International Journal of Sustainable Development and Planning
Vol. 19, No. 7, July, 2024, pp. 2559-2568
Journal homepage: http://iieta.org/journals/ijsdp

Influence of Building Height on Microclimate and Human Comfort: A Case Study from the New Administrative Capital

Amany A. Ragheb[1], Riham Aly[2], Ghada Ragheb[2], Hesham Mohamed[1], Rasha Ali El Ashmawy[1,3*]

[1] Department of Architectural, Faculty of Engineering, Delta University for Science and Technology, Gamasa 35712, Dakahlia, Egypt
[2] Pharos University in Alexandria, Alexandria 21648, Egypt
[3] Department of Architectural, Delta Higher Institute of Engineering and Technology, Mansoura 35681, Egypt

Corresponding Author Email: rasha.elashmawy@deltauniv.edu.eg

https://doi.org/10.18280/ijsdp.190712

Received: 4 May 2024
Revised: 13 June 2024
Accepted: 13 July 2024
Available online: 30 July 2024

Keywords:
sustainable design, urban space, human comfort, urban microclimate

ABSTRACT

This manuscript investigates the impact of urban development on microclimates worldwide, highlighting the critical role of pedestrian thermal comfort in human well-being and global climate. The built environment plays a significant role in moderating these effects, which are influenced by factors such as building heights and materials. To anticipate outdoor conditions, this research utilizes ENVI-met simulation to model various aspects of the microclimate, including wind patterns and solar radiation, which are crucial for human comfort. The manuscript emphasizes the importance of air motion, temperature, and humidity in determining thermal comfort and recommends radiant temperature adjustments in urban areas to mitigate adverse climate impacts. Focusing on the New Administrative Capital's neighborhood design, the research demonstrates how microclimatic enhancement through simulation techniques can inform city planning and shape urban design. The findings underscore the interconnectedness of human comfort, urban design, and microclimatic conditions, suggesting that modifying specific design elements can alter local climates. The study recommends that urban planners consider building heights and arrangements to optimize microclimatic conditions, enhancing human comfort while mitigating adverse climate impacts. This research presents evidence of how urban design influences microclimates and highlights the potential to enhance human comfort through informed design choices, providing practical recommendations for urban planners to incorporate into their designs.

1. INTRODUCTION

The rapid urbanization and densification of cities have raised concerns about the effects of built environments on microclimates. As cities strive to become more sustainable, the design and development of neighbourhoods that promote environmental well-being have gained significant attention [1, 2]. One crucial aspect of neighbourhood design is the building height, which has the potential to influence the microclimate and contribute to the creation of more sustainable urban environments.

The relationship between building height and microclimate has been widely acknowledged in urban planning and climatology literature. Previous studies have primarily focused on the negative effects of tall buildings, such as the urban heat island effect, increased energy consumption, and reduced outdoor comfort. However, there is a growing body of research emphasizing the importance of sustainable building practices and their potential to mitigate these negative impacts [3, 4]. Sustainable neighbourhood building height refers to the design and construction of buildings that prioritize energy efficiency, passive design strategies, and the integration of renewable energy sources. These buildings are often equipped with green roofs, vertical gardens, and shading devices, which can significantly influence the microclimate by mitigating the adverse effects of urbanization [5, 6].

Additionally, sustainable building height can enhance natural ventilation, reduce the urban heat island effect, and improve outdoor thermal comfort. The incorporation of green spaces and vegetation at different building heights can also contribute to enhanced air quality, reduced noise levels, and increased biodiversity [7].

This research aims to investigate the impact of sustainable neighbourhood building height on microclimate, considering the various environmental factors and their interactions [8, 9]. The study will focus on assessing the influence of sustainable building height on outdoor thermal comfort in selected neighbourhoods, analyze the impact of sustainable building height on energy consumption and the urban heat island effect and to evaluate the effectiveness of green building practices, such as green roofs and vertical gardens, in enhancing the microclimate. To achieve these objectives, the research will employ a combination of quantitative and qualitative methodologies. Data collection will involve site measurements of temperature, humidity, wind speed, and solar radiation in selected neighbourhoods with varying building heights. Computer simulations using Computational Fluid Dynamics (CFD) models will be employed to assess the airflow patterns, energy consumption, and outdoor comfort in these neighbourhoods. The findings of this study will contribute to the existing body of knowledge on sustainable urban design and its impact on microclimates. The research outcomes will offer valuable insights for urban planners, architects, and policymakers in making informed decisions regarding building height regulations, green building practices, and sustainable neighbourhood development.

2. THEORETICAL BACKGROUND

The sustainable design of neighbourhoods has become increasingly crucial for creating liveable urban spaces. Building height plays a significant role in shaping microclimate conditions and influencing human comfort. This literature review investigates the impact of sustainable neighbourhood building height on microclimate and human comfort. The review draws upon multiple studies to provide an overview of the current understanding of this relationship.

The theoretical background of sustainable urban design and its impact on microclimates and human comfort is crucial for creating livable urban spaces. Building height plays a significant role in shaping microclimate conditions and influencing human comfort. Urban microclimates are influenced by various factors such as building height, street width, orientation, and land usage. Urban design encompasses the arrangement of buildings, streets, public spaces, and neighborhoods, focusing on aesthetics, ambiance, and overall quality of spaces. Research suggests that building height has a substantial influence on microclimate conditions, including wind patterns and airflow. Strategies to enhance microclimate conditions and human comfort include the integration of green spaces, tree planting, and sustainable urban design approaches. The integration of climate in urban design is essential for achieving sustainable outcomes, and climate analysis must be incorporated early in the design process to prevent sound decisions from closing off feasible options.

2.1 Urban microclimate

Climate refers to the long-term patterns of the surrounding environment in a particular area, including features like humidity, temperature, wind, pressure, precipitation, and cloud cover. A densely populated area has more structures built by humans than the surrounding areas. A local atmospheric zone with a different climate from the surrounding area is known as a microclimate. The phrase can be used to describe spaces that are many square meters in size or many square kilometres in size [10, 11]. Microclimates can manifest in various environments, such as close-to-water bodies capable of moderating air temperature or within urban areas characterized by high population density. Urban heat islands, a specific type of microclimate, emerge due to materials like brick, concrete, and asphalt absorbing and emitting solar heat, thereby warming the surrounding air [5, 12].

