



# **A FRAMEWORK DEVELOPMENT FOR CLASSIFYING URBAN CONFIGURATION INDICATORS ACCORDING TO ENVIRONMENTAL IMPACTS: USING ECOTECT SOFTWARE**

**Duaa Hameed Alkhuzai<sup>1</sup>, Hamzah S. Al-Mamoori<sup>2</sup>,  
and Raed Fawzi Mohammed Ameen<sup>3,4</sup>**

<sup>1</sup> Postgraduate student at Architectural Department, Babylon University, Iraq,  
Email:eng455.duaa.hameed@student.uobabylon.edu.iq.

<sup>2</sup> Prof. Doctor, Architectural Engineering Dept. / Babylon University, Iraq,  
Email:Eng.hamzah.salman@uobabylon.edu.iq.

<sup>3</sup> BRE Institute for Sustainable Engineering, Cardiff University, Cardiff, UK.

<sup>4</sup> Prof. Doctor, Architectural Engineering Dept. / Karbala University, Iraq,  
Email:raedameen@uokerbala.edu.iq.

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## **ABSTRACT**

The rapid urbanization of the modern cities, alongside growing concerns about urban heat islands and climate change, has presented increasing challenges to cities, particularly regarding their resilience to these changes and ensuring their environmental sustainability. Urban configuration plays a pivotal role in influencing the climate conditions, and this influence differs according to environmental conditions of the region. Hence the importance of studying and analyzing each urban configuration separately based on its unique environmental characteristics. Based on the foregoing, this research paper aims to address the following question: How do urban configuration contribute to affecting the level of thermal comfort within urban spaces? The research adopts an analytical approach and employing the simulation Ecotect software to investigate the degree to which urban form affects thermal comfort in outdoor spaces, by an analytical study conducted on two different urban patterns in Baghdad, Iraq: the gridiron pattern and the organic pattern. The study results showed that the organic planning prevalent in ancient cities, achieved the best thermal performance in hot, dry climates. Where, the results showed that the Mean Radiant Temperature (MRT) was decreased by more than 15 degrees in comparison to the gridiron pattern. In conclusion, the results confirm that



adopting an appropriate urban pattern significantly contributes to enhancing external thermal comfort and mitigating the effects of climate change.

**KEYWORDS**

Thermal comfort, Ecotect Software, Urban Configuration, Urban Configuration indicators.

## **1. INTRODUCTION**

Urban Configuration, with its various elements, is considered one of the decisive factors in determining the level of thermal comfort within the urban environment (Sanagar Darbani et al., 2018). Open spaces gain particular importance as they constitute an integral part of the city's urban Configuration, with their physical characteristics contributing to shaping the urban climate and directly affecting the quality of life in urban areas, especially concerning the level of outdoor thermal comfort for users (Shehata, 2023). In this context, the research aims to develop a methodology to understand the relationship between urban Configuration and the thermal environment of urban spaces, by conducting a systematic review of relevant literature to investigate the urban Configuration indicators influencing thermal comfort. The previous literature revealed that most studies classified urban form indicators based on the foundations and principles of urban planning, with limited attention to the environmental factor in classifying urban indicators and determining their impact on thermal comfort. Furthermore, many of these studies lacked analytical tools that would allow for a more understanding of the relationship between urban Configuration and environmental factors, such as environmental simulation programs. Based on the above, the research problem emerged as a lack of comprehensive methodological frameworks that consider the environmental dimension when classifying urban form indicators, coupled with the limited use of advanced digital technologies, particularly environmental simulation techniques, in analyzing and measuring the impact of these indicators on achieving thermal comfort in urban spaces. Therefore, this research aims to develop a comprehensive methodological framework for classifying urban form indicators, taking environmental considerations as the basis of the study. These considerations play a crucial and fundamental role in the urban form process and the construction of its specific indicators, as the basic indicators of urban form are linked, in one way or another, to the thermal environment. Consequently, controlling the thermal environment and improving external thermal comfort becomes possible through controlling the elements of urban form (Parsons, 2019).

## **2. METHODOLOGY**

This study aims to analyze urban Configuration indicators, and examine their impact on climatic variables. An analytical methodology was adopted to achieve the study's objectives by using the environmental simulation Ecotect software.

## **3. LITERATURE REVIEW**

This research focuses on studies that quantitatively analyze urban configuration, in contrast to the predominant qualitative analyzes prevalent in the literature concerning urban form. The

studies included in this review were classified according to several criteria:

1. Scale: In this research, The scales of urban form classified into three levels: city scale (macro scale), neighborhood scale (meso scale), and urban block scale (micro scale).
2. Time Frame: The selected studies spanned different periods from 2015 to 2023.
3. The number of indicators in each study, including studies that analyzed a single indicator, and studies that covered a comprehensive set of indicators.
4. Selection of studies that presented comparable research outcomes despite variations in the number of indicators, measurement techniques and tools used.

After reviewing the previous literature, it was found that dozens of studies have explored this field, with each study employing a different set of indicators. This variation highlights the differences in the importance and prioritization of the selected indicators across different geographical regions. Table 1 shows a summary of the indicators mentioned in the literature that are related to the environmental aspect, and the rest of the indicators related to the social, economic and other aspects were excluded. The review of previous studies resulted in (8 main indicators) and (37 secondary indicators) on the three scales (total, medium, and small).

