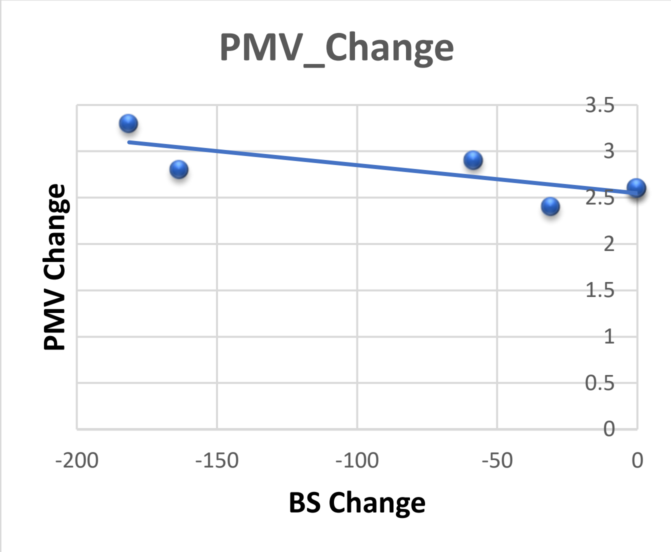


Figure 24. Correlation Between BS-PMV.

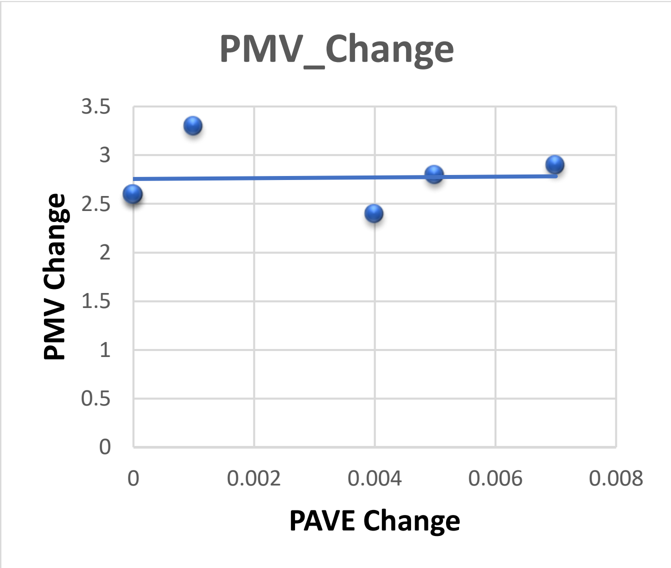


Figure 25. Correlation Between PAVE-PMV.

8. CONCLUSIONS

Based on the results achieved from the urban environmental simulation process of the urban formative models of the University of Baghdad campus for the years 1989-2024, to measure the levels of external thermal comfort, and after conducting descriptive and statistical analyses of the research results, the study concluded the following:

- There is a significant increase in the average PMV between 1989 and 2024, from (4.91) to (7.68), which reflects a general thermal deterioration in the campus environment, and weakens the possibility of using outdoor spaces during critical periods during working hours.
- The urban formative indicators did not change much in some zones such as (1,2), and despite that, a significant increase in PMV values was observed, indicating that they were affected by many other factors such as climate changes that affected the general thermal performance.
- The decline in vegetation cover, the increase in building mass and paving, and the shrinkage of open spaces played a major role in raising the average projected PMV by +2.77, a significant difference that is classified as severe environmental degradation.

- Zones that retained some plant cover or balanced open spaces, such as zone 5, recorded the lowest PMV values, which confirms the possibility of achieving a more balanced thermal environment in light of rising temperatures, provided that the urban design is well thought out.
- The relationship between urban formation and average thermal sensation can also be considered qualitative, as changes in urban formation have transformed the nature of the campus from a freely usable outdoor space to an uncomfortable, hot environment, especially during peak hours.
- The study showed that the built environment of the University of Baghdad campus has not developed sufficiently to adapt to climate change or contain its effects. Outdoor spaces remain exposed to solar radiation, with a lack of functional integration between urban and natural elements.

Acknowledgment

Thanks, and appreciation to the staff and engineers of the Department of Construction and Projects at the University of Baghdad Presidency for providing support and master plans of University of Baghdad campus.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Zainalabideen A.Y.: Preparing and conducting the research.

Zaynab R.A.: Supervision and discussion of the research.

