International Journal of Sustainable Development and Planning
Vol. 20, No. 1, January, 2025, pp. 13-23
Journal homepage: http://iieta.org/journals/ijsdp

Environmental Aspect Impact on Frameworks Development for Classifying Urban Configuration Indicators

Duaa Hameed Abd[1*], Hamzah S. Al-Mamoori[1], Raed Fawzi Mohammed Ameen[2,3]

[1] Architectural Engineering Department, Babylon University, Babylon 51002, Iraq
[2] Architectural Engineering Department, Karbala University, Karbala 56001, Iraq
[3] BRE Institute for Sustainable Engineering, Cardiff University, Cardiff CF10 3AX, UK

Corresponding Author Email: eng455.duaa.hameed@student.uobabylon.edu.iq

https://doi.org/10.18280/ijsdp.200102

Received: 20 October 2024
Revised: 26 November 2024
Accepted: 6 December 2024
Available online: 24 January 2025

Keywords:
urban configuration, urban configuration indicators, thermal comfort, Ecotect software

ABSTRACT

The urban environment consists of the complex interaction between the physical elements of urban areas and surrounding environmental factors, making it difficult to measure and manage. Urban configuration of the city can substantially influence on the local climate, and this influence varies according to the region's environmental conditions. Therefore, to attain outdoor thermal comfort, it is necessary to understand and study each urban context according to its own environmental conditions. Accordingly, the study aims to analysis the relationship between urban configuration and its thermal environment. To fulfill the research purpose, a simulation was executed utilizing Ecotect software, which assesses environmental performance, concentrating on two distinct scenarios characterized by organic and grid urban designs. The simulation results demonstrated that the organic urban planning achieved superior thermal comfort compared to grid- based planning. This discovery 'indicates that the urban configuration best adapted to hot, arid weather is a compact urban fabric, a defining trait of traditional historical cities. In these designs, building masses are intricately intertwined and overlapping, while streets and pedestrian routes comprise small, winding, and branching lanes. These features offer protection from climatic conditions, diminish direct solar radiation exposure, and generate substantial shadowing, thereby improving thermal comfort.

1. INTRODUCTION

Urban configuration elements are significant components in urban design, delineating the physical structure of a city as an urban system comprised of elements that collectively constitute the entire system. The configuration of urban areas illustrates the interaction between spaces and masses [1], the articulation and link between mass and space influence several design features, including aesthetic and functional considerations. This study emphasizes the environmental function, particularly the attainment of thermal comfort for users. Numerous researches have indicated that outdoor urban environments exhibit differing degrees of thermal comfort attributable to variations in physical components, including the Sky View Factor (SVF), canyon ratios, vegetation cover, landscape element diversity, and albedo (surface reflectivity) [2]. The attributes of urban configuration, influenced by environmental factors, lead to the development of various urban form patterns in cities, impacting their exterior environment, internal structure, neighborhood distribution, and land utilization. Moreover, these patterns affect the mobility network, routes, and accessible external areas [3]. The generation of urban configurations is a complex process that encompasses various criteria, the categorization and development of urban configuration indicators assist engineers and planners in enhancing the urban configuration process [4]. Consequently, numerous urban studies focused on the notion of configuration have examined the categorization of urban configuration indicators. The literature has identified numerous aspects and indicators of urban form, which are assessed either independently or collectively, employing diverse classification and measuring techniques across multiple spatial scales. A review of previous literature revealed that most urban morphology studies rely on analyzing a small, pre-selected set of indicators, with the majority limited to a single scale. The research gap lies in the absence of a comprehensive framework for analyzing and classifying these indicators. Moreover, most studies classify these indicators based on principles and foundations specific to urban design without considering the environmental dimension’s impact in their classification. This represents a key issue in previous research, which has overlooked the role of environmental factors in configuration the urban fabric. Therefore, the methodological aim of this study is to establish a complete framework for categorizing urban configuration indicators based on environmental factors, which are essential for the urban configuration process and for formulating its distinctive metrics. The principal indicators of urban configuration are intrinsically connected to the thermal environment, necessitating the regulation of the thermal environment and enhancement of outdoor thermal comfort through the management of urban form. Given the escalating worries over climate change, such classification is essential for tackling modern environmental difficulties and developing climate-resilient cities. The study employs an analytical methodology to tackle the research problem and attain the intended results. This is achieved by analytical research utilizing simulation software (Ecotect) to measure the thermal comfort of urban environments and evaluate the impact of urban configuration on it, grounded on certain principles, parameters, and concepts.

2. CONCEPTUAL FRAMEWORK

The research's conceptual framework centers on urban configuration and its influencing elements, seeking to examine the correlation between indicators of urban configuration and environmental parameters. This functions as a theoretical framework that offers a thorough comprehension for constructing the research's theoretical foundation.

2.1 Urban configuration elements

The structure of urban areas is regarded as a multifaceted subject due to its correlation with diverse issues, including environmental, economic, and social elements, each necessitating distinct definitions, methodologies, and frameworks. Consequently, urban form possesses various concepts that cannot be readily unified into a singular interpretation [5]. Urban form denotes the spatial configuration and patterns of the constructed environment [6]. It is characterized as the spatial depiction of diverse physical, environmental, economic, social, and cultural variables, which significantly influence human activities in both contemporary and historical urban development [7]. Al-Madhhaji characterizes urban form as "the overall appearance of human settlements, comprising a collection of urban attributes that include two-dimensional elements (shape, dimensions, and boundaries) and three-dimensional components (elevations, masses, and spaces)" [3]. The configuration process in urban planning relies on the reciprocal interplay of masses and spaces, including streets, open spaces, and green areas [4]. Mass and space are seen as the paramount components of urban configuration, with each being defined by the existence of the other. When an edifice is situated in an open area, the surrounding environment delineates and differentiates the structure, rendering it the focal point. Conversely, when masses encircle and delineate a space, the space becomes more readily identifiable and perceptible. Consequently, the interplay between mass and space influences the fundamental aesthetic of the urban landscape, determining the order and organization of the spatial configuration within the city. The relationship between mass and space is a crucial element of urban design and significantly influences the attainment of thermal comfort for individuals in outdoor settings.