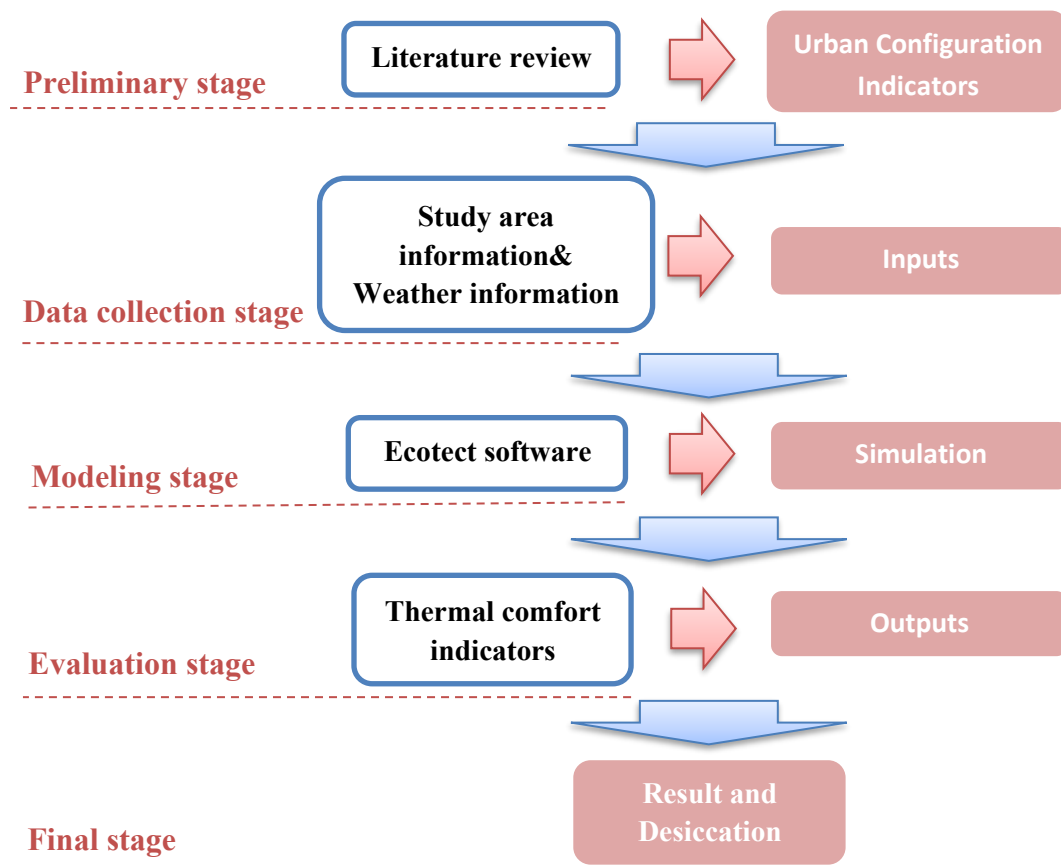


Fig. 1. Research Methodology

**Table 1. Urban Configuration Indicators**

| Main Indicator        | Sub-indicators                            | Scale                | Source   |
|-----------------------|---|----------------------|--|
| 1.Urban configuration | Complexity index                          | Macro- Scale         | (Mehr & Kheirkhah, 2021)<br>(Fleischmann et al., 2021)   |
|                       | Compactness index                         | Macro- Scale         | (Mehr & Kheirkhah, 2021)<br>,(Fleischmann et al., 2021)  |
|                       | Urban fabric pattern Spatial distribution | Macro- Scale         | (Esmaeilpour Zanjani et al., 2023)<br>(Fleischmann et al., 2021)   |
| 2.Land Use            | Urban Diversity                           | Macro and Meso Scale | (Abdelmonem et al., 2016),<br>(Fleischmann et al., 2021)   |
|                       | Infrastructure                            | Macro and Meso Scale | (Esmaeilpour Zanjani et al., 2023),<br>(Mehr & Kheirkhah, 2021)  |
|                       | Access to services                        | Macro and Meso Scale | (Mehr & Kheirkhah, 2021),<br>(Abdelmonem et al., 2016)<br>(Esmaeilpour Zanjani et al., 2023)                         |
| 3.Density of building | The distance between buildings            | Meso-Scale           | (Abdul Rahman, Mahmoud, 2017)  |
|                       | Average height                            | Meso-Scale           | (Mirabi & Nasrollahi, 2020),<br>,(Abu Zaid, et al., 2019)  |
|                       |   | Meso-Scale           | (Arsiya Ravari & Mazloomi, 2015),<br>(elzeni et al., 2021), (Wang et al., 2023)                                      |
|                       | Sky view factor (SVF)                     | Meso-Scale           | (Chen et al., 2021),( elzeni et al., 2021), (Shehata, 2023),<br>(Wang et al., 2023)                                  |
|                       | Built-up area density                     | Macro and Meso Scale | (Arsiya Ravari & Mazloomi, 2015),<br>( elzeni et al., 2021),( Fleischmann et al., 2021), (Shehata, 2023)             |
|                       | Ratio of open space                       | Macro and Meso Scale | (elzeni et al., 2021), (Fleischmann et al., 2021), (Shehata, 2023)   |
| 4.Population density  | Ratio of built-up area to open space      | Macro and Meso Scale | (Fleischmann et al., 2021),<br>(Abdelmonem et al., 2016)   |
|                       | Number of people per unit of area         | Micro and Meso Scale | (Abdelmonem et al., 2016)<br>(Mehr & Kheirkhah, 2021)  |
|                       | Type of activity                          | Micro and Meso Scale | (Al-Saaidy & Alobaydi, 2021),<br>(Olayemi, O. A.,et al.,2020)  |
|                       | Volume of pedestrian flow                 | Micro and Meso Scale | (Al-Saaidy & Alobaydi, 2021)   |
| 5.Urban blocks        | Hours of operation                        | Micro and Meso Scale | (Al-Saaidy & Alobaydi, 2021)   |
|                       | Configuration of building                 | Micro Scale          | (Mirabi & Nasrollahi, 2020),(Abu Zaid, et al., 2019), (Abdul Rahman, Mahmoud, 2017)                                  |
|                       | Orientation                               | Micro Scale          | (Arsiya Ravari & Mazloomi, 2015),<br>(Abdul Rahman, Mahmoud, 2017),<br>(Qian WU, et al, 2015)                        |
|                       |   | Micro Scale          | (Y. Chen et al., 2021),(elzeni et al., 2021) ,(Shehata, 2023),<br>(Fleischmann et al., 2021), (Qian WU, et al, 2015) |
|                       | Facade details                            | Micro Scale          | (Mirabi & Nasrollahi, 2020),<br>(Abdul Rahman, Mahmoud, 2017)  |
|                       | Height to width ratio                     | Micro Scale          | (Y. Chen et al., 2021), (elzeni et al., 2021), (Shehata, 2023)   |
| 6.Urban space         | Properties of building materials          | Micro Scale          | (Esmaeilpour Zanjani et al., 2023),<br>( Alyasari, et al, 2018)  |
|                       | Space ratios                              | Micro Scale          | (Abdul Hamid et al., 2019)   |
|                       | Space hierarchy                           | Micro and Meso Scale | (Al-Mosawy et al., 2020)   |