REFERENCES

[1] Abaas, Z. R. (2020). Impact of development on Baghdad's urban microclimate and human thermal comfort. Alexandria Engineering Journal, 59(1), 275–290. https://doi.org/10.1016/j.aej.2019.12.040
[2] Abaas, Z. R. (2021). Toward Resiliency Through Sustainable Urban Formation in Baghdad.
[3] Abaas, Z. R., & Khalid, Z. (2023). Towards local sustainability: A case study to evaluate outdoor urban spaces in Baghdad using physiological equivalent temperature index. City and Environment Interactions, 20, 100115. https://doi.org/10.1016/j.cacint.2023.100115
[4] Al-Alwan, H. A. S., Al-Bazzaz, I. A., & Mohammed Ali, Y. H. (2022). The potency of architectural probabilism in shaping cognitive environments: A psychophysical approach. Ain Shams Engineering Journal, 13(1), 101522. https://doi.org/10.1016/j.asej.2021.06.008
[5] Al-Azzawi, L. R., & Abaas, Z. R. (2023a). Potential powers of urbanism. 020055. https://doi.org/10.1063/5.0105474
[6] Al-Azzawi, L. R., & Abaas, Z. R. (2023b). Power between potentiality and actuality in urban sustainability and urban resilience. 060004. https://doi.org/10.1063/5.0168589
[7] Al-Saaidy, H. J. E. (2020). Urban Morphological Studies (Concepts, Techniques, and Methods). Journal of Engineering, 26(8), 100–111. https://doi.org/10.31026/j.eng.2020.08.08
[8] Ar-Rifai, T. D. E. D. (1983). The New University Environment: A 20th Century Urban Ideal (Europe, America). University of Pennsylvania.
[9] Chen, J., Pellegrini, P., Yang, Z., & Wang, H. (2023). Strategies for Sustainable Urban Renewal: Community-Scale GIS-Based Analysis for Densification Decision Making. Sustainability, 15(10), 7901. https://doi.org/10.3390/su15107901
[10] Dober, R. P. (2000). Campus landscape: Functions, forms, features. John Wiley & Sons.
[11] elzeni, mostafa, elmokadem, ashraf, & badawy, nancy. (2021). Classification of Urban Morphology Indicators towards Urban Generation. Port-Said Engineering Research Journal, 0(0), 0–0. https://doi.org/10.21608/pserj.2021.91760.1135
[12] Eslamirad, N., Sepúlveda, A., De Luca, F., & Sakari Lylykangas, K. (2022). Evaluating Outdoor Thermal Comfort Using a Mixed-Method to Improve the Environmental Quality of a University Campus. Energies, 15(4), 1577. https://doi.org/10.3390/en15041577
[13] Fanger, P. O. (1970). Thermal comfort. Analysis and applications in environmental engineering.
[14] Frey, M. and D. J. (1964). Tropical architecture. Рипол Классик.
[15] Givoni, B. , N. M. , S. H. , P. O. , Y. Y. , F. N. and B. S. (2003). Outdoor comfort research issues. . . Energy and Buildings, 35(1), 77–86.