The urban microclimate, as extensively described in practical literature, is contingent upon various factors such as the size, location, population density, and land usage of a city, along with specific elements of street design including building height, street width, orientation, and building layout. Consequently, each neighborhood within a metropolis develops its unique local climate influenced by the urban planning within it [5, 13, 14].

2.2 Urban design

Designing and forming cities, towns, and villages is known as urban design. While architecture concentrates on individual structures, urban design works on a broader scale, involving groups of buildings, streets and public spaces, entire neighbourhoods and districts, and entire towns, with the goal of creating sustainable, aesthetically pleasing, and functioning city areas.

Instead of providing an idealised plan based on climate concerns, the main goal is to produce a workable plan, which is both economically feasible and acknowledges that the planner must take other aspects into account in addition to the requirements of transportation systems. An urban design that aligns with meteorological ideals offers educational advantages, yet it overlooks practical planning constraints where climate factors may not hold primary significance [14, 15]. Urban planning encompasses the arrangement of buildings, streets, public spaces, neighborhoods, districts, and entire cities on a broader scale. Forward-thinking urban design focuses on the aesthetics, ambiance, and overall quality of spaces, encompassing both buildings and the surrounding areas [16], the following aspects are addressed by urban design (Table 1).

Table 1. Aspects addressed by urban design [14]

Pedestrian zones	areas of a city or town reserved for pedestrian-single use and in which some or all automobile traffic may be prohibited.
Incorporation of nature within a town	preserves and complements the liveability of towns, large and small, by incorporating extra nature.
Aesthetics	creation and appreciation of beauty.
Urban structure	how a place is put together and how its components relate to each other.
Urban typology	density and sustainability – spatial kinds and morphologies associated with intensity of use, consumption of resources and manufacturing and renovation of viable communities.
Accessibility	providing for ease, safety and choice while transferring to and through places.
Legibility and way finding	helping people to discover their way around and recognize how a place works.
Animation	designing places to stimulate public activity.
Function and fit	shaping places to assist their various planned uses.
Complementary mixed uses	locating activities to permit constructive interaction between them.
Character and meaning	recognizing and valuing the variations among one location and other.
Order and incident	balancing consistency and variety in the urban environment in the interests of appreciating both.
Continuity and change	locating people in time and place, including heritage respect and support for modern culture.
Civil society	making places in which people are free to encounter each other as civic.

Currently, marketing influences are driving urban design due to housing demands. When decision-makers minimize the significance of climate considerations in urban design, it becomes essential to utilize computerized predictive tools that yield measurable insights into the impact of proposed designs on the climate [17, 18]. It's imperative for authorities to consider these quantitative metrics, which enable individual structures to optimize their utilization of natural energy and enhance pedestrian comfort and outdoor activities. To establish such metrics, urban planners require accurate information about the microclimate conditions within their communities [19].

2.3 Microclimate effects of building height

Research suggests that building height has a substantial influence on microclimate conditions. Some researchers highlight how tall buildings can create wind tunnels, altering wind patterns and airflow within the urban environment [20]. This phenomenon affects pedestrian comfort and safety. Similarly, other researches explore the effects of microclimate and park and surrounding building configuration on thermal comfort in urban parks, emphasizing the importance of building height in park design [21]. The adverse microclimate effects resulting from building height can impact human thermal comfort. Abaas [22] examines the impact of urban development on Baghdad's microclimate and human thermal comfort, emphasizing the need for sustainable design to mitigate discomfort caused by tall buildings. Others investigate the impact of microclimate and recreational participation on human thermal comfort, highlighting the significance of microclimate conditions in enhancing comfort levels [23, 24].

2.4 Strategies to enhance microclimate and human comfort

Several strategies can be employed to enhance microclimate conditions and human comfort within neighbourhoods. The effects of landscape patterns on summer microclimate and human comfort in urban squares in China, emphasizing the importance of green spaces in mitigating adverse microclimate effects were examined [25]. Also, the influence of tree cover and species on microclimate and pedestrian comfort in a residential district in Iran was explored, suggesting that tree planting can positively impact microclimate and enhance comfort levels [26].

Sustainable urban design approaches can effectively address the challenges associated with building height and microclimate. A case study was presented on the role of green infrastructure in enhancing microclimate conditions in a low-rise neighbourhood in Abu Dhabi. They demonstrate how the integration of green spaces can mitigate adverse microclimate effects [27]. The influence of microclimate was examined on comfort, health, and energy demand, emphasizing the importance of understanding microclimate dynamics for sustainable urban planning [28]. Furthermore, the effects of a denser city were investigated on urban microclimate, highlighting the need to consider building height in urban planning to achieve sustainable outcomes [29].

2.5 Microclimatic considerations in urban design

If there will be significant benefits from achieving the design's objectives, then the integration of climate in planning and design processes is likely to be enhanced. If applicable, automated prediction methods must be used for their evaluation, which must focus on realistic and difficult scenarios. The importance of climatic factors in urban planning is typically downgraded by decision makers based on well-documented information from many planning professions and the lack of quantitative studies on the impact of proposed designs on climate [30].

Early in the design process, climate analysis must be incorporated to prevent sound decisions from closing off feasible options. Seldom can appropriate climate solutions be implemented retroactively to correct errors in the original design states. To effectively include urban climatology into town design, a complete approach that balances many considerations, such as building energy efficiency and pedestrian comfort, must be used [31].

Climate scientists should be able to work with various design group members to assess the economic effects in their recommendations for decision-making, which may include avenue width or building height, which may also have important economic ramifications. This is because the developers frequently measure a project's success by its immediate financial return. Environmental effects, however, should be considered in any assessment of long-term sustainability [32, 33].

3. CASE STUDY: THE NEW ADMINISTRATIVE CAPITAL (NAC)

Since 2015, Egypt has been constructing a new capital city on an immense scale known as the New Administrative Capital (NAC) Figure 1. It is situated 35 km east of Cairo, Egypt with a total area of 170 acres. This project lies between the Cairo-Suez road, Cairo-ElAin ElSokhna road and the regional ring road. By offering more places for people to live, work, and travel, the new capital city will contribute to the country's economic potential's expansion and diversification. There will be several significant catalytic initiatives built within the center of this new capital city to attract tourists. The project will comprise a wide range of urban areas, a new government administrative district, and a cultural district.