2.2 Urban configuration and the environmental factor

Research has shown that urban planning and design are intricately connected to environmental and climatic variables. Consequently, incorporating urban climate knowledge into the urban design process is imperative [8]. The environmental dimension must be a key concern, as the primary objective of planning is to establish an environment that fulfills human needs. Urban configuration techniques can alter and enhance the urban climate to satisfy people's requirements by affecting key environmental parameters, including building heights and spacing, street network orientation, and the allocation of open spaces and parks. These parameters are influenced by aspects like solar exposure, shading, radiation protection, precipitation, wind, and ventilation conditions. The extent of influence fluctuates according to the climate of the place. In warm and humid conditions, the principal source of discomfort is the perception of skin moisture [9]. The interplay between relative humidity and air temperature can profoundly influence thermal comfort in humid regions [10]. Ongoing ventilation is necessary to facilitate enough sweat evaporation and uphold the body's thermal equilibrium. Consequently, urban development must focus on improving ventilation and shade, while ensuring optimal protection against solar radiation, heat reflection, and glare. Conversely, in arid and hot climates, the primary source of discomfort is elevated daytime temperatures, intense direct sun radiation, and dust storms. The principal focus of urban planning in these regions is to mitigate the effects of solar radiation on structures and to offer shading for buildings, thoroughfares, and public spaces, along with safeguarding against hot, dust-laden winds [11].

2.3 Urban configuration and thermal comfort

Research indicates a strong correlation between urban configuration and thermal comfort, underscoring the necessity to examine diverse urban forms to comprehend their effects on urban attributes [2]. Prior to examining the influence of urban configuration on thermal comfort, it is crucial to comprehend the concept of thermal comfort itself. Numerous definitions exist in several languages to characterize this universal human condition; nevertheless, the predominant definition describes thermal comfort as "that mental state expressing satisfaction with the thermal environment". This definition highlights the psychological aspect of thermal comfort, acknowledging that it is a subjective experience that differs among persons in the same environment. Fanger [12] posits that thermal comfort in an outdoor environment is influenced by six factors: environmental elements (air temperature, radiation, relative humidity, air movement) and behavioral aspects (metabolic rate, clothing). Numerous scholars have proposed that outdoor urban environments demonstrate differing degrees of thermal comfort attributable to variations in their physical attributes. The physical characteristics of metropolitan environments can influence the urban climate in multiple ways, eventually affecting the degree of outdoor thermal comfort [2]. Consequently, urban configuration significantly influences the local urban climate and environmental temperatures [13]. The primary indicators of urban configuration are intrinsically linked to the thermal environment, necessitating an examination of the mechanisms through which these indicators affect the thermal environment across various scales (city, neighborhood, and urban block levels). This comprehension facilitates the possibility of regulating the thermal environment and enhancing outdoor thermal comfort via the management of urban design [14]. Consequently, other research has examined the intricate link between these urban indicators and thermal environmental factors [15]. These studies have demonstrated that multiple urban indicators are necessary to assess the direct influence of urban layout on thermal environmental parameters [16].

2.4 Urban configuration indicators

Various terminologies, including scales, indicators, parameters, and variables, denote the same concept across multiple research. Numerous studies have emphasized the significance of these indicators and their crucial role in evaluating and analyzing urban organization. The indicators for each component of urban configuration delineate the physical attributes of urban form and assess the morphological relationships, including dimensions, volumes, percentages, and spatial arrangements observed among urban configuration elements, to characterize and categorize the built environment [4]. A multitude of theories have been created to categorize urban configuration indicators across various dimensions, including environmental aspects, socio-economic issues, and population-related metrics such as density and demographics. Researchers and practitioners seeking to assess a city's urban form may select from a range of indicators [17]. This study will categorize urban configuration indicators according to the environmental dimension, utilizing these indicators to delineate the relationship between urban configuration and environmental circumstances.

2.5 Literature review

This research examines studies that quantitatively assess markers of urban configuration, contrasting with the prevalent qualitative methodologies in the literature on urban form. The research included in this review was categorized based on various criteria:

1. Time Frame: Studies were chosen from several periods spanning 2008 to 2023.
2. Scale: The scales of urban form in this research were categorized into three distinct levels: city scale (macro scale), neighborhood scale (meso scale), and urban block/building size (micro scale).
3. Potential Comprehensiveness: This pertains to the quantity of indicators assessed in each study, varying from those that reached findings based on a solitary indicator to those employing an extensive array of indicators.
4. Study selection: Selection of studies yielding comparable research outcomes despite diverse indicator counts and measurement techniques.

Prior research has suggested numerous components and metrics for urban configuration. The indicators were measured either singly or together, employing diverse classification and measuring techniques across various spatial scales. Due to the extensive array of indicators in the literature, there are two primary methodologies for their selection: either opting for a limited set of indicators grounded in pre-existing assumptions, or examining a broad spectrum of indicators to empirically ascertain the most appropriate ones [17]. Most research on urban configuration predominantly depends on a limited selection of pre-determined measures, with just a minority evaluating the suitability of these chosen indicators. This approach is essential for defining the key indicators necessary to attain thermal comfort, considering local environmental concerns and context. A total of 18 studies quantitatively examining urban form were reviewed: two at the micro size, eight at the meso scale, four at the macro scale, and four that encompassed all three dimensions. Several of the analyzed studies centered on assessing indicators at the micro scale, whilst the majority focused on evaluating indicators at a macro level. Nonetheless, these micro-scale signs are crucial and must not be disregarded. Table 1 delineates the attributes of the prior investigations.

Table 1. Collecting previous literature and determining the indicators used in each study

No.	Ref.	Urban Form Spatial Scale	Indicators Used in the Study
1	[1]	Macro-Scale	This study has clarified that the structure of cities consists of paths and blocks. Focusing on these two components, the study proposed seven specific indicators related to paths, which are: number of paths per block, average width, average lengt, orientation, the slope of the paths and distribution method, permeability. And 13 indicators related to blocks, which are: occupancy factor, number building sites on a block, building compaction, the area of a block, the average number of floors in a buildings on the block, the overall form of building sites in the blocks, the overall orientation of building sites on the blocks, placement of building sites adjacent to each other on a block, orientation of blocks, the overall form of the yards, size, distribution of plot sizes
2	[2]	Macro-Scale	The study presents a framework that links urban form indicators with urban sustainability. The main indicators used were: paths, buildings, plots, and urban mass permeability
3	[4]	Macro-Scale	The research focuses on the importance of utilizing urban form indicators in generating urban shapes. The study categorized the indicators into four main types, which are: Building, Streets, Open spaces and plots
4	[5]	Macro, Meso & Micro Scale	This study presents a systematic review of previous research on the classification of urban form indicators. A total of 89 indicators were identified. Based on the results, the most important sub-indicators at the macro scale were determined as: land use mix, density distribution and type of density AT meso-scale: land use mix, street network and type of density At the micro scale, street design is prioritized
5	[17]	Macro-Scale	This study aims to identify the minimum set of indicators for measuring urban form and recommends selecting the following seven indicators from among the many discussed in the literature. These indicators are: Area of the discontinuous urban fabric, number of patches, mean patch size, edge density, population number, and population density, compactness index of the largest patch
6	[18]	Macro, Meso & Micro Scale	This study developed a systematic classification of urban configuration according to six main indicators, which are: dimension, spatial distribution, intensity, shape, connectivity and diversity
7	[19]	Meso-Scale	This research discusses a set of indicators related to urban planning and their role in controlling the climatic conditions of the region. These indicators are: 1. Urban fabric pattern, 2. Compactness index, 3. Density of building
8	[20]	Macro, Meso &	This research paper analyzes the relationship between climatic indicators and urban energy planning

