e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET
International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 3, March 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.423

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |

Role of Built Geometry in the Micro-climatic Modifications: Case of Addis Ababa, Ethiopia

Jayesh Dashrath Khaire[1], Leticia Ortega Madrigal[1], Begona Serrano Lanzarote[1]

Department of Architecture, Building, Urban Planning, and Landscape, Polytechnic University of Valencia, 46022, Spain[1]

ABSTRACT:The urban expansion in the city has created a negative impact on the outdoor microclimate. With the lack of green spaces in the city, the built mass itself can be designed in such a way that it can have a minimal negative impact on the adjacent outdoor spaces. This study analyzed the microclimatic behavior of outdoor open spaces in the existing built environment and attempted to identify the favorable configuration of the built environment with an emphasis on the extreme temperature of summer days. In this study, the existing site is compared with the modified built environments. The modifications were done in terms of building orientations and building heights. The numerical model 'Envi-MET 5.0.2' was used to simulate the modified built mass. Meteorological data was used as input for various calculations. Microclimatic indexes Ambient temperature (Ta), wind speed (Va), and mean radiant temperature (Tmrt) were evaluated and a comparative analysis is done. To calculate Tmrt, 'Rayman Pro' was used. Results have shown a strong correlation between the geometric parameters of the built environment and the microclimatic indices. It was also seen that the slight modification in the built mass resulted in different values of microclimatic indices. The study also highlights the importance of shading to improve the microclimate. The sky view factor (SVF), height-to-width (H/W) ratio, the orientation of the building surfaces, and the relation of vertical surfaces to each other are important aspects to consider for the future design of outdoor spaces. This study is important for the sustainability of the urbanized space in a way it helps to improve the microclimate of the open spaces and ultimately helps mitigate the urban heat island effect of the city by only adopting the right approach to the design of the built masses.

KEYWORDS: Urban microclimate, Outdoor open space, Thermal comfort, Built geometry.

I. INTRODUCTION

Outdoor open spaces are an integral part of urban areas. These spaces are important in the physical and mental growthof the citizens. Outdoor activities help improve concentration among children (Sophia & Hyatt, 2019). socializing helps in the personal development of the user' (Gaffar, Yuniawati & Ridwanudin, 2019). It thus becomes important that citizens use outdoor spaces very frequently. It is also important to make sure these spaces are safe and comfortable in all aspects so that the citizens don't refuse to use these spaces.

Urban expansion of the city is one of the concerns thatmay lead to a microclimatic impact on the city. (Teferi &Abraha, 2017) studied the change in the land use land cover in Addis Ababa from 1986 to 2011 and identified that urban built-up areas expanded dramatically whereas (Ahmed, 2006) highlighted the effect of industrial expansion on the microclimate at Addis Ababa.

The microclimate of an urban area is one of the important aspects which should be considered when it comes tooutdoor space use. several studies have evaluated the microclimate of their research. (Delpak, Sajadzadeh, Hasanpourfard& Aram, 2021) studied the effect of street orientation on outdoor thermal comfort in a cold mountainous climate and identified that the mean radiant temperature ($Tmrt$) is affected by the orientation, duration of the solar access, and wind speed. (Berardi & Wang, 2016) studied the effect of denser cities on microclimatic conditions in Toronto and concluded that the building height affects the $Tmrt$; higher buildings reduce the temperature up to 1°C.

There is a lack of studies that are focused on the micro-climate of Ethiopia. This study tries to fill this gap. This paper aims to analyze and explore the role of built geometry in microclimatic modifications and evaluate their impact on the adjacent microclimate with a focus on warmer conditions during the summer months.

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |

The study is limited to the vertical profiles of the built masses of the city. Only the geometrical aspects are analyzed and the impact of material and related aspects are not focused on. Since outdoor activities are observed during the daytime, only the daytime microclimate is analyzed.

II. METHODOLOGY

The first step deals with the identification of various built morphology in terms of building heights and orientations. the height to width ratio and sky view factors are also studied to understand the configuration of adjacent open spaces around them.In the next step, the meteorological data is analyzed to understand the weather pattern, this data is also used as input for the simulations.In the third step, simulations are performed using thesoftware Envi-met 5.0.2. The simulation is an important part of the study since the microclimatic value for any given location is affected by various parameters of the built environment. but if the effect of only the built form has to be observed then the simulation software is important. Thesoftware selected for the study can simulate the microclimate for any specific parameter of the built environment.