| Main Indicator           | Sub-indicators                    | Scale                | Source   |
|--------------------------|-----------------------------------|----------------------|--|
|                          | Space Configuration               | Micro Scale          | (Abdul Hamid et al., 2019)   |
|                          | Space scale                       | Micro Scale          | (Abdul Hamid et al., 2019)   |
|                          | Space enclosure degree            | Micro Scale          | (Abdul Hamid et al., 2019)   |
|                          | Space function type               | Micro Scale          | (Esharjabi, 2019)  |
| 7.Street                 | Street configuration              | Micro and Meso Scale | (Arsiya Ravari & Mazloomi, 2015), (Bao et al., 2023), (Fleischmann et al., 2021) |
|                          | Street Orientation                | Micro and Meso Scale | (Arsiya Ravari & Mazloomi, 2015), (Y. Chen et al., 2021), (Shehata, 2023)        |
|                          | Properties of finishing materials | Macro- Scale         | (Esmacilpour Zanjani et al., 2023)   |
|                          | Height to Width Ratio (H/W)       | Micro and Meso Scale | (S. Chen et al., 2020), (elzeni et al., 2021), (Fleischmann et al., 2021)        |
|                          | Road network density              | Micro and Meso Scale | (Shehata, 2023), (Abdul Rahman, Mahmoud, 2017)                                   |
|                          | 8.Green areas                     | Shading              | Macro and Meso Scale   |
| Green space ratio        |                                   | Macro and Meso Scale | (S. Chen et al., 2020),( Y. Chen et al., 2021), (Abdul Rahman, Mahmoud, 2017)    |
| Water surface area ratio |                                   |                      | (Al-Mosawy et al., 2020)   |

#### 4. THE PRACTICAL FRAMEWORK OF THE STYDY

The research practical framework involved a comprehensive analytical of two different urban configurations within the Rusafa region of Baghdad, Iraq. The selected case studies illustrate contemporary and traditional urban patterns in Baghdad, thereby highlighting the city's architectural, historical, and geographical diversity of the region. Fig.2 present study areas, which consist of two different urban patterns. Area (A) has an organic design, while Area (B) has a grid-based planning pattern, where it relies on organizing urban Configuration within a grid of rectangular blocks.