		Micro Scale	indicators. Seven main indicators were identified, which are: (physical, land use, and transportation, movement/accessibility, infrastructure, cultural and technological), of these, 61 secondary indicators were identified
9	[21]	Macro, Meso & Micro Scale	This study classified urban configuration indicators into three scales: 1. Macro-Scale indicators, which include: the shape of the project land, heat dissipators on-site such as large water bodies and forests, road network design, and various urban forms, 2. Meso-Scale indicators, which include: the adjacency and arrangement of buildings, as well as landscape elements, 3. Micro-Scale indicators, which include: the shape and orientation of the building block, building envelope, wind facilitators, and the interior design of the building
10	[22]	Meso-Scale	The study demonstrated that the morphological indicators that have a significant impact in different climatic regions are: 1. Sky view factor (SVF), 2. Ratio of built-up area to open space, 3. Street Orientation, 4. Height of building, 5. Green space ratio
11	[23]	Meso-Scale	The research concluded that the Sky View Factor (SVF) is one of the most important urban form indicators affecting urban thermal comfort. The urban form indicators used were: 1. Sky view factor (SVF), 2. Average height, 3. Built-up area density
12	[24]	Micro- Scale	The research concluded that urban façade indicators have a significant impact on outdoor thermal comfort by controlling airflow and shading. The indicators used in the measurement are: 1. Configuration of building, 2. Facade details
13	[25]	Micro- Scale	This research focused on urban configuration indicators at the block level and their impact on outdoor thermal comfort. The block-level indicators used were: 1. Configuration of building, 2. Height of building
14	[26]	Meso-Scale	This research paper provides preliminary evidence indicating a relationship between the urban planning pattern of street networks and population density. The focus was placed on a set of indicators, which are: 1. Volume of pedestrian flow, 2. Type of activity, 3. Hours of operation, 4. Urban fabric pattern, 5. Road network density
15	[27]	Meso-Scale	This research paper highlights urban space and presents certain design and planning criteria to achieve urban spaces suitable for current and future needs by focusing on urban space indicators, which are: 1. Space ratios, 2. Space scale, 3. Space Configuration, 4. Space enclosure degree, 5. Space function type, 6. Space hierarchy
16	[28]	Meso-Scale	The research highlighted the importance of the thermal environment of streets, as it determines the thermal environment of the urban area. The indicator used was: Street configuration
17	[29]	Meso-Scale	This research focused on two categories of indicators: 1. Green space ratio, 2. Height to Width Ratio (H/W)
18	[30]	Meso-Scale	This study has demonstrated that the urban configuration indicators significantly influencing the thermal comfort of outdoor spaces are: 1. Height of building, 2. Orientation of building, 3. Shading, 4. Green space ratio

Upon examining the existing literature, it was determined that numerous research had explored this domain, each utilizing distinct indicators and categorization methodologies. Many of these studies categorized urban configuration indicators according to the principles and foundations of urban design, focusing on the physical and spatial attributes of urban form, while neglecting the influence of the environmental component on the classification of these indicators. Recently, due to increasing apprehensions over climate change, research and scientific initiatives have redirected focus towards environmental solutions, highlighting ecological elements and climatic attributes in urban development. This transition has prompted several efforts to establish a methodological framework that connects urban climate with urban configuration indicators to discern the most impactful and pertinent aspects in attaining thermal comfort in accordance with the local climatic context. Furthermore, the quantity of indicators differed among investigations, with some research obtaining outcomes through a single indication while others employed a diverse array of indicators. Results obtained from the influence of a solitary indicator or a restricted set of indicators, frequently lacked a solid scientific foundation. The interconnection and mutual influence of urban configuration indicators complicate the analysis of the impact of a singular component on the thermal environment. One of the examined investigations is that of Bao [28], in which the researcher employed a single indicator (street configuration) to assess the thermal environment of streets. The researcher determined that the study neglected to account for additional elements influencing the thermal environment of roadways, including street greening and pedestrian activity. As a result, a discrepancy was noted between simulation outcomes and actual conditions, leading the researcher to anticipate future advancements to rectify these deficiencies, boost result precision, and augment their applicability. The research highlighted the necessity for more detailed rules in the construction of street layouts to alleviate thermal conditions. A complete scientific framework for identifying urban configuration indicators should be established, emphasizing the environmental dimension in their categorization. This framework can yield precise, relevant outcomes and reduce the limitations of studies concentrating on single-indicator impacts. Table 2 delineates the environmentally pertinent variables referenced in the literature, omitting those related to social, economic, or other dimensions. The analysis of prior research revealed eight principal indicators and 37 subordinate indicators at three levels: macro, meso, and micro.

Table 2. Urban configuration indicators

Main Indicator	Sub-Indicators	Scale	Source
Urban configuration	Complexity index	Macro- Scale	[5, 18]
	Urban fabric pattern	Macro- Scale	[19, 20]

Land use	Compactness index	Macro- Scale	[5, 17, 18]
	Spatial distribution	Macro- Scale	[18]
	Urban Diversity	Macro & Meso Scale	[18, 31]
	Access to services	Macro & Meso Scale	[5, 20, 31]
	Infrastructure	Macro & Meso Scale	[5, 20]
Density of building	The distance between buildings	Meso-Scale	[21]
	Sky view factor (SVF)	Meso-Scale	[2, 4, 22, 23]
	Average height	Meso-Scale	[1, 4, 24, 25]
	Built-up area density	Macro & Meso Scale	[1, 2, 4, 17, 18, 26]
	Ratio of open space	Macro & Meso Scale	[2, 4, 17, 18]
	Ratio of built-up area to open space	Macro & Meso Scale	[17, 18, 31]
Population density	Number of people per unit of area	Micro & Meso Scale	[5, 31]
	Volume of pedestrian flow	Micro & Meso Scale	[26]
	Type of activity	Micro & Meso Scale	[26]
	Hours of operation	Micro & Meso Scale	[26]
Urban blocks	Configuration of building	Micro Scale	[21, 24, 25]
	Height	Micro Scale	[2, 4, 18, 22]
	Orientation	Micro Scale	[1, 21]
	Facade details	Micro Scale	[21, 24]
	Height to width ratio	Micro Scale	[2, 4, 22]
	Properties of building materials	Micro Scale	[20]
Urban space	Space ratios	Micro Scale	[27]
	Space scale	Micro Scale	[27]
	Space Configuration	Micro Scale	[27]
	Space enclosure degree	Micro Scale	[27]
	Space function type	Micro Scale	[3]
	Space hierarchy	Micro & Meso Scale	[32]
Street	Street Orientation	Micro & Meso Scale	[1, 2, 22]
	Street configuration	Micro & Meso Scale	[1, 18, 27]
	Height to Width Ratio (H/W)	Micro & Meso Scale	[4,18, 29]
	Properties of finishing materials	Micro & Meso Scale	[20]
	Road network density	Macro- Scale	[2, 22, 27]
	Shading	Micro & Meso Scale	[30, 32]
Green areas	Green space ratio	Macro & Meso Scale	[21, 22, 29]
	Water surface area ratio	Macro & Meso Scale	[5, 18]