An empty land was chosen for designing a neighborhood to achieve a livable sustainable walkable community. The total area of this land is 196.5 acres. This proposed neighborhood is located near the main green spine.

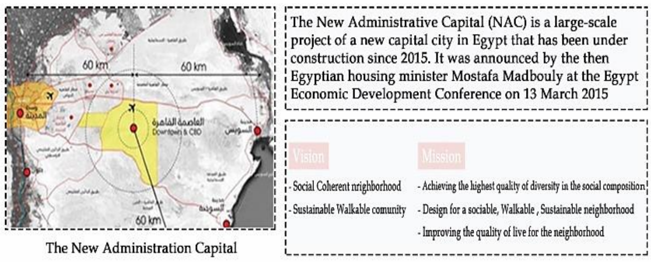


Figure 1. The New Administrative Capital (NAC)

3.1 Simulation with ENVI-met 5 software

Various simulation models like ENVI-met, TownScope, OTC Model, Rayman, Ecotect, and SOLWEIG-model are utilized to evaluate human thermal comfort outdoors. Among these, the ENVI-met 3D program serves as a key tool for simulating urban design. ENVI-met was adapted to simulate the micro-scale atmospheric conditions characteristic of urban environments, providing a valuable resource for such analyses. This modeling application is regarded as one of the most popular ones for evaluating microclimate conditions in urban development planning. The software makes estimations for variables like relative humidity, wind speed, and surface air temperature [34].

Figure 2. The proposed neighborhood model

First, the proposed neighborhood model was produced in AutoCAD format. It was then built using spaces, one of the ENVI-met modules Figure 2. The processes of the soil, plants, buildings, and atmosphere are all taken into account in this simulation. Moreover, it provides precise weather simulations for urban areas, enabling in-depth research on microclimate fluctuations.

A computer simulation was used to conduct the case study and assess the neighborhood's design. Thus, enhanced building and urban design by emphasizing the neighborhood's development of the urban microclimate and attaining thermal comfort, three alterations were applied utilizing different building heights in the ENVI-met program modeling. The reason of applying ENVI-met was its capacity for representing three-dimensional buildings in addition to calculating the impacts of vegetation, shading, and how these factors relate to outdoor thermal comfort.

Subsequently, the conclusions and suggestions derived from the simulation model were utilized to tackle challenges related to mitigating the heat island effect and improving outdoor thermal comfort in hot weather conditions. All of the measures obtained consider building height concerns. The goals of this study are to examine how different building heights affect surface temperatures and, in turn, urban heat island effects, and to identify the building height that most effectively enhances and promotes balanced outdoor thermal comfort.

3.2 Analysis of the proposed neighborhood's urban context

The SWOT technique was used to identify the most important internal and external factors shown in the proposed neighborhood Figure 3. This neighborhood respects the key factors for the urban planning concept of the 15-minute city where everything needed in daily life is accessible in 15 minutes by foot or bike Figure 4. The population density in this neighborhood is suitable as it is 35 people / acre with a total population of 6878 people. The main goals of the neighborhood design strategies are to achieve a social coherent neighborhood, smart mobility, the highest quality of diversity in the social composition, a livable sustainable walkable community and to improve the quality of life.

Designing a suitable street network that allows cars to reach all services without crossing pedestrian paths. Solve all intersections as (T) intersections which provide low car crashes.

There are three residential building types: 131 Villas for 524-person, 126 Semi attached buildings for 3024 people, and 54 Attached buildings for 3330 persons. There are a variety of services: mosque, primary school, kindergarten, secondary school, health care unit, and shopping center. These services are in a central service node connected with every zone & the spine mark neighborhood entrances. A long green spine in the heart of the land connects all residential buildings and the main center of the services Figure 5.