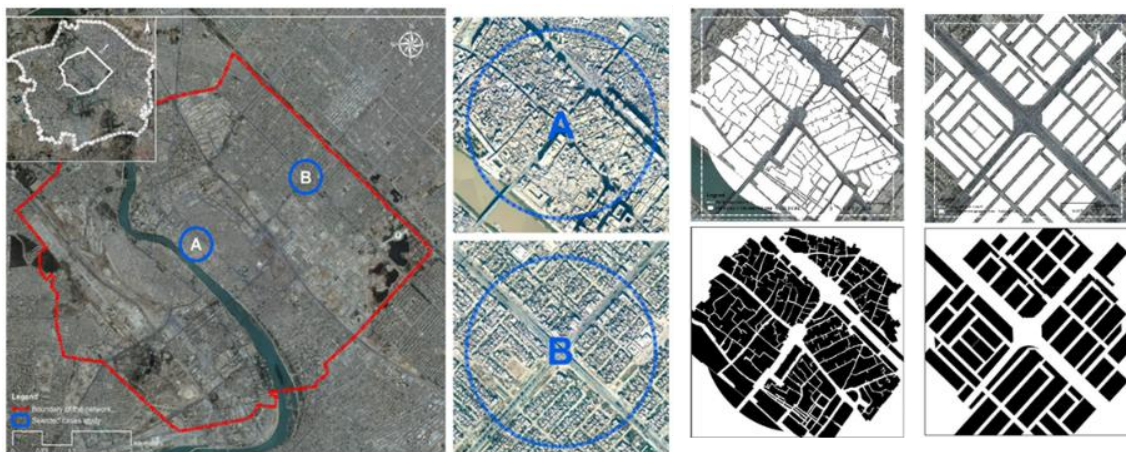


Fig. 2 The Study Area

##### 4.1. Climatic data for the study Area

The study area is located in Baghdad, positioned at a longitude of 44° E and a latitude of 33° N. The climate of this region is hot-dry climate in the summer and a cold-dry climate in the

winter. To assess the impact of urban Configuration on thermal comfort levels, the days of measurement were carefully selected to ensure an accurate representation of prevailing conditions. The researcher selected June 21 (the summer solstice) to conduct the simulation, as the sun reaches its highest elevation above the horizon on this date. The following charts illustrate the climatic data of the region, including average temperatures, humidity levels, wind speed and frequency, and rainfall rates throughout the year. These data were extracted using the weather tool of the Ecotect software.

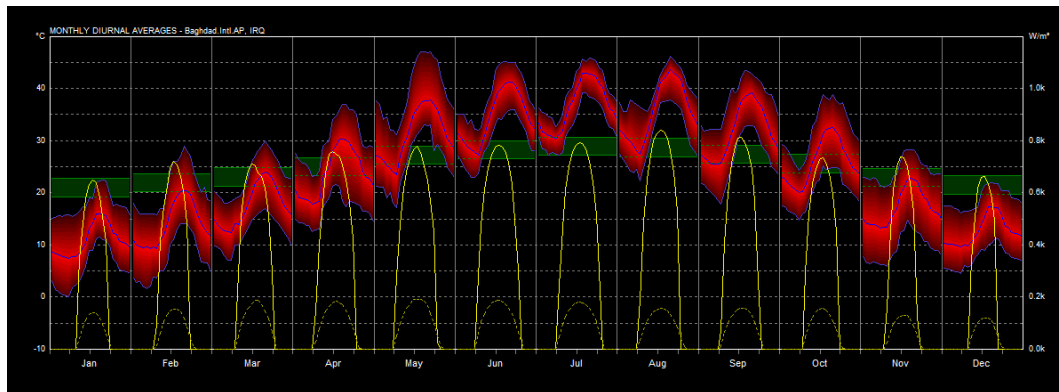


Fig.4 Average monthly temperatures in Baghdad

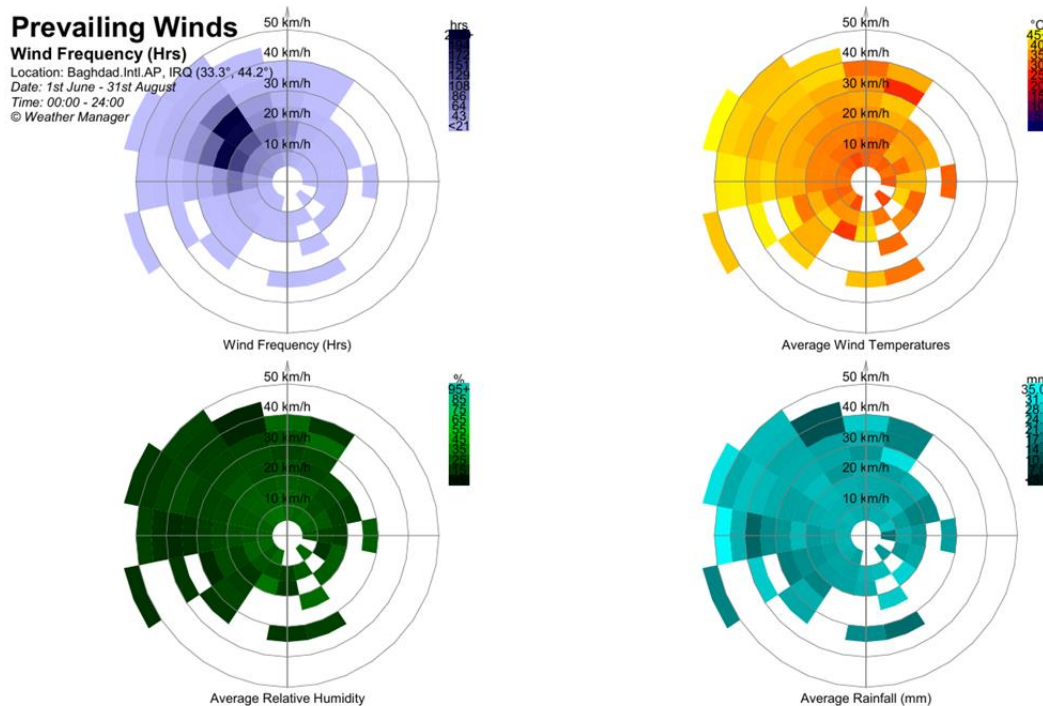


Fig.5 Prevailing wind direction and frequency, wind temperature, relative air humidity, and rainfall rate in Baghdad