Figure1:Selectedlocation

Study area: Addis Ababa (8.9806° N, 38.7578° E) the capital city of Ethiopia is located at the heart of the country. the city experiences cold to moderate weather for most of the du- ration of the year. During summers moderate temperature is experienced along with intermittent rains. the average temperature of the city is well below the limit of the user's thermal comfort. it thus becomes a challenge to analyze the factor which can affect this comfortable weather.

The locations (figure 1) are selected based on varying morphological (figure characteristics 2) like orientation, H/W

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |

ratio, and SVF. The heights taken for the analysis are 15 meters, 24 meters, 33 meters, 42 meters, 63 meters, and 84 meters. The difference in the height gives variation in the H/W ratio and SVF, which is important to observe the solaraccess to the open spaces. The orientations taken are the building's vertical surfaces facing north, south, east, west, northeast, northwest, southeast, and southwest. the orientations selected are having equal increments to understand the pattern in the variation of microclimate. It is also based on vertical surface exposure to direct sunlight at different times of the day.

The H/W ratio is calculated by taking the height of the building to the width of the adjacent open space for whichbuildings are acting as an enclosure. Many studies (Ali-Toudert & Mayer, 2007, 2006; Kakon, Nobuo, Kojima &Yoko, 2010; Sharmin, Kabir & Rahaman, 2012; Perera &Weerasekara, 2014; Abdollahzadeh & Biloria, 2020; Nas-rollahi, Namazi & Taleghani, 2021) have found that the higher H/W ratio along with the appropriate orientation of the adjacent buildings is an important factor affecting the microclimatic level. Along with the H/W ratios, the SVF is also used for all the studied morphologies. 'SKYHELIOS' (Matzarakis & Matuschek, 2011; Matzarakis, 2012; Fröhlich& Matzarakis, 2018) is used to develop the SVFs for all the morphologies.

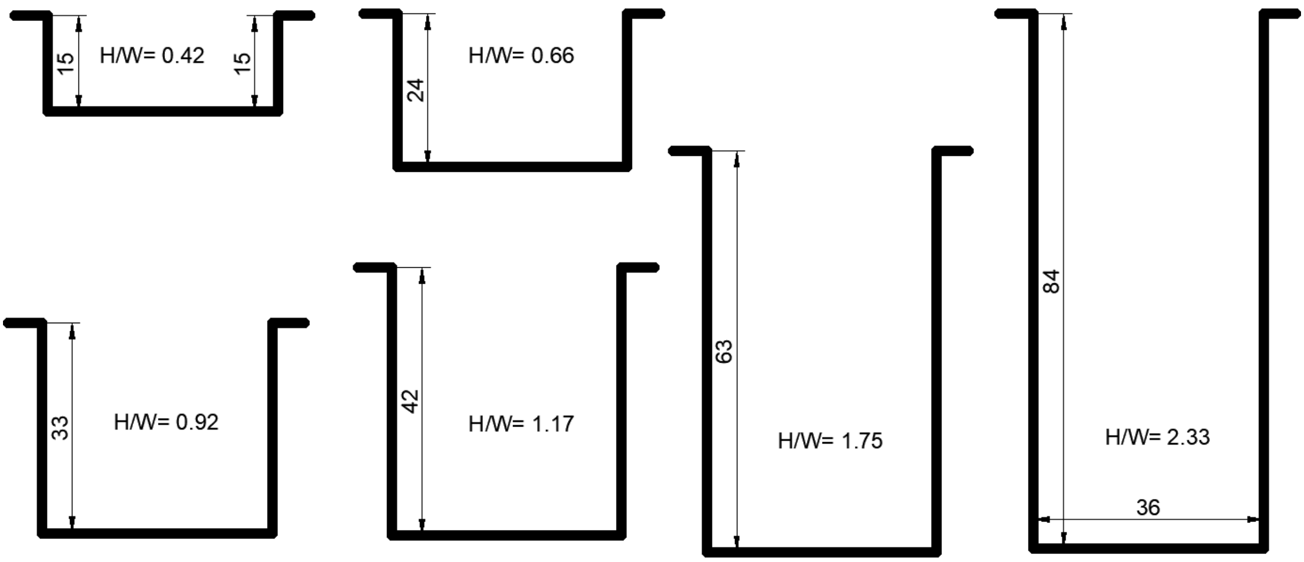


Figure2: Sections showing height to width(H/W) ratios of the studied morphologies