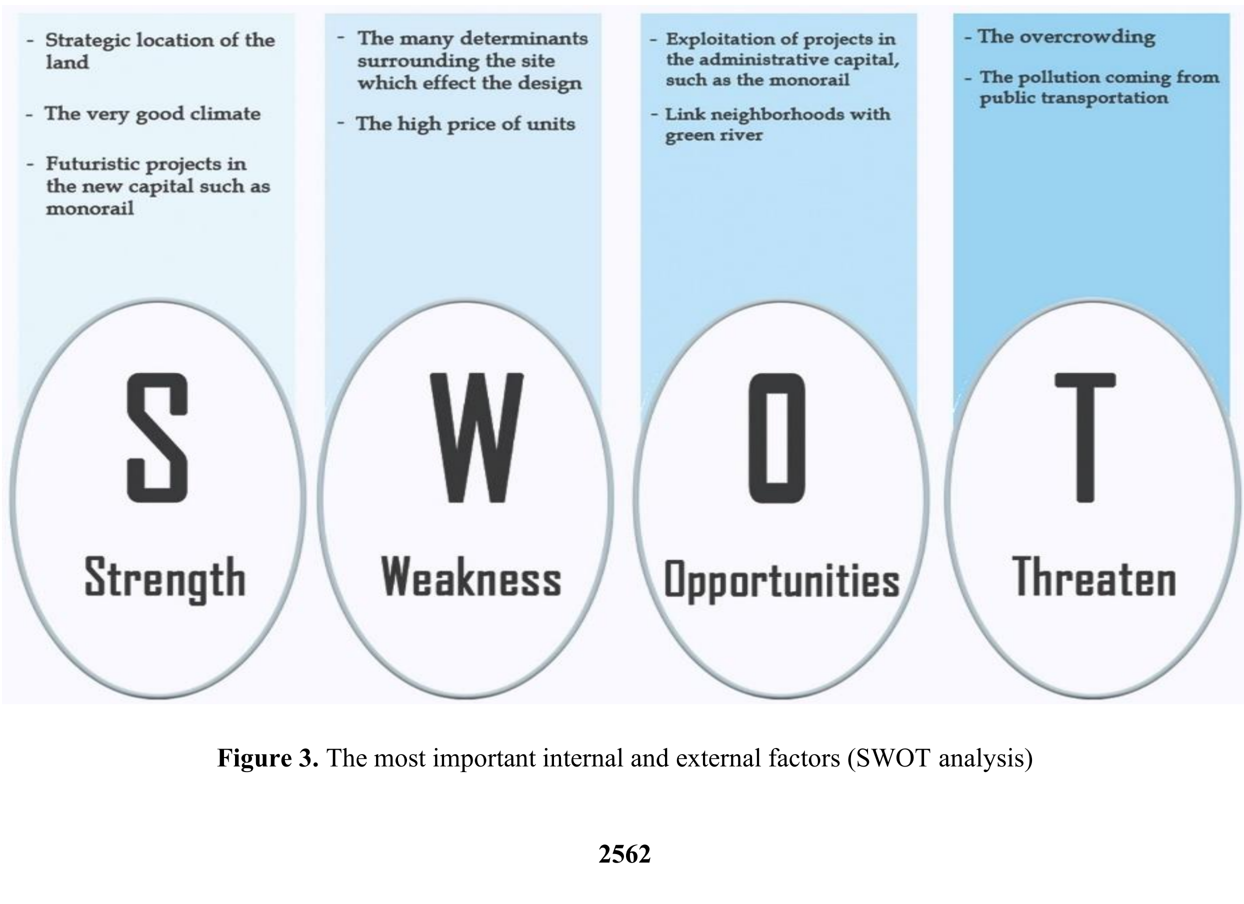
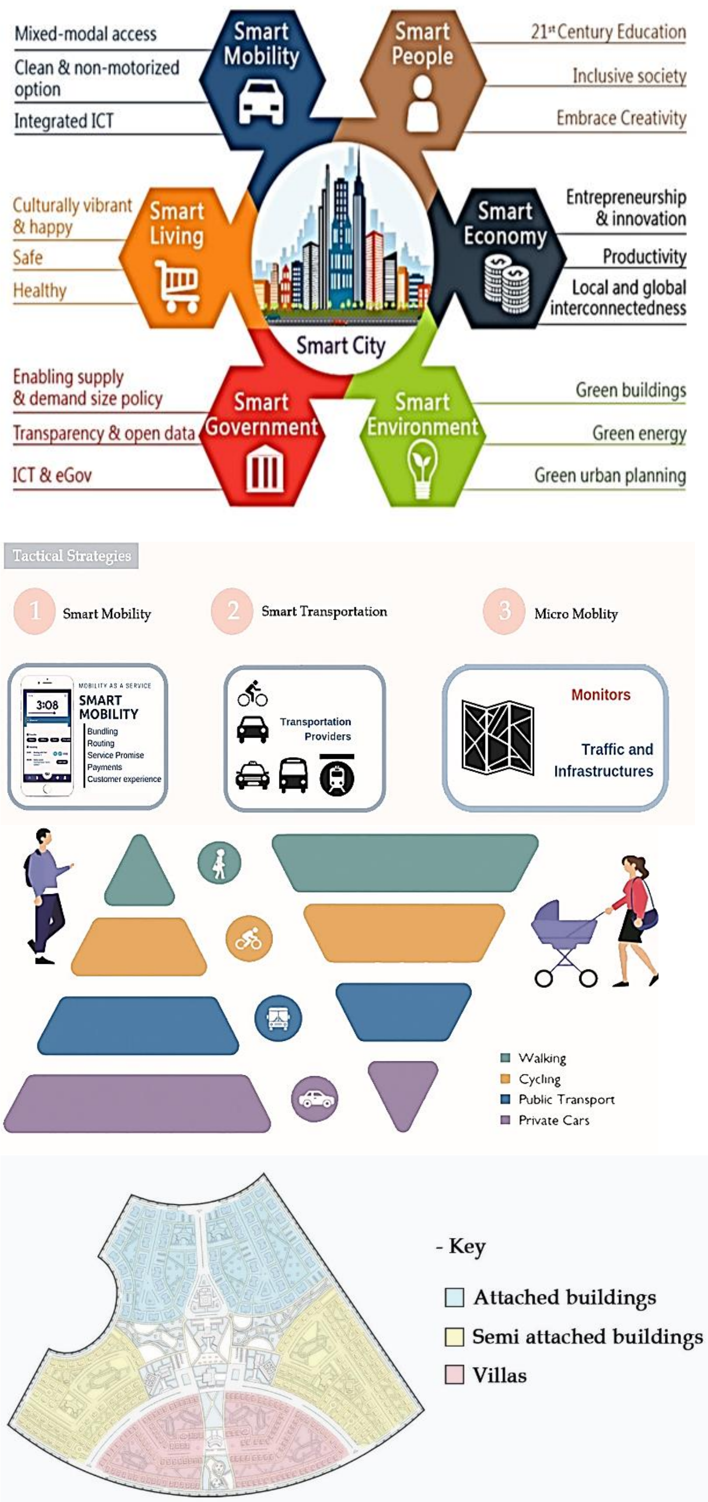


Figure 3. The most important internal and external factors (SWOT analysis)



Everything needs to be accessible in 15 minutes or less by foot or bike.

This includes: workplace, grocery, shopping, child-care, healthcare, parks, culture, sport, coffee, shops, restaurants, public transport, bike and schools.

The bike plays a special role in 15-Minute city. Therefore new bike lanes need to be implemented. Other supporting infrastructure would be bike - and car sharing opportunities and electric charging stations for bikes and cars.

Greening of areas that would become unused for example parking lots would make the district more livable.

The 15-Minutes city as the ideal solution?

* Create a district where everything you need in your daily life is accessible in 15 minutes by foots or bike, workplace included.

* Centralize cars and individual passenger transport at central points (e.g. neighborhood garage), synchronize mobility service (public transport) and create recreation and experience zones. Easy to say but difficult to implement/accomplish.