3. THE PRACTICAL FRAMEWORK OF THE STUDY

Figure 1. Boundary of the case study area

The research framework comprised an analytical examination of two distinct urban configurations in the Rusafa area of Baghdad, Iraq. The chosen case studies illustrated the unique traditional and contemporary urban patterns present in Baghdad, showcasing its historical, architectural, and geographical complexity. The distribution and arrangement of urban masses and spaces correspond with the study's aim to investigate the influence of urban configuration on outdoor thermal comfort. Figures 1 and 2 depict the chosen case studies, comprising two urban designs. The area (A) is defined by a complex layout of meandering streets, elevated building densities, and low-rise edifices. Conversely, Area (B) exemplifies a grid pattern, a contemporary urban planning methodology distinguished by grid-based configurations and detached structures organized in elongated, rectangular blocks. Area (A) demonstrated a greater population density than modern Area (B), where urban life, movement, and activity were more pronounced in organic areas, in contrast to the less dynamic modern environments. Both regions, however, exhibit a deficiency in vegetation cover, with the exception of a few dispersed trees in Area (B).

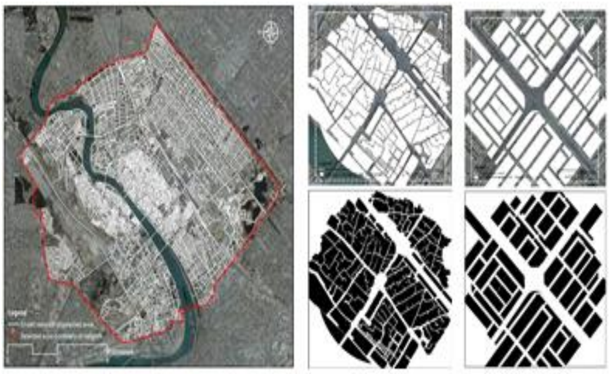


Figure 2. Two selected areas A and B, on the left area A: organic pattern, and on the right area B: grid pattern

3.1 Climatic data for the case study

The research area is situated in Baghdad, at a latitude of 33° N and a longitude of 44° E. It is situated in the Middle East, characterized by a hot-dry climate in summer and a cold-dry climate in winter. Measurement days were meticulously chosen to assess the influence of urban design on daytime thermal comfort, ensuring a clear portrayal of conditions. The impact of urban development on local climates is most apparent under particular conditions, such as clear sky, tranquil winds, no precipitation, and minimal cloud cover. The researcher conducted the simulation using July, the warmest month in Baghdad. Figure 3 presents the climatic data for this month, indicating that maximum temperatures reach nearly 50°C during the day. The maximum relative humidity reached 35% in July, while the wind speed was measured at 0.5 kph, coming from a direction of 315 degrees.