Climate: As per Koppen climatic regions (Köppen, 2011), Addis Ababa is located in a subtropical highland climate. (ASHRAE-55, 2010) suggests the optimum thermal comfort level of the user is 24.5 °C with an acceptable range of 23-26°C whereas there is no such range evaluated by any study forthe city of Addis Ababa where the climate is usually cold to moderate. The understanding of the level of thermal comfort required by the user is an important parameter that leads us to design an urban environment considering the microclimate as a sensitive issue.

The climate of the city is such that it is well under the maximum limit of the required thermal comfort level. during the warmest season of the year, the temperature of the city goes past the standard value of thermal comfort.The average minimum temperature of the city is 9°C in November and December and the average maximum is 25°C between March, April, and May (World MeteorologicalOrganisation).

Ambient air temperature (Ta), and mean radiant temperature ($Tmrt$) are focused on in this paper. $Tmrt$ is an important index since it takes longwave radiation and shortwave radiation fluxes into account(Kántor & Unger, 2011) affect the microclimate level (Mayer & Hoppe, 1987). $Tmrt$ in an outdoor space gets influenced by the urban

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |

geometry (Thorsson, Rocklöv, Konarska, Lindberg, Holmer, Dousset & Rayner, 2014) (Chen, Yu, Yang & Mayer, 2016).

Simulation: The microclimate of an urban area is regulated by many variables and processes. From the field surveys, it is difficult to understand the contribution of only one or two variables due to the complexity in an urban area. For this reason, software simulations are used in this study to identify the contribution of a single variable. 'ENVI-met 5.0.2' (Bruse & Fleer, 1998) is used for the simulations of the selected morphologies. Full forcing mode was used to achieve maximum accuracy, which can calculate all-important thermal comfort indicators such as 'Ambient air temperature (Ta), 'Mean radiant temperature ($Tmrt$), and 'wind speed (Va)'. Numerous studies (Crank, Sailor, Ban-Weiss & Taleghani, 2018; Auttarat & Sudarat, 2015; Alle-grini, Dorer & Carmeliet, 2015; Yahia, Johansson, Thorsson,Lindberg & Rasmussen, 2018; Baruti, Johansson & Åstrand, 2019; Sharmin & STEEMERS, 2013; Sodoudi & Cubasch, 2014; Carfan, Galvani & Nery, 2012) have used the ENVI- met program to simulate the outdoor microclimate. Simulations were performed on the date of 15th of May which is the typical warmest day in a year for the studied location. The temperature was set as 11°C to 23°C along with relative humidity between 20% to 60%, and a wind speed of 5 m/s with wind direction from the east. As a thermal input, ENVI-met 5.0.2. databased was used as an input for material properties for the built environment. To achieve maximum accuracy, the simulations were performed for the whole 24-hour cycle out of which the duration of the daytimebetween 7 am to 6 pm was taken for the analysis. Other than vertical surfaces of the built geometry, no other entities such as vegetation, the albedo of outdoor flooring, and street furniture were taken into the simulation input to get more accurate results only from vertical surfaces. Measurements of building footprints, streets, and open spaces were taken using satellite images and on-site measurements. The results were achieved at 1-hour intervals.

III. EXPERIMENTAL RESULTS

Spatial and temporal variation of air temperature (Ta) and mean radiant temperature (Tmrt):

Figure 3 (a) shows the spatial variation of Ta. Not a huge variation of Ta was observed for various morphologies. It is least dependent on the shadow pattern, wind speed, or relative humidity. The open spaces having enclosures in the west and southwest directions are observed with the least value of Ta. On the other hand, the buildings which are having vertical surfaces in the north and south directions are observed with the maximum value of Ta for the longer duration of the day.The highest $Ta$is observed at 4 pm. At this hour $Ta$for west-facing vertical