[16] Goloshubin, V., & Pavlova, V. (2022). Campus: University or a Modern Urban Structure? Civil Engineering and Architecture, 10(3), 913–922. https://doi.org/10.13189/cea.2022.100313
[17] Guo, F., Miao, S., Xu, S., Luo, M., Dong, J., & Zhang, H. (2024). Multi-Objective Optimization Design for Cold-Region Office Buildings Balancing Outdoor Thermal Comfort and Building Energy Consumption. Energies, 18(1), 62. https://doi.org/10.3390/en18010062
[18] Hebbert, M. (2018). The campus and the city: a design revolution explained. Journal of Urban Design, 23(6), 883–897.
[19] Huang, C., & Xu, N. (2022). Climatic factors dominate the spatial patterns of urban green space coverage in the contiguous United States. International Journal of Applied Earth Observation and Geoinformation, 107, 102691. https://doi.org/10.1016/j.jag.2022.102691
[20] Ibraheem, B. A. and A. Z. R. (2023). . Evaluating Urban Thermal Comfort through a Holistic Micro-Climate Model: Baghdad as a Case Study. Al-Farabi for Engineering Sciences, 2(1), 12–12.
[21] Jing, W., Qin, Z., Mu, T., Ge, Z., & Dong, Y. (2024). Evaluating thermal comfort indices for outdoor spaces on a university campus. Scientific Reports, 14(1), 21253. https://doi.org/10.1038/s41598-024-71805-5
[22] Kadhim, A. J., & Abaas, Z. R. (2023). An analytical study of the spread patterns of the informal settlements in Baghdad and sustainable urban improvement approaches. 020063. https://doi.org/10.1063/5.0109671
[23] Kamoona, G. M. I. A. R. (2016). Passive Design Strategies to Enhance Natural Ventilation in Buildings "Election of Passive Design Strategies to Achieve Natural Ventilation in Iraqi Urban Environment with Hot Arid Climate." Journal of Engineering, 22(6), 16–38. https://doi.org/10.31026/j.eng.2016.06.13
[24] Kastner, P. and D. T. (2020). Predicting space usage by multi-objective assessment of outdoor thermal comfort around a university campus.
[25] Kesarovski, T., & Hernández-Palacio, F. (2023). Time, the other dimension of urban form: Measuring the relationship between urban density and accessibility to grocery shops in the 10-minute city. Environment and Planning B: Urban Analytics and City Science, 50(1), 44–59. https://doi.org/10.1177/23998083221103259
[26] Khalid, Z., Abaas, Z. R., & Fadhil, A. (2021). Achieving urban sustainability by revitalizing the performance of Islamic geometric pattern on residential façades. Periodicals of Engineering and Natural Sciences (PEN), 9(4), 729. https://doi.org/10.21533/pen.v9i4.2393
[27] Khalid, Z., & Radi Abaas, Z. (2021). Defining the aspects of the local urban sustainability: Eco-cities as a model. IOP Conference Series: Earth and Environmental Science, 754(1), 012005. https://doi.org/10.1088/1755-1315/754/1/012005
[28] Khalili, S., Fayaz, R., & Zolfaghari, S. A. (2022). Analyzing outdoor thermal comfort conditions in a university campus in hot-arid climate: A case study in Birjand, Iran. Urban Climate, 43, 101128. https://doi.org/10.1016/j.uclim.2022.101128
[29] Kristjánsdóttir, S. (2019). Roots of Urban Morphology. Iconarp International J. of Architecture and Planning, 7(Special Issue "Urban Morphology"), 15–36. https://doi.org/10.15320/ICONARP.2019.79
[30] Mahdi, S. A. and J. S. N. (2024, July). Utilizing Geospatial Techniques for Change Detection of the Baghdad Campus landscape from 1988 to 2022.
[31] Pan, X.-Z., Zhao, Q.-G., Chen, J., Liang, Y., & Sun, B. (2008). Analyzing the Variation of Building Density Using High Spatial Resolution Satellite Images: the Example of Shanghai City. Sensors, 8(4), 2541–2550. https://doi.org/10.3390/s8042541
[32] Qi, Y., Chen, L., Xu, J., Liu, C., Gao, W., & Miao, S. (2025a). Influence of university campus spatial morphology on outdoor thermal environment: A case study from Eastern China. Energy and Built Environment, 6(1), 43–56. https://doi.org/10.1016/j.enbenv.2023.08.004
[33] Qi, Y., Chen, L., Xu, J., Liu, C., Gao, W., & Miao, S. (2025b). Influence of university campus spatial morphology on outdoor thermal environment: A case study from Eastern China. Energy and Built Environment, 6(1), 43–56. https://doi.org/10.1016/j.enbenv.2023.08.004
[34] Salih, Z. S., & Abaas, Z. R. (2022). Towards Sustainable Local Tourism to Conserve the Natural Environment: Foundations of Sustainable Ecolodge Design. In Geotechnical Engineering and Sustainable Construction (pp. 769–779). Springer Singapore. https://doi.org/10.1007/978-981-16-6277-5_62
[35] Taleghani, M. (2018). The impact of increasing urban surface albedo on outdoor summer thermal comfort within a university campus. Urban Climate, 24, 175–184. https://doi.org/10.1016/j.uclim.2018.03.001
[36] Wang, Y., de Groot, R., Bakker, F., Wörtche, H., & Leemans, R. (2017). Thermal comfort in urban green spaces: a survey on a Dutch university campus. International Journal of Biometeorology, 61(1), 87–101. https://doi.org/10.1007/s00484-016-1193-0
[37] Wei, R., Xu, C., Song, D., Tong, H., & Chen, Z. (2023). Study on the Correlation Analysis between Urban Morphological Factors and Microclimate Based on Empirical Methods on a University Campus in a Hot-Summer–Cold-Winter Region. Buildings, 13(8), 1920. https://doi.org/10.3390/buildings13081920

Journal of Information Systems Engineering and Management
2025, 10(49s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[38] Wong, N. H., Jusuf, S. K., Syafii, N. I., Chen, Y., Hajadi, N., Sathyanarayanan, H., & Manickavasagam, Y. V. (2011). Evaluation of the impact of the surrounding urban morphology on building energy consumption. Solar Energy, 85(1), 57–71. https://doi.org/10.1016/j.solener.2010.11.002
[39] Xi, T., Li, Q., Mochida, A., & Meng, Q. (2012). Study on the outdoor thermal environment and thermal comfort around campus clusters in subtropical urban areas. Building and Environment, 52, 162–170. https://doi.org/10.1016/j.buildenv.2011.11.006
[40] Yang, L., Liu, J., & Zhu, S. (2022). Evaluating the Effects of Different Improvement Strategies for the Outdoor Thermal Environment at a University Campus in the Summer: A Case Study in Northern China. Buildings, 12(12), 2254. https://doi.org/10.3390/buildings12122254
[41] Yu, Z., Chen, S., & Wong, N. H. (2020). Temporal variation in the impact of urban morphology on outdoor air temperature in the tropics: A campus case study. Building and Environment, 181, 107132. https://doi.org/10.1016/j.buildenv.2020.107132
[42] Zhang, S., Li, S., Shu, L., Xiao, T., & Shui, T. (2023). Landscape Configuration Effects on Outdoor Thermal Comfort across Campus—A Case Study. Atmosphere, 14(2), 270. https://doi.org/10.3390/atmos14020270