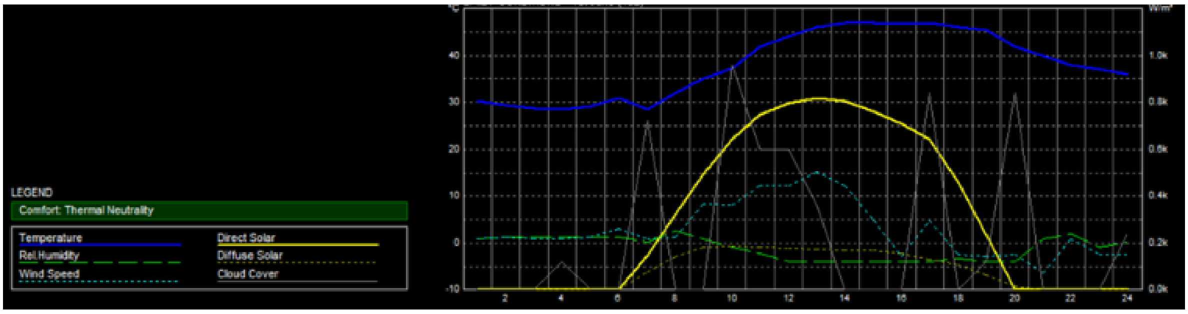


Figure 3. Climatic data for July in Baghdad

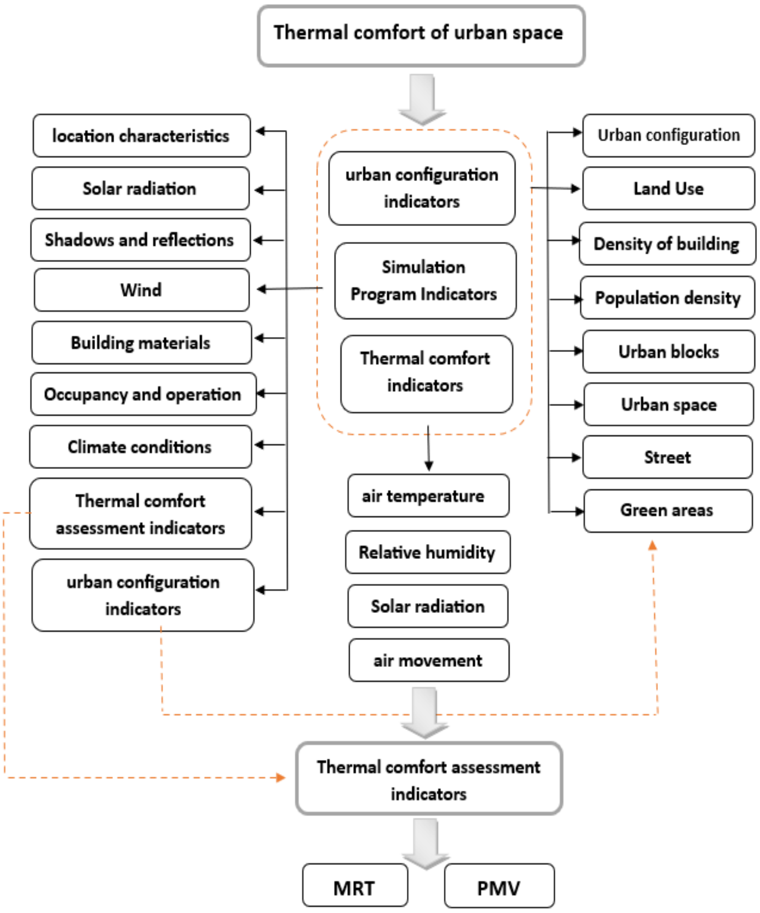


Figure 4. Main indicators for measuring the thermal comfort of urban space

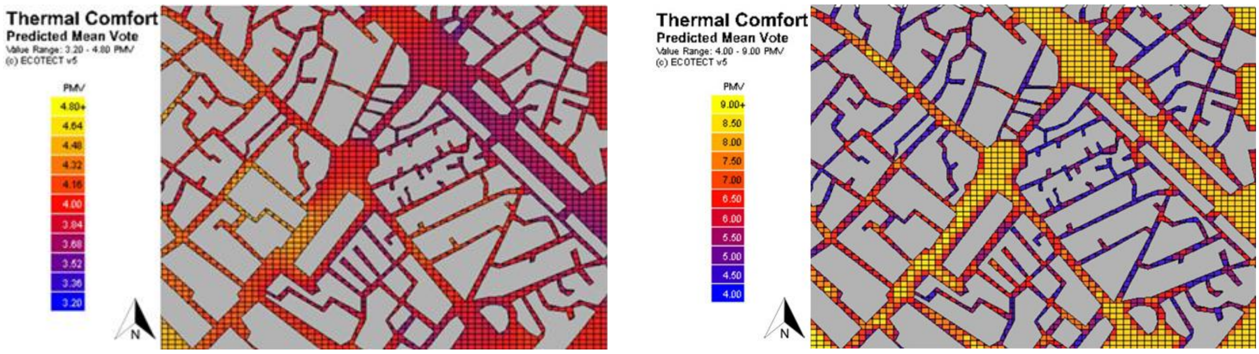
3.2 Thermal simulation preparation stages

The assessment of thermal comfort for the two urban forms was performed using Ecotect, a sophisticated architectural design and analysis program that integrates several performance analytic features with a 3D editor and designer. The performance analysis features encompass heat, lighting, energy, shading, cost, and acoustics. This study evaluated thermal comfort levels utilizing the *Predicted Mean Vote* (PMV), which forecasts the average thermal response of individuals subjected to environmental factors such as air temperature, wind speed, relative humidity, and employing a scale from very hot to very cold. PMV values typically range from +3 (very hot) to -3 (extremely cold), with a value of zero indicating optimal thermal comfort and neutrality. Research indicates that utilizing the PMV equation for outdoor thermal comfort in hot climates can produce PMV values of +8 or greater. Mathematically, these conclusions are precise, although they surpass the actual PMV scale [33]. The *Mean Radiant Temperature* (MRT) served as a metric for assessing outdoor thermal comfort. The most significant aspect influencing thermal comfort in outdoor urban environments is the consideration of various radiation types, including direct, diffuse, and reflected radiation. Utilizing Ecotect, the sample areas for both models were established. After the entry of meteorological data for Baghdad in wea format, simulations were executed at three distinct times: 6:00 AM, 12:00 PM, and 6:00 PM. The three measurement intervals were determined by the differing angles of solar radiation over the day. The angles reach their minimum at sunrise, progressively ascend to their peak at noon, and thereafter diminish again to their minimum at sunset. This method facilitates the evaluation of solar radiation angles and shading ratios on outdoor thermal comfort, a crucial parameter utilized by Ecotect software. Besides this parameter, the program integrates other critical inputs, such as site features, climate data, urban configuration attributes of the region, occupancy durations, and the nature of activities performed in the measured spaces. Figure 4 shows a summary of the main indicators used to measuring the thermal comfort of urban space.

3.3 Thermal simulation results

Upon examining thermal maps that illustrate the simulation outcomes for the prevailing thermal conditions of the study area (A) at three distinct times of day (6:00 AM, 12:00 PM, and 6:00 PM) on July 1st, when temperatures near 50℃, it was noted that the Mean Radiant Temperature (MRT) did not surpass 38℃ at 6:00 AM. At 12:00 PM, the MRT values fluctuated between 36℃ and 65℃, however, at 18:00 PM, the radiant temperature attained a range of 42℃ to 45℃. The Predicted Mean Vote (PMV) index registered values ranging from 3.5 to 4.16 at 6:00 AM. At 12:00 PM, the PMV varied from 4 in the secondary streets to 8 in the expansive main roadways. At 18:00, the values varied from 4.8 to 6.5, as depicted in Figures 5 and 6.

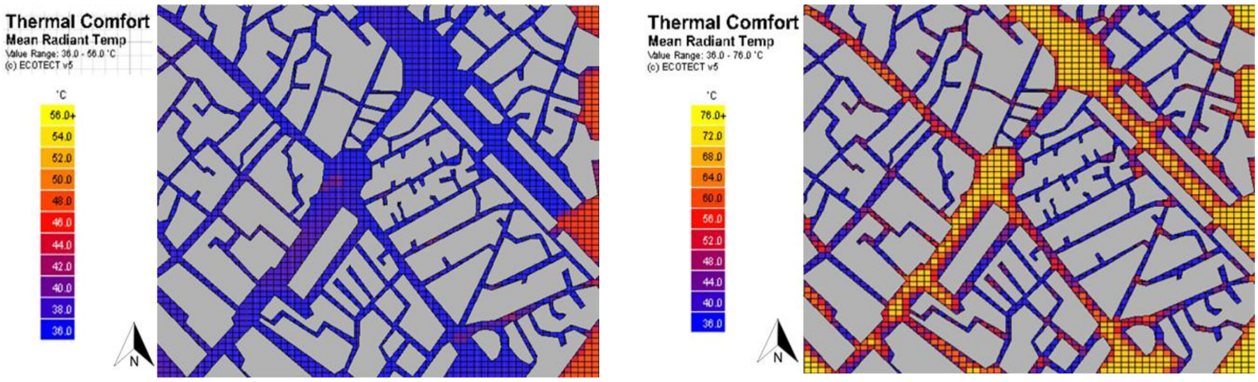
The simulation study results for site (B) are illustrated in Figures 7 and 8, which presents the Mean Radiant Temperature (MRT) and Predicted Mean Vote (PMV) values for site B at 6:00 AM, 12:00 PM, and 6:00 PM, respectively. The MRT values at this location varied from 38-40℃ at 6:00 AM, peaked at 12:00 PM with values between 55-80℃, and subsequently declined by 6:00 PM, recording values between 44-55℃. At 6:00 AM, the PMV values for site (B) fluctuated between 4 and 4.8, however at 12:00 PM, the average PMV varied from 6.8 to 9. At 18:00, the values fluctuated between 5.4 and 6, as depicted in Figures 7 and 8.