Calculations

Total area : 826,034 m square = 196.5 acre
Population density : 35 person / arce
Population : 196.5*35 = 6878 person

Residential buildings types

1) 131 Villas for 524 person
2) 126 Semi attached building for 3024 person
3) 54 Attached building for 3330 person

Services

Mosque : 1.5*6190 = 9285 m square
Kindergarten : 6*460 = 2760 m square
Primary school : 6*610 = 3660 m square
Secondary school : 10*756 = 7560 m square
Health care unit : 0.2*6878= 1375.6 m square
Shopping center : 1.8*6878= 12,380 m square

Figure 4. The proposed neighborhood respects the key factors for the urban planning concept of the 15-minute city

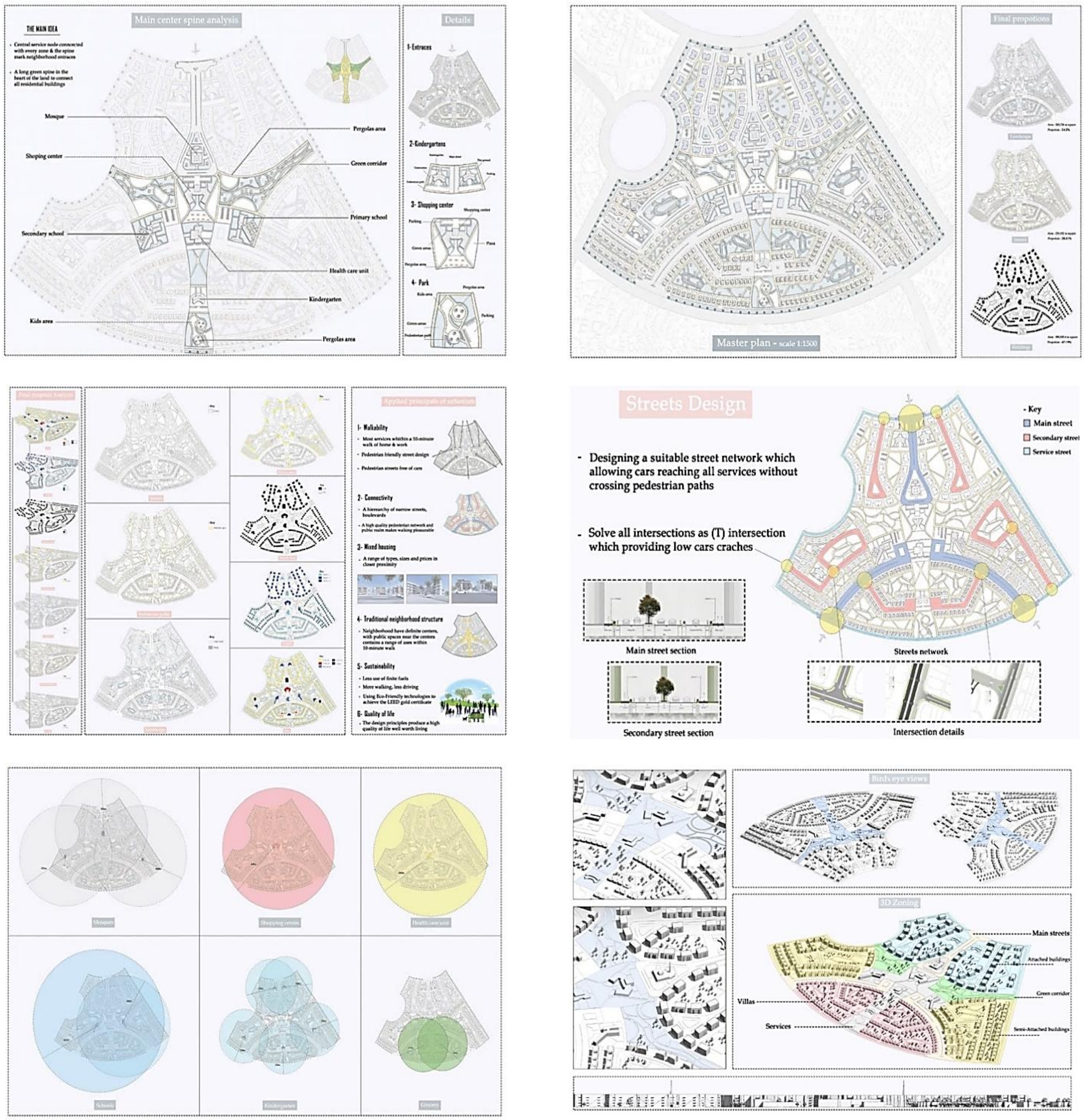


Figure 5. Design details of the proposed neighborhood

3.3 Simulation of the current thermal comfort situation

The duration of a New Administrative Capital day varies annually. In 2023, the longest day was 21 June (14hr 4min. 55sec.) and the shortest day was 22 December (10hr 12min. 42sec.)

In the New Administrative Capital, the winter is cold, dry, and windy, but the summer is lengthy, hot, humid, and desert. Furthermore, there is a 20-35-degree Celsius temperature range. This phenomenon validates the simulation that concentrates on the summer because it is the warmest season and the longest time exposed to the light for resolving the UHI issue and the longest day was taken to simulate the proposed neighborhood.

3.3.1 Different cases for changing building heights

To assess thermal comfort levels and heat stress, several building height cases are simulated by applying the ENVI-met 5.0 program (Table 2). During summer 2023, the inputs for ENVI-met were acquired on the 21st of June which represents the longest daytime and at 2:00 p.m. which is one of the peak temperature hours. The simulation was performed throughout a period of twelve hours, starting at 6:00 a.m. and finishing at 6:00 p.m. LEONARDO, an integrated ENVI-met module, was then used to average the findings. To produce the prevailing climate conditions, the ENVI-met model has utilized boundary conditions sourced from the initial EPW file corresponding to the nearest weather station to the location under study. The simulation's first phase was to set up the site as an empty land that is completely exposed to the sun all over the year and the second phase consisted of creating a simulation of the proposed neighborhood and trying several buildings' heights by ENVI-met software.

The examined cases throughout the study structure point to the following four situations:

- **Case I** consists of the current situation where there is just empty land, the site is covered by sand and the roads are covered by conventional asphalt. The surface air temperature was a minimum of 34.49℃ and a maximum of 35.79℃.
- **Case II** adherence to the suggested neighborhood plan involves implementing an appropriate street layout, substituting vehicle road material with basalt, and using granite paving stones for sidewalks, along with incorporating a small water feature and green elements. Additionally, buildings are designed with heights ranging from 1 to 2 floors. This approach yielded a reduction in surface air temperature ranging from 3.32 to 1.63 degrees Celsius.
- **Case III** conforms to Case II. However, changing the building heights to 2 and 3 floors. This situation presented a result of a 3.00-1.11℃ decrease in the surface air temperature.
- **Case IV** corresponds to Case II. However, changing the building heights to 3 and 4 floors. This situation resulted in a 3.74-2.08℃ decrease in the air's surface temperature.

The table below (Table 3) illustrates the outcomes of varying building heights and the computation of the four cases regarding surface air temperature.