#### 4.2. Thermal simulation preparation stages

Thermal comfort levels were assessed for the two urban pattern was conducted utilizing Ecotect software, an advanced architectural design and analytical tool, that enables multiple analyses such as heat, lighting, shading, energy, acoustics, and cost, alongside a three-dimensional

editing and design capacity. This study used the \*Predicted Mean Vote\* (PMV) index to assess comfort levels, which indicates the average thermal response of individuals exposed to environmental variables including air temperature, relative humidity, and wind speed, employing a scale that ranges from "very hot" to "very cold." PMV values span from +3 (indicating very hot) to -3 (indicating extremely cold), value of zero representing optimal thermal comfort and neutrality. Research indicates that the application of the PMV equation for evaluating outdoor thermal comfort in hot climates may yield PMV values of +8 or higher (Ridha, 2022). The \*Mean Radiant Temperature\* (MRT) index has been used as another measure to assess external thermal comfort. Using the Ecotect software, simulations were conducted at three-time intervals: 6:00 a.m., 12:00 p.m., and 6:00 p.m. These intervals were selected based on the varying angles of solar radiation throughout the day, this methodology contributes to study of the effect of solar radiation angles and shading ratios on thermal comfort, parameters of significant importance within the Ecotect software.

#### **4.3. Thermal simulation results**

After analyzing thermal maps that show the simulation results of the current thermal conditions of the study area (A) and at three different times of the day 6:00 a.m., 12:00 p.m., and 6:00 p.m., on (21 June) when ambient temperatures approached 50°C, it was observed that the Mean Radiant Temperature (MRT) did not exceed 38°C at 6:00 a.m.. By 12:00 p.m., the MRT exhibited considerable variability, ranging between 36°C and 65°C. In the evening, at 6:00 p.m., the MRT stabilized within a range of 42°C to 45°C. The Predicted Mean Vote (PMV) index recorded values from 3.5 to 4.16 at 6:00 a.m.. At noon, the PMV fluctuated between 4 in secondary streets and 8 on the extensive main thoroughfares. By 6:00 p.m., the index values ranged from 4.8 to 6.5, as illustrated in Figs 6 & 7.

The results of the simulation study for zone (B) are depicted in Figs.8 & 9, which presents the Predicted Mean Vote (PMV) and Mean Radiant Temperature (MRT) values for the specified times of 6:00 a.m., 12:00 p.m., and 6:00 p.m.. At 6:00 a.m., the MRT values at this location ranged from 38 to 40°C, reached a peak at 12:00 p.m. with values between 55 and 80°C, and subsequently declined by 6:00 p.m., with recorded values ranging from 44 to 55°C. The PMV values for Site B at 6:00 a.m. fluctuated between 4 and 4.8; however, at 12:00 p.m., the average PMV ranged from 6.8 to 9. By 6:00 p.m., the PMV values varied between 5.4 and 6.

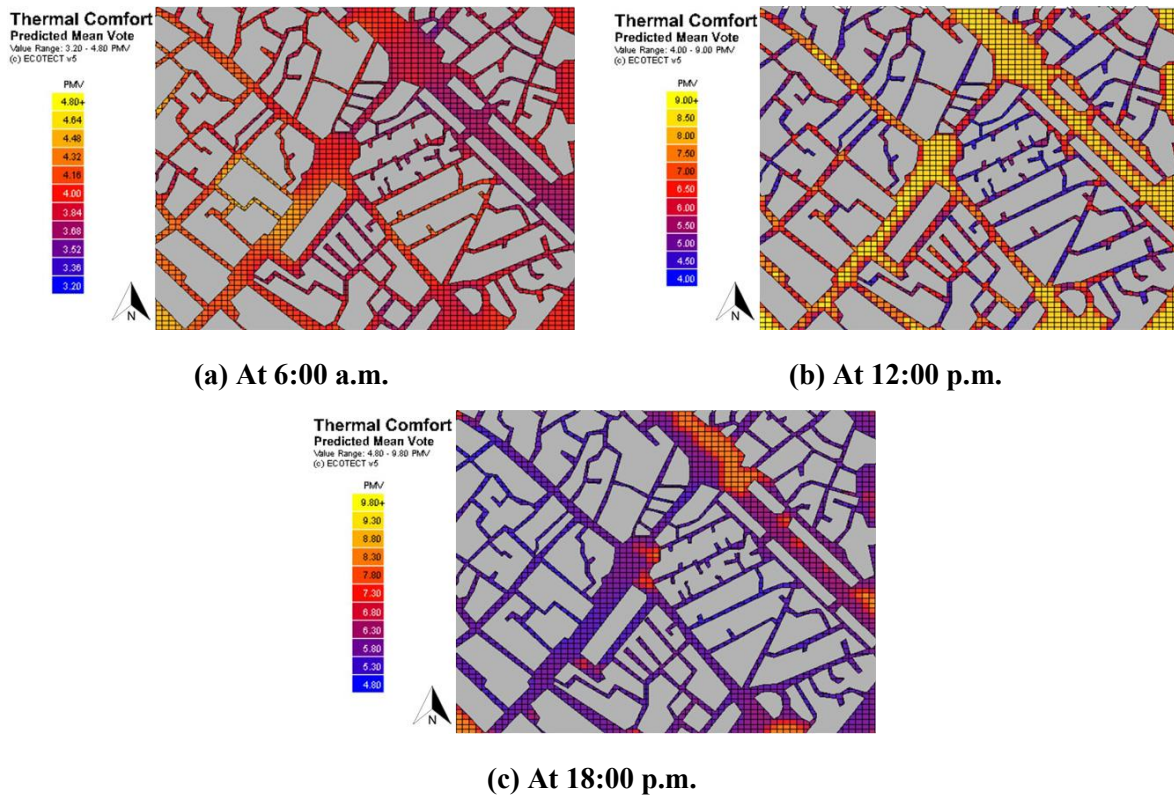


Fig. 6 PMV analysis of study area (A)