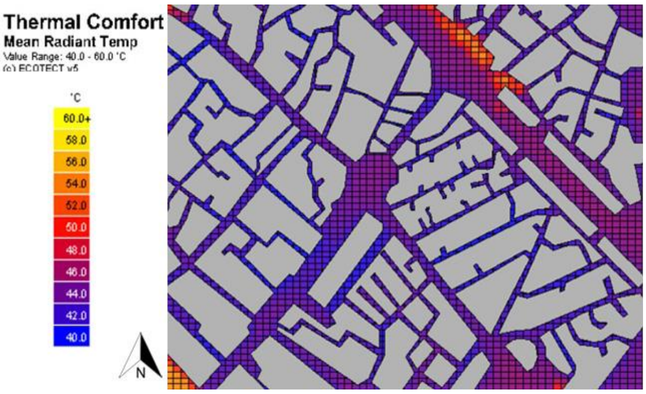
(a) At 6:00 am (b) At 12:00 pm

(c) At 18:00 pm

Figure 5. PMV analysis of study area (A) at (6:00 am, 12:00 pm, 18:00 pm respectively) for the month of July

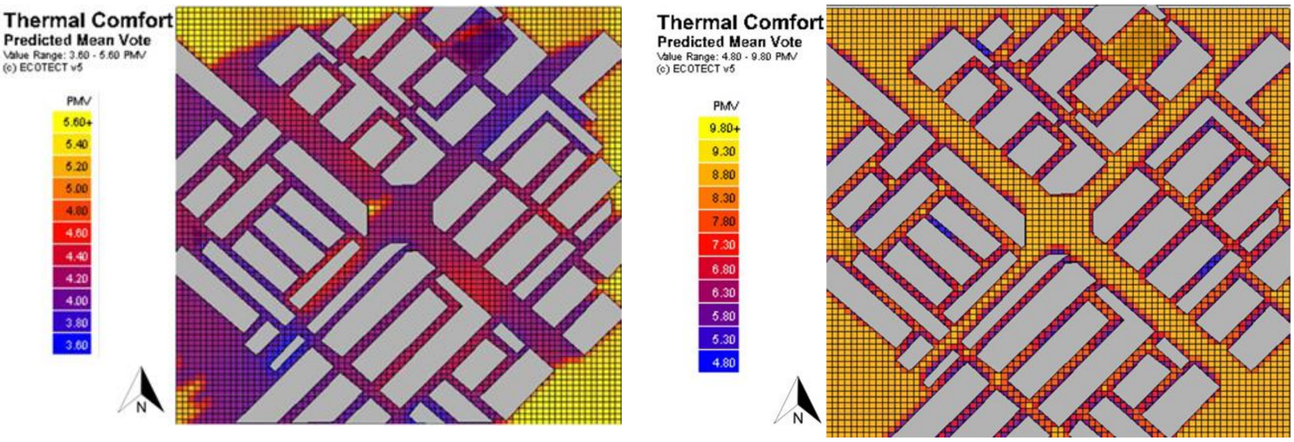


(a) At 6:00 am (b) At 12:00 pm

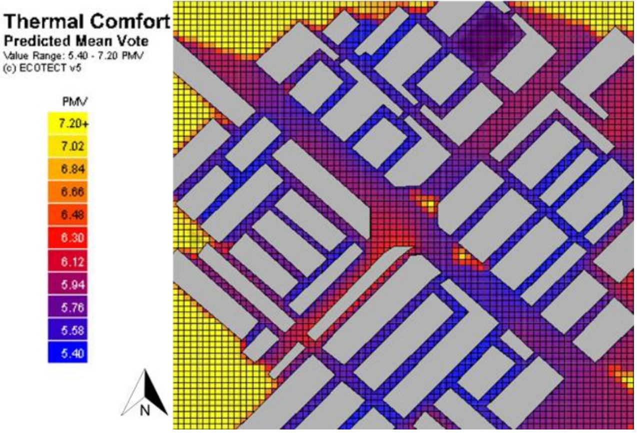


(c) At 18:00 pm

Figure 6. MRT analysis of study area (A) at (6:00 am, 12:00 pm, 18:00 pm respectively) for the month of July

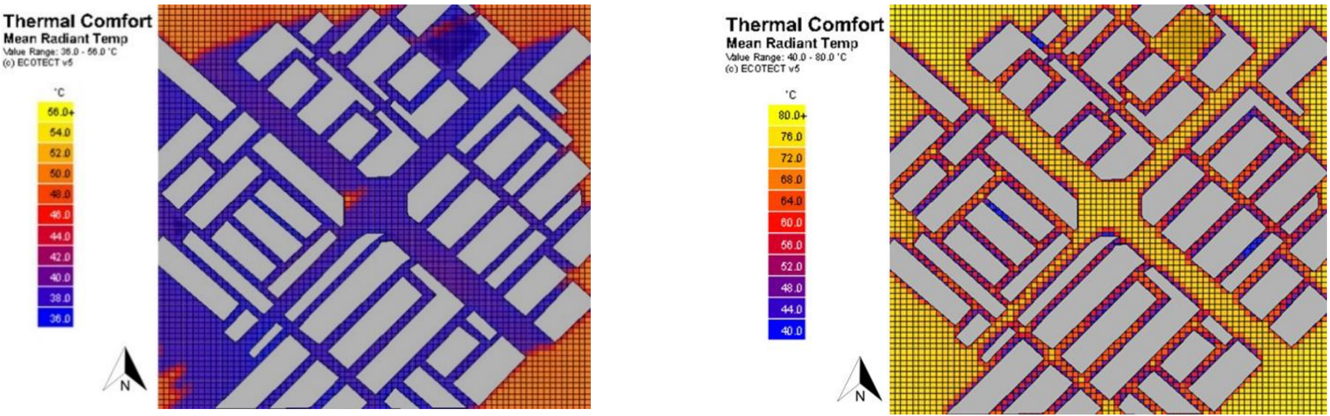


(a) At 6:00 am (b) At 12:00 pm

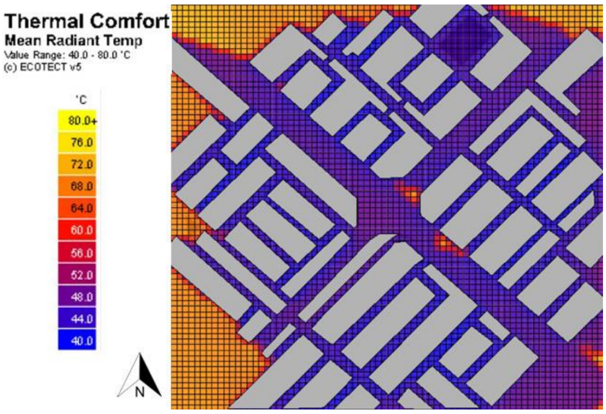


(c) At 18:00 pm

Figure 7. PMV analysis of study area (B) at (6:00 am, 12:00 pm, 18:00 pm respectively) for the month of July