Table 2. The ENVI-met program's input parameters

Type	Input Parameters	Value
Location	City	The New Administrative Capital
Simulation	Latitude	30.0186 ^{0}N
	Longitude	31.7320 ^{0}E
	Day	21 June 2023
	TIME	12h from 6:00 a.m. to 6:00 p.m.
Metrological condition	Initial temperature	From 20 C^0 to 35 C^0
	Relative humidity	45%
	Mean wind speed	2.5 m/s
	Prevailing wind direction	North west 315^0
Buildings	Thermal conductivity	1.6
	Albedo of walls	0.5
Road	Road width	18m
	Road material	Conventional asphalt
	Sidewalk material	Conventional interlock tiles
Greening	Trees (Hedge dense) 2m-4m	Albedo 0.2

The simulation's findings show how the neighborhood's thermal comfort is influenced by building heights. The color-coded maps were used to contrast surface air temperatures as influenced by alterations in building heights, aiming to mitigate the urban heat island effect and enhance thermal comfort (Figure 6).

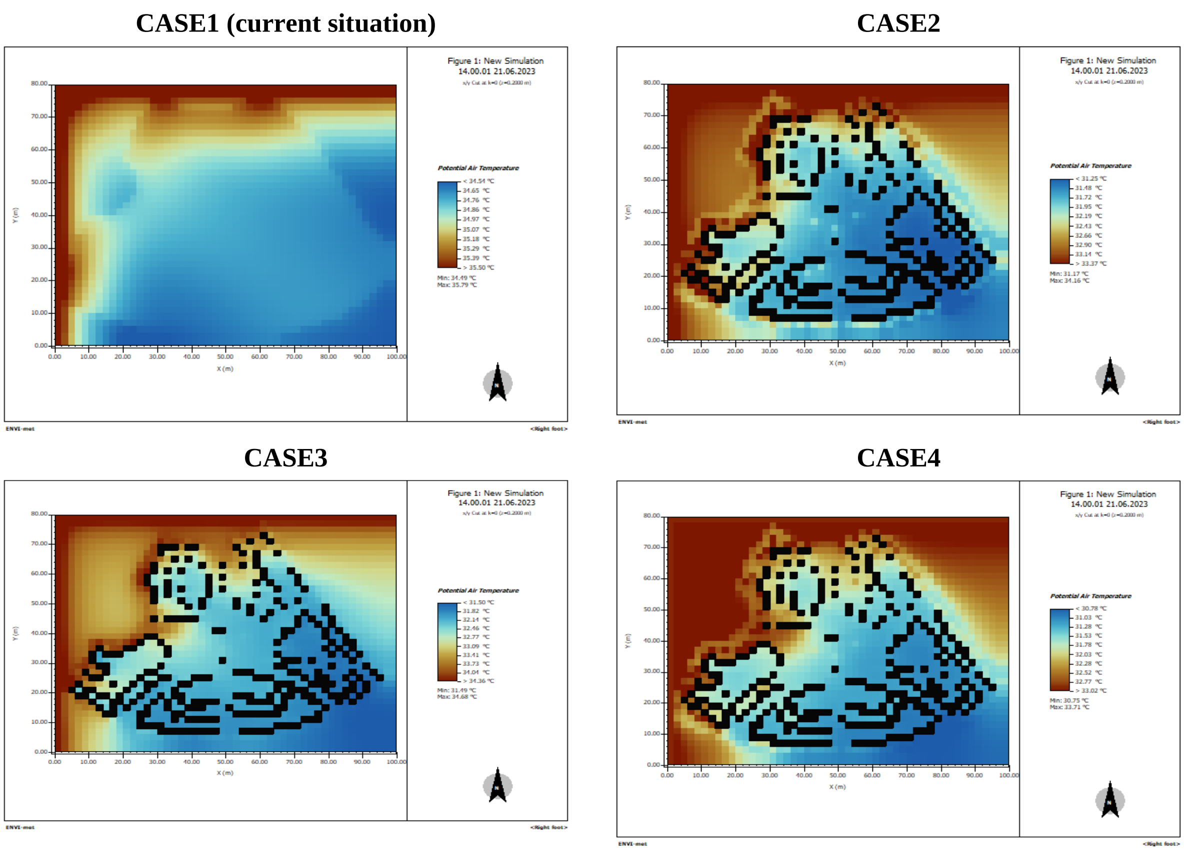


Figure 6. Color-coded maps were used to contrast surface air temperatures as influenced by alterations in building heights, aiming to mitigate the urban heat island effect and enhance thermal comfort

Table 3. Comparison between the three suggested cases and the existing case

Case No.	Time	Site Pavement	Vegetation & Water Bodies	Building Heights	Air Temperature	Wind Speed	Relative Humidity
Case I (current situation)	2:00 pm	Conventional asphalt & Sand	No	No buildings	**34.49°C** **35.79°C**	**0.83** **1.18**	**38.15** **40.00**
Case II	2:00 pm	Basalt & Granite stones	Yes	1-2 floors	**31.17°C** **34.16°C**	**0** **1.11**	**41.01** **46.05**
Case III	2:00 pm	Basalt & Granite stones	Yes	2-3 floors	**31.49°C** **34.68°C**	**0** **1.22**	**40.19** **45.22**
Case IV (best case)	2:00 pm	Basalt & Granite stones	Yes	3-4 floors	**30.75°C** **33.71°C**	**0** **1.48**	**42.65** **46.50**

3.3.2 Measurements and results

The ENVI-met simulation results show a significant reduction in surface temperature, with a mean decrease of 3.74°C compared to the baseline scenario, particularly in Case IV where a combination of building height, vegetation, trees, small water elements, and paving materials resulted in the most substantial temperature decrease. The results are consistent with existing studies on the importance of building height and urban design elements in mitigating the urban heat island effect and improving pedestrian thermal comfort. However, the results also reveal discrepancies with existing studies, such as the optimal building height for thermal comfort being between three and four stories, which is lower than the commonly cited threshold. The findings highlight the importance of vegetation and water elements in mitigating the urban heat island effect and suggest that the type and density of vegetation may have a significant impact on effectiveness. The results have significant implications for urban planning and design practices, suggesting that urban designers should prioritize building heights between three and four stories, incorporate vegetation and water elements, and utilize specific paving materials to improve pedestrian thermal comfort and urban microclimates (Figures 7, 8, 9).