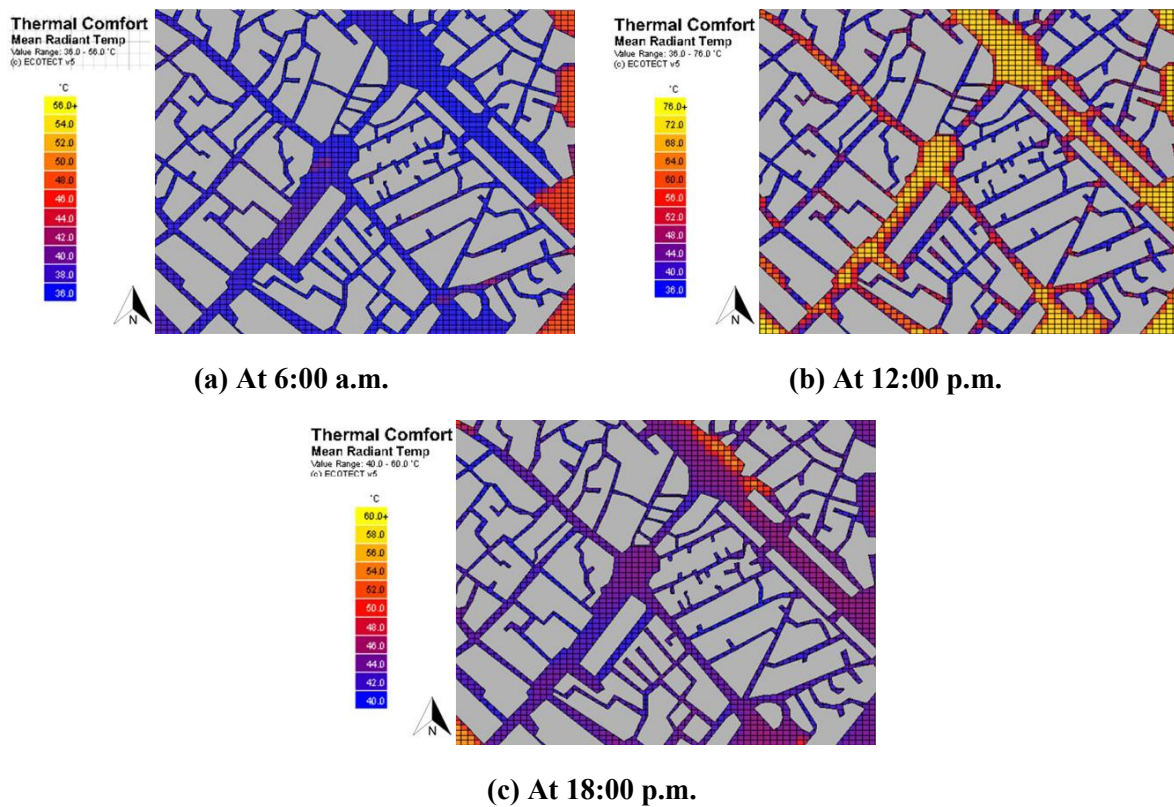


Fig. 7 MRT analysis of study area (A)