(a) At 6:00 am (b) At 12:00 pm



(c) At 18:00 pm

Figure 8. MRT analysis of study area (B) at (6:00 am, 12:00 pm, 18:00 pm respectively) for the month of July

4. RESULTS ANALYSIS AND DISCUSSION

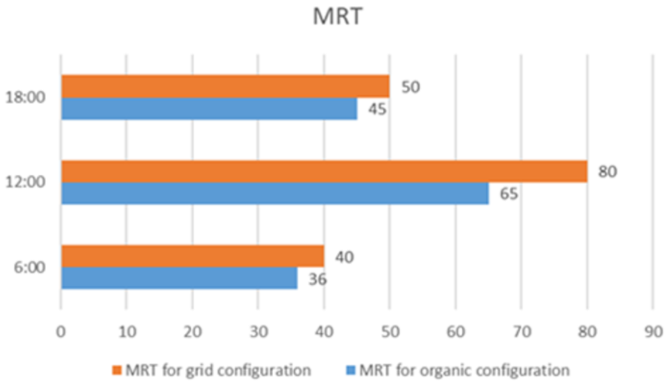


Figure 9. Comparison of Mean Radiant Temperature (MRT) between study area B (orange) and study area A (blue)

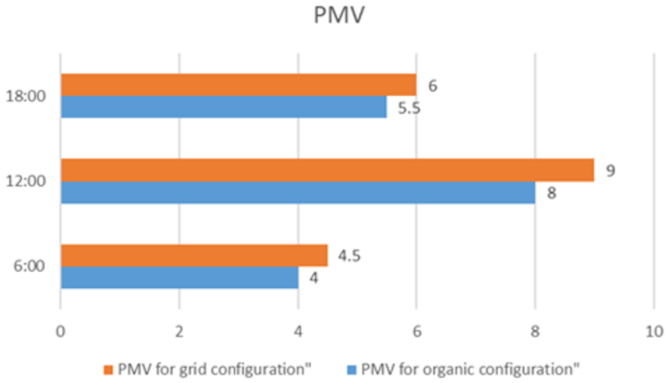


Figure 10. Comparison Predicted Mean Vote (PMV) between study area B (orange) and study area A (blue)

The simulation examination of Models A and B reveals that thermal comfort indicators, specifically Mean Radiant Temperature (MRT) and Predicted Mean Vote (PMV), exhibited their lowest values in Model A, characterized by an organic layout, Figures 9 and 10. This indicates that the urban layout of Area A attained superior thermal comfort relative to Area B, where elevated MRT values were recorded. The increased MRT values adversely affected the anticipated thermal comfort rating for Occupants. The notable disparity in thermal comfort between the two regions can be attributed to the impact of urban configuration indicators on environmental parameters, including radiant temperature and shading variables. The study location, marked by a hot, arid urban climate, has thermal discomfort mostly due to elevated daytime temperatures caused by intense direct sun radiation. Therefore, urban architecture in these climates must emphasize mitigating solar radiation impacts, offering shade in structures, thoroughfares, and public areas, and safeguarding against hot, dust-filled winds. The organic urban layout of Area A, characterized by high building density, restricted outdoor spaces, and near building proximity, minimizes solar radiation exposure. This diminishes the Sky View Factor (SVF), thus reducing direct solar gain and improving shade. The correlation between SVF and radiant temperature is apparent in the MRT readings for Area A, which consistently stayed below 40°C in most open areas, especially in constricted internal streets, even at noon when the sun reaches its peak intensity. Conversely, radiant temperatures in other regions surpassed 80°C. The orientation and irregular configuration of streets in Area A resulted in increased shading, markedly reducing outdoor temperatures in contrast to the grid street pattern of Area B. In Area B, the regular layout and suboptimal Width-to-Height (W/H) ratios of streets caused prolonged exposure to direct radiation for most of the day, resulting in elevated levels of thermal stress. This analysis indicates that the urban layout most appropriate for a hot, arid climate is the organic form, characteristic of ancient historic cities. These layouts feature interlaced and overlapping structures, with streets and pedestrian routes creating small, serpentine alleys that shield against climatic conditions and offer substantial shading.

5. CONCLUSIONS AND RECOMMENDATIONS

This work analyzes outdoor thermal comfort in hot, arid locations, specifically focusing on Baghdad, by investigating the correlation between urban configuration and environmental elements and their influence on achieving thermal comfort in urban areas. The study's findings, obtained through environmental simulation techniques, indicate that the organic layouts typical of old historic towns are the most efficient in alleviating the severe climatic conditions of these areas. Dense urban environments featuring shaded narrow pathways and interconnected structures substantially diminish direct sun radiation exposure, therefore improving thermal comfort for occupants. The study utilized a comprehensive methodology to categorize urban configuration indicators through a systematic evaluation of prior research, highlighting the necessity of including environmental factors into urban design practices. It identified eight principal indicators and 37 subordinate indicators, classified into three scales: macro, meso, and micro. The study concludes that the initial step in analyzing and developing urban forms should involve the classification of urban configuration indicators. It underscores the necessity of incorporating environmental elements as a vital element in urban planning processes and in the formulation of specific indicators. This method seeks to establish thermally comfortable and environmentally adaptive urban environments.

6. RESEARCH LIMITATIONS

The research examined two distinct urban patterns in the Al-

Rusafa region of Baghdad, Iraq, both of which exhibit identical meteorological circumstances, defined by a hot, arid climate. This underscores the necessity of corroborating the findings by juxtaposing them with research undertaken in areas with varying climatic circumstances. The impact of urban design on thermal comfort is primarily contingent upon the city's dominant climatic attributes. The research recommends more investigation into distinct urban layouts and different climatic zones to elucidate the relationship between prevailing meteorological conditions, urban morphology, and their effects on outdoor thermal comfort. The results of this study may provide a reference for future research, assisting scholars and urban planners in establishing criteria and indicators for urban form.

REFERENCES

[1] Arsiya Ravari, A., Mazloomi, M. (2015). A framework for urban morphology with respect to the form. Armanshahr Architecture & Urban Development, 8(14): 91-103.

[2] Shehata, A.M. (2023). Sustainable-oriented development for urban interface of historic centers. Sustainability (Switzerland), 15(3): 2792. https://doi.org/10.3390/su15032792

[3] Esharjabi, A.G. (2019). The architectural elements of visual image and urban structure and their role in enhancing the future of the Yemeni city: A case study of Sana'a city. https://search.mandumah.com/Record/1443498.