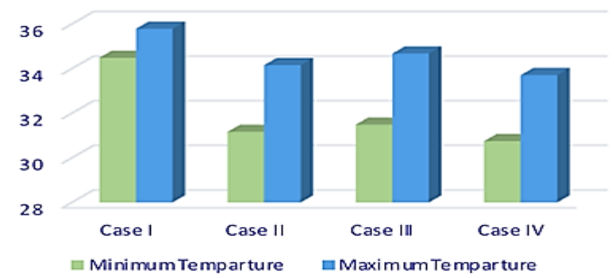


Figure 7. Contrast between the highest and lowest air temperatures across various scenarios

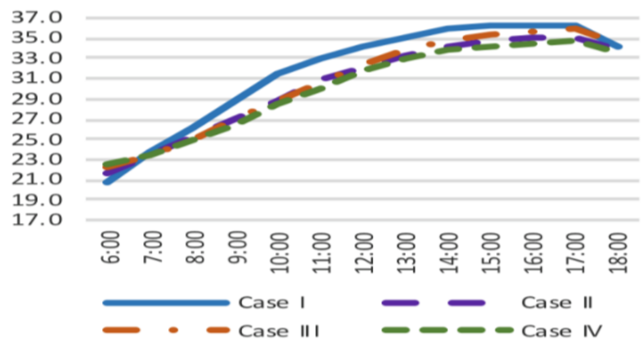


Figure 8. Assessing the highest air temperature

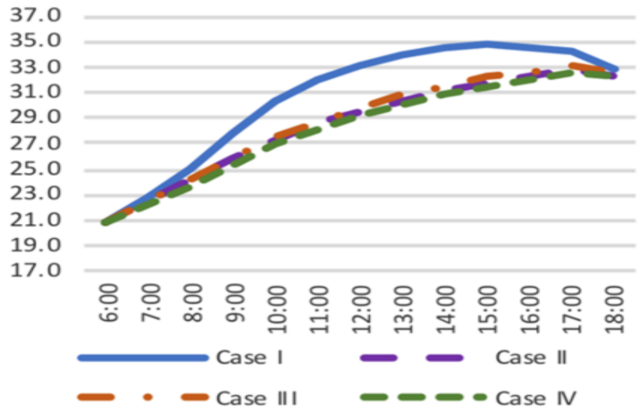


Figure 9. Assessing of lowest air temperature

4. CONCLUSION

The literature review reveals a significant correlation between sustainable neighborhood building height and microclimate conditions, with a substantial impact on human comfort. The findings suggest that incorporating green spaces, optimizing building height-to-street width ratios, and employing passive design features are essential strategies for mitigating adverse microclimate effects and enhancing human comfort. Also, there are several limitations and assumptions, including the potential biases in simulation studies and the need for further research to refine our understanding of the relationship between sustainable building height, microclimate, and human comfort.

A critical analysis of the findings reveals some contradictions and unexpected results within the reviewed studies. For instance, some studies suggest that taller buildings can create wind tunnels, while others indicate that they can also enhance natural ventilation. These contradictions underscore the complexity of the relationship between building height and microclimate conditions, emphasizing the need for further research to better understand the interplay between these factors.

In light of these findings, we recommend that urban planners and decision-makers adopt the following policy recommendations:

- Integrate Green Spaces: Incorporate green spaces and vegetation into urban design to mitigate adverse microclimate effects and enhance human comfort.
- Optimize Building Height-to-Street Width Ratios: Ensure that building height-to-street width ratios are optimized to minimize wind tunnel effects and enhance natural ventilation.

- Employ Passive Design Features: Incorporate passive design features, such as shading devices and insulation, to reduce energy consumption and enhance human comfort.
- Conduct Site-Specific Assessments: Conduct site-specific assessments to better understand the unique microclimate conditions of each urban area and tailor urban design strategies accordingly.
- Collaborate with Stakeholders: Encourage collaboration between urban planners, architects, and local communities to ensure that urban design strategies are informed by local needs and preferences.

By adopting these policy recommendations, urban planners and decision-makers can create more sustainable and livable urban spaces that prioritize human comfort and well-being.

REFERENCES

[1] UNDP. (2017). Rapid urbanisation: opportunities and challenges to improve the well-being of societies. Human Development Reports. https://hdr.undp.org/content/rapid-urbanisation-opportunities-and-challenges-improve-well-being-societies.

[2] Abdelrazek, S., Ragheb, A., Makram, A. (2018). Knowledge as a holistic, integrated approach to future urban development. International Journal of Current Research, 10(10): 74582-74587. https://doi.org/10.24941/ijcr.32876.10.2018

[3] Yang, S., Wang, L.L., Stathopoulos, T., Marey, A.M. (2023). Urban microclimate and its impact on built environment-A review. Building and Environment, 238: 110334. https://doi.org/10.1016/j.buildenv.2023.110334

[4] Shareef, S., Abu-Hijleh, B. (2020). The effect of building height diversity on outdoor microclimate conditions in hot climate. A case study of Dubai-UAE. Urban Climate, 32: 100611. https://doi.org/10.1016/j.uclim.2020.100611

[5] Aung, T.H.E.I.N.G.I., Liana, S.R., Htet, A.R.K.A.R., Bhaumik, A.M.I.Y.A. (2023). Integrating green infrastructure into urban high-rise buildings: Design strategies and benefits. Seybold Report, 18: 1571-1579. https://doi.org/10.17605/OSF.IO/XCPH7

[6] Ragheb, R., Ragheb, S. (2022). Assessment framework for sustainable community in the MENA Region. الدورية العلمية لكلية الفنون الجميلة, 10(1): 15-25. https://doi.org/10.21608/sjfa.2022.217636

[7] Wong, N.H., Tan, C.L., Kolokotsa, D.D., Takebayashi, H. (2021). Greenery as a mitigation and adaptation strategy to urban heat. Nature Reviews Earth & Environment, 2(3): 166-181. https://doi.org/10.1038/s43017-020-00129-5

[8] Manesh, S.V., Tadi, M., Zanni, F. (2012). Integrated sustainable urban design: Neighbourhood design proceeded by sustainable urban morphology emergence. WIT Transactions on Ecology and the Environment, 155: 631-642. https://doi.org/10.2495/SC120532

[9] Barry, R.G., Blanken, P.D. (2016). Microclimate and local climate. Cambridge University Press, pp. 1-316, https://doi.org/10.1017/CBO9781316535981

[10] Xi, C., Ren, C., Wang, J., Feng, Z., Cao, S.J. (2021). Impacts of urban-scale building height diversity on urban climates: A case study of Nanjing, China. Energy and Buildings, 251: 111350. https://doi.org/10.1016/j.enbuild.2021.111350

[11] Elshimy, H., Ragheb, A.A., Ragheb, G. (2017). Sustainability concept in neighbourhood by using computing technique ecotech as a tool to evaluate design and urban design process in neighboring residential in tenth of Ramadan city, Egypt. International Journal of Engineering and Technology, 77: 44.