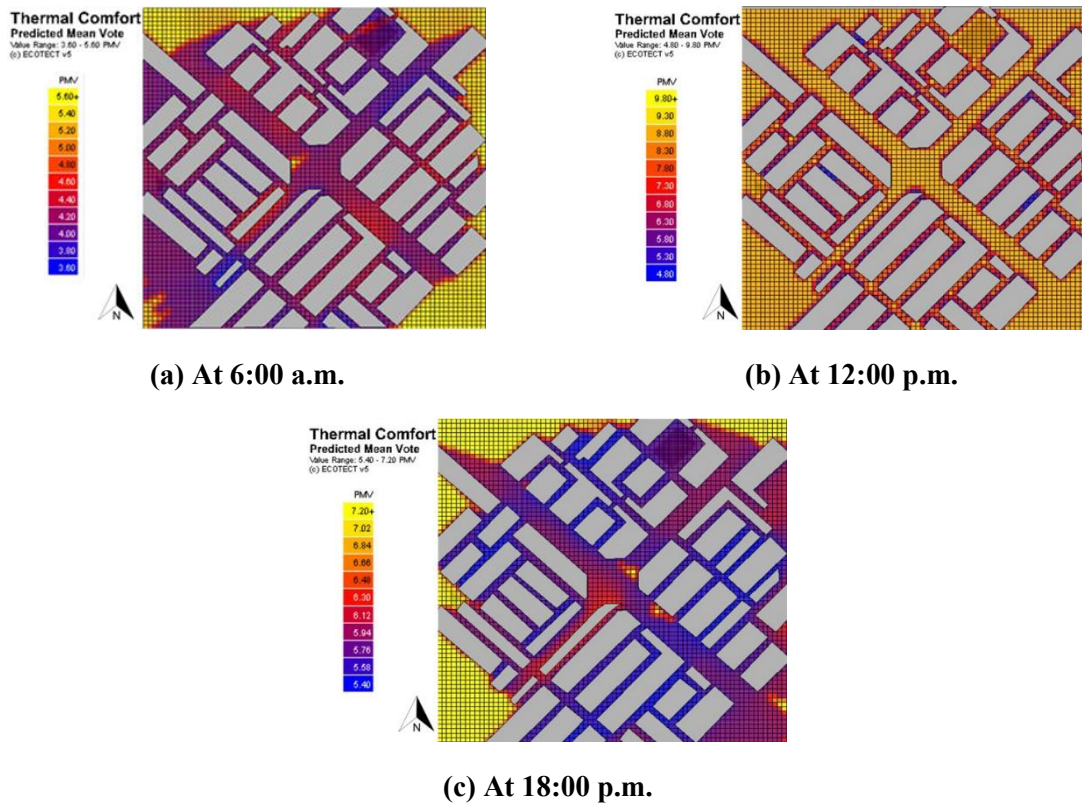


Fig. 8 PMV analysis of study area (B)

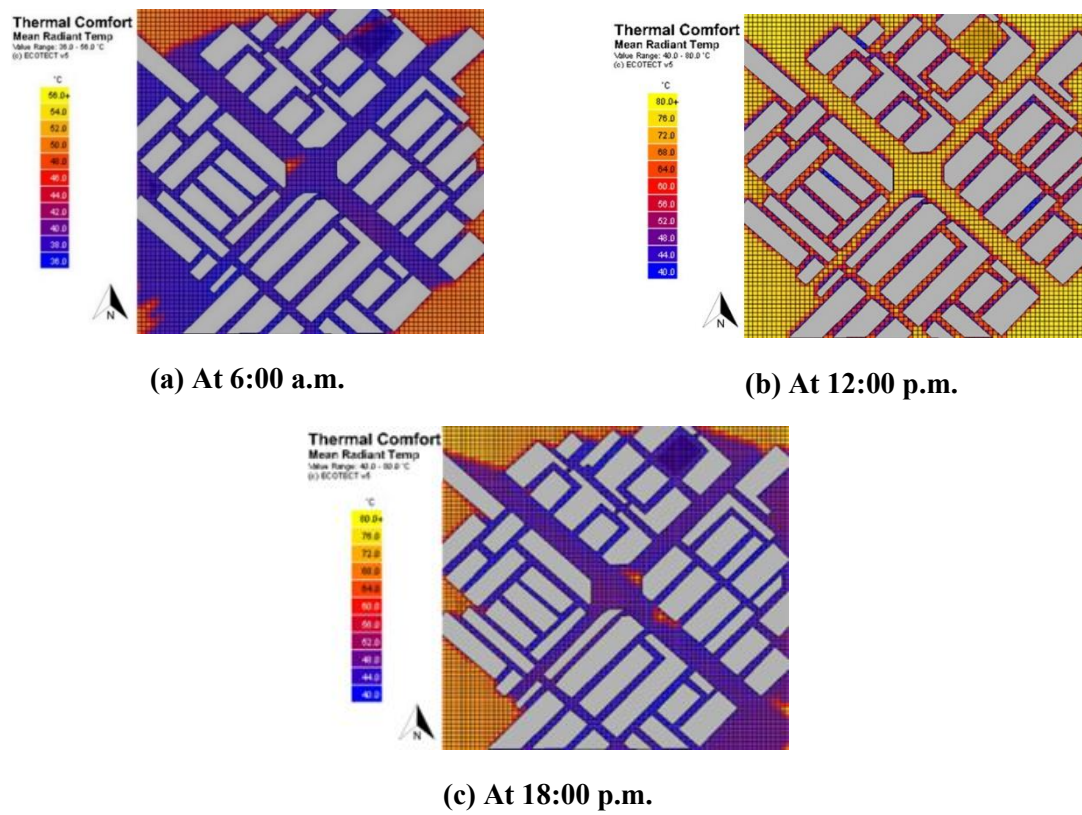
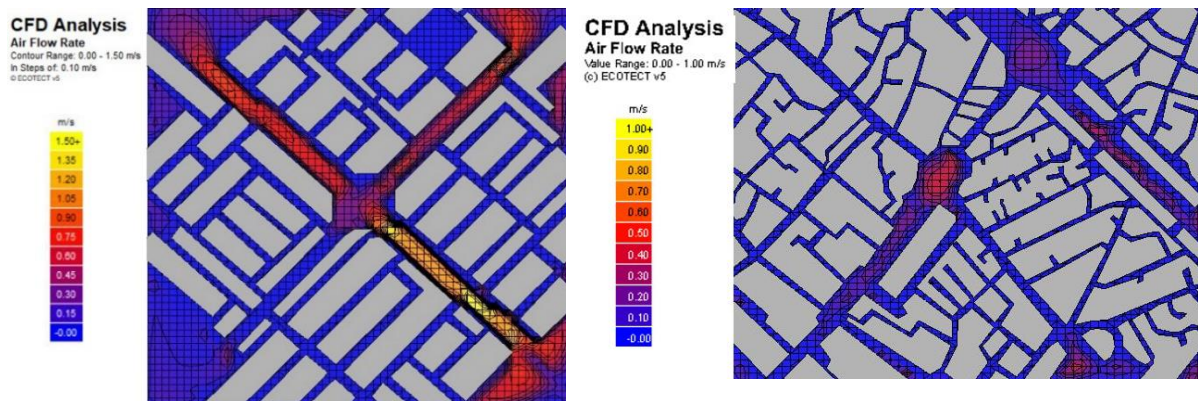


Fig. 9 MRT analysis of study area (B)

Regarding the impact of the wind index, there is a significant difference between areas with organic layouts featuring narrow alleys and areas with grid layouts and wide streets in terms of wind flow and speed. In Area A, the narrow alleys create a “wind shadow” effect, where closely spaced buildings obstruct air movement. However, this configuration provides protection against undesirable winds. In contrast, the grid-based planning of Area B, with its straight and open streets, enhances wind flow and speed more effectively compared to organic layout, as illustrated in Fig.10.

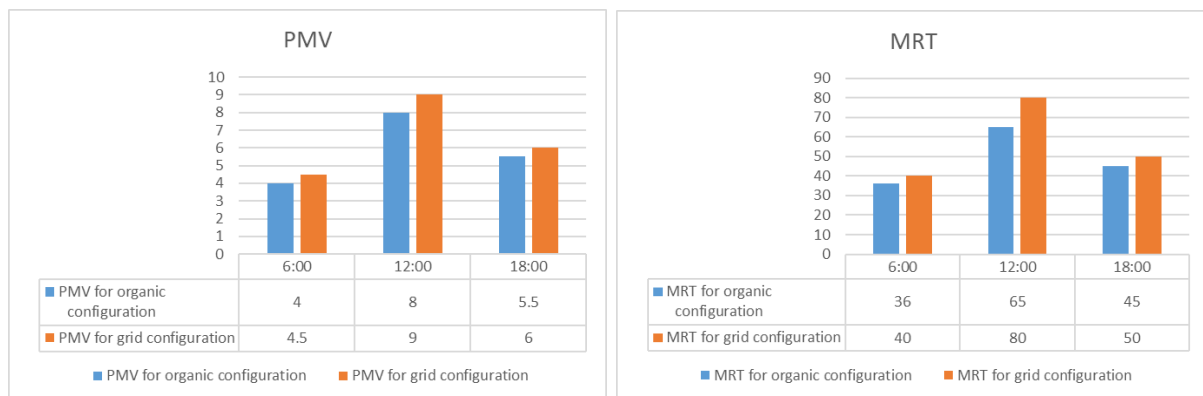


**Fig. 10 Wind flow and speed ratio in the study area**

## 5. RESULTS ANALYSIS AND DISCUSSION

The simulation analysis of areas A and B shows that thermal comfort indicators, Predicted Mean Vote (PMV) and Mean Radiant Temperature (MRT), recorded their lowest values in zone A, as illustrated in Fig. 11. This reflects the superior thermal performance of urban design in zone (A) compared to zone (B), where higher MRT values were observed. The elevated MRT values in zone B contributed to lower expected thermal comfort levels for the population. The significant difference in thermal comfort between the two areas can be attributed to the influence of urban configuration indicators on environmental factors, including shading and radiant temperature. The study area suffers from low levels of thermal comfort due to high daytime temperatures resulting from intense exposure to direct solar radiation. Therefore, urban design in such climates must prioritize mitigating the effects of solar radiation by enhancing shading elements, as well as providing protection from hot winds. In this context, the organic urban planning, characterized by high building density, limited outdoor spaces, and close proximity between buildings, effectively reduces exposure to direct solar radiation through increased shading. The relationship between Sky View Factor and radiant temperature is evident in the MRT measurements for zone A, which consistently remained below 40°C in the majority of open spaces, particularly in the narrower streets, even during peak solar intensity at noon. In contrast, radiant temperatures in other zones exceeded 80°C for the average radiant

temperature. The irregular geometry and orientation of the streets in Area A contributed to enhanced shading levels, significantly lowering outdoor temperatures in comparison to the grid street pattern observed in Area B. In Area B, the regular design and suboptimal (W/H) ratios of the streets resulted in continuous exposure to direct solar radiation and increased thermal stress. This analysis demonstrates that the most suitable urban pattern for a hot, dry climate is the organic pattern.



**Fig. 11 Comparison (MRT & PMV) between study zone A (blue) and study zone B (orange)**

## 6. CONCLUSIONS AND RECOMMENDATIONS

This study examines the outdoor thermal comfort topic in hot-dry climate, by study the relationship between urban configuration and environmental factors, and their impact on achieving thermal comfort within urban space. The results were shown based on the simulation program, that organic urban planning, characteristic of ancient historical cities, is the most effective in mitigating the climatic conditions in these regions. The research adopted a comprehensive methodology to classifying indicators through a review of relevant literature. The study identified 8 primary indicators and 37 subsidiary indicators, to investigate the degree to which urban form affects thermal comfort, by an analytical study conducted on two different urban patterns in Baghdad, Iraq. The study emphasizes the importance of integrate environmental factors as a central element in urban planning processes. This approach aims to promote the creation of more environmentally responsive urban environments. In conclusion, the study recommends integrating simulation programs into the architectural education curriculum, as this will help link theoretical knowledge with practical application, enabling students to develop advanced analytical skills, make more sustainable design decisions, and improve the efficiency of architectural projects.

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