[4] Elzeni, M., Elmokadem, A., Badawy, N.M. (2022). Genetic algorithms application in urban morphology generation. Port-Said Engineering Research Journal, 26(1): 21-34. https://doi.org/10.21608/pserj.2021.87367.1129

[5] Nemati Mehr, M.A. (2021). Elements and indicators of urban form: A meta-synthesis study. Space Ontology International Journal, 2(2): 45-60. https://doi.org/10.22094/soij.2021.1923638.1405

[6] Lowry, J.H., Lowry, M.B. (2014). Comparing spatial metrics that quantify urban form. Computers, Environment and Urban Systems, 44: 59-67. https://doi.org/10.1016/j.compenvurbsys.2013.11.005

[7] Sharifi, A. (2019). Resilient urban forms: A macro-scale analysis. Cities, 85: 1-14. https://doi.org/10.1016/j.cities.2018.11.023

[8] Zhao, C., Fu, G., Liu, X., Fu, F. (2011). Urban planning indicators, morphology and climate indicators: A case study for a north-south transect of Beijing, China. Building and Environment, 46(5): 1174-1183. https://doi.org/10.1016/j.buildenv.2010.12.009

[9] Al-Kaissi, S.M. (1984). The influence of natural and cultural environment on the fabric of the city, with special reference to Iraq. Doctoral dissertation, University of Sheffield.

[10] Al-Sharif, O.A., Newir, A.E., Halawa, M.A. (2023). Geographical variations in thermal comfort preferences based on ashrae database II. http://doi.org/10.13140/RG.2.2.17856.81929

[11] Al-Mamoori, H.S. (2014). Urban design, urban housing design & sustainability: Interrelated values & concept. https://www.researchgate.net/publication/312316895.

[12] Fanger, P.O. (1973). Assessment of man's thermal comfort in practice. Occupational and Environmental Medicine, 30(4): 313-324. https://doi.org/10.1136/oem.30.4.313

[13] Sanagar, E., Rafieian, M. (2020). The effects of urban heat Islands mitigation on human health through change in urban form hot and arid climate of Mashhad (Case study: Graticular texture of Shahed and organic texture of Pachenar neighborhoods).

[14] Parsons, K. (2019). Human Thermal Comfort. CRC Press.

[15] Raman, V., Kumar, M., Sharma, A., Froehlich, D., Matzarakis, A. (2021). Quantification of thermal stress abatement by trees, its dependence on morphology and wind: A case study at Patna, Bihar, India. Urban Forestry & Urban Greening, 63: 127213. https://doi.org/10.1016/j.ufug.2021.127213

[16] Tsoka, S., Tsikaloudaki, K., Theodosiou, T. (2017). Urban space's morphology and microclimatic analysis: A study for a typical urban district in the Mediterranean city of Thessaloniki, Greece. Energy and Buildings, 156: 96-108. https://doi.org/10.1016/j.enbuild.2017.09.066

[17] Schwarz, N. (2010). Urban form revisited—Selecting indicators for characterising European cities. Landscape and Urban Planning, 96(1): 29-47. https://doi.org/10.1016/j.landurbplan.2010.01.007

[18] Fleischmann, M., Romice, O., Porta, S. (2021). Measuring urban form: Overcoming terminological inconsistencies for a quantitative and comprehensive morphologic analysis of cities. Environment and Planning B: Urban Analytics and City Science, 48(8): 2133-2150. https://doi.org/10.1177/2399808320910444

[19] Fahmy, M., Sharples, S. (2008). 307; Passive design for urban thermal comfort: A comparison between different urban forms in Cairo, Egypt. In 25th Conference on Passive and Low Energy Architecture, Dublin, pp. 1-6.

[20] Zanjani, N.E., Ziyari, Y.A., Zarabadi, Z.S., Sabbaghi, H.R. (2023). Urban energy system and climate indicators for urban energy planning. International Journal of Human Capital in Urban Management, 8(2): 261-278. https://doi.org/10.22034/IJHCUM.2023.02.08

[21] Abdelrahman, M.M. (2017). The role of CFD techniques in the environmental sustainability in architecture and urban design: A case study on the intermediate cities. Master Thesis, National University of Singapore.

[22] Chen, Y., Wang, Y., Zhou, D. (2021). Knowledge map of urban morphology and thermal comfort: A bibliometric analysis based on citespace. Buildings, 11(10): 427. https://doi.org/10.3390/buildings11100427

[23] Wang, R., Liu, R., Chen, Q., Cheng, Q., Du, M. (2023). Effects of sky view factor on thermal environment in different local climate zoning building scenarios—A case study of Beijing, China. Buildings, 13(8): 1882. https://doi.org/10.3390/buildings13081882

[24] Mirabi, E., Nasrollahi, N. (2020). Urban facade geometry on outdoor comfort conditions: A review. European Online Journal of Natural and Social Sciences, 9(3): 655-677.

[25] Abu Zaid, N.E.D., Sameh, H., Abdul Aziz, H. (2019). Architectural mass as a tool for achieving thermal comfort in the external urban space. Journal of the Egyptian Society of Engineers, 58(3): 53-47. https://egsen.journals.ekb.eg/article_177682.html.

[26] Al-Saaidy, H.J., Alobaydi, D. (2021). Studying street centrality and human density in different urban forms in

Baghdad, Iraq. Ain Shams Engineering Journal, 12(1): 1111-1121. https://doi.org/10.1016/j.asej.2020.06.008

[27] AbdelHamid, G., Abu El-Ayoun, A., Abdelwahab, A., Ahmed Musa, M. (2019). Urban spaces. A visual study of the form and content relationship. Journal of Advanced Engineering Trends, 38(2): 45-69.

[28] Bao, J., Xu, L., Shi, Y., Ma, Q., Lu, Z. (2023). The influence of street morphology on thermal environment based on ENVI-met simulation: A case study of Hangzhou core area, China. ISPRS International Journal of Geo-Information, 12(8): 303. https://doi.org/10.3390/ijgi12080303

[29] Chen, S., Zhang, W., Wong, N.H., Ignatius, M. (2020). Combining CityGML files and data-driven models for microclimate simulations in a tropical city. Building and Environment, 185: 107314. https://doi.org/10.1016/j.buildenv.2020.107314

[30] Wu, Q., Jo, H.K. (2015). A study on Ecotect application of local climate at a residential area in Chuncheon, Korea. Journal of Environmental Engineering and Landscape Management, 23(2): 94-101. https://doi.org/10.3846/16486897.2014.980264

[31] Ibrahim, R., Mushatat, S., Abdelmonem, M.G. (2016). The role of urban pattern indicators for sustainable urban forms in the developed countries. https://www.researchgate.net/publication/320715935.

[32] Al-Mosawy, S.K.A., Al-Jawari, S.M., Al-Jabari, A.A. (2020). The effect of urban form on temperature for hot arid zones. The case study of Baghdad, Iraq. IOP Conference Series: Earth and Environmental Science, 459(6): 062109. https://doi.org/10.1088/1755-1315/459/6/062109

[33] 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, 17(1): 50-63.