[12] Manteghi, G., bin Limit, H., Remaz, D. (2015). Water bodies an urban microclimate: A review. Modern Applied Science, 9(6): 1. https://doi.org/10.5539/mas.v9n6p1

[13] Emmanuel, R. (2021). Urban microclimate in temperate climates: A summary for practitioners. Buildings and Cities, 2(1): 402-410. https://doi.org/10.5334/bc.109

[14] Ragheb, A.A., El-Darwish, I.I., Ahmed, S. (2016). Microclimate and human comfort considerations in planning a historic urban quarter. International Journal of Sustainable Built Environment, 5(1): 156-167. https://doi.org/10.1016/j.ijsbe.2016.03.003

[15] Ren, C., McGregor, G. (2021). Urban Climate Science for Planning Healthy Cities. Springer Cham. https://doi.org/10.1007/978-3-030-87598-5

[16] Al-Ghiyadh, M.A.K., Al-Khafaji, S.J.N. (2021). The role of urban planning and urban design on safe cities. In IOP Conference Series: Materials Science and Engineering, 1058(1): 012065. https://doi.org/10.1088/1757-899X/1058/1/012065

[17] Abd Elrahman, A.S., Asaad, M. (2021). Urban design & urban planning: A critical analysis to the theoretical relationship gap. Ain Shams Engineering Journal, 12(1): 1163-1173. https://doi.org/10.1016/j.asej.2020.04.020

[18] RA, E.A., Ragheb, A., Ragheb, G.A., Abdelrazik, D. (2022). Participatory methods for urban development. Journal of Urban Development and Management, 1(2): 87-101. https://doi.org/10.56578/judm010202

[19] Petroselli, A., Ioannilli, M. (2019). Quali-quantitative methods for analyzing urban structure and supporting regeneration policies. Journal of Biourbanism, 7: 61-75.

[20] Tumini, I., Higueras García, E., Baereswyl Rada, S. (2016). Urban microclimate and thermal comfort modelling: Strategies for urban renovation. International Journal of Sustainable Building Technology and Urban Development, 7(1): 22-37. https://doi.org/10.1080/2093761X.2016.1152204

[21] Chan, S.Y., Chau, C.K. (2021). On the study of the effects of microclimate and park and surrounding building configuration on thermal comfort in urban parks. Sustainable Cities and Society, 64: 102512. https://doi.org/10.1016/j.scs.2020.102512

[22] 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

[23] Sanusi, R., Bidin, S. (2020). Re-naturing cities: Impact of microclimate, human thermal comfort and recreational participation. Climate Change, Hazards and Adaptation Options: Handling the Impacts of a Changing Climate, Springer, Cham, 545-562. https://doi.org/10.1007/978-3-030-37425-9_28

[24] Ragheb, A., El Sharnouby, H. (2021). Sustainable urban development for costal city case study: Bourg el-bourols city. International Journal of Sustainable Development &

Planning, 16(6): 1039-1047. https://doi.org/10.18280/ijsdp.160605
[25] Liu, S., Zhao, J., Xu, M., Ahmadian, E. (2021). Effects of landscape patterns on the summer microclimate and human comfort in urban squares in China. Sustainable Cities and Society, 73: 103099. https://doi.org/10.1016/j.scs.2021.103099
[26] Teshnehdel, S., Akbari, H., Di Giuseppe, E., Brown, R.D. (2020). Effect of tree cover and tree species on microclimate and pedestrian comfort in a residential district in Iran. Building and Environment, 178: 106899. https://doi.org/10.1016/j.buildenv.2020.106899
[27] Abu Ali, M., Alawadi, K., Khanal, A. (2021). The role of green infrastructure in enhancing microclimate conditions: A case study of a low-rise neighborhood in Abu Dhabi. Sustainability, 13(8): 4260. https://doi.org/10.3390/su13084260
[28] Moonen, P., Defraeye, T., Dorer, V., Blocken, B., Carmeliet, J. (2012). Urban physics: Effect of the micro-climate on comfort, health and energy demand. Frontiers of Architectural Research, 1(3): 197-228. https://doi.org/10.1016/j.foar.2012.05.002
[29] Berardi, U., Wang, Y. (2016). The effect of a denser city over the urban microclimate: The case of Toronto. Sustainability, 8(8): 822. https://doi.org/10.3390/su8080822
[30] Eliasson, I. (2000). The use of climate knowledge in urban planning. Landscape and Urban Planning, 48(1-2): 31-44. https://doi.org/10.1016/S0169-2046(00)00034-7
[31] Li, L. (2021). Integrating climate change impact in new building design process: A review of building life cycle carbon emission assessment methodologies. Cleaner Engineering and Technology, 5: 100286. https://doi.org/10.1016/j.clet.2021.100286
[32] Myers, K.F., Doran, P.T., Cook, J., Kotcher, J.E., Myers, T.A. (2021). Consensus revisited: Quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later. Environmental Research Letters, 16(10): 104030. https://doi.org/10.1088/1748-9326/ac2774
[33] Ragheb, G.A., Ragheb, A. (2021). A multi-criteria decision for touristic revitalization of historic waterfront based on AHP analysis: A case study of Ezbet El-Borg city, Damietta, Egypt. International Journal of Sustainable Development & Planning, 16(8): 1437-1448, https://doi.org/10.18280/ijsdp.160804
[34] Faragallah, R.N., Ragheb, R.A. (2022). Evaluation of thermal comfort and urban heat island through cool paving materials using ENVI-met. Ain Shams Engineering Journal, 13(3): 101609. https://doi.org/10.1016/j.asej.2021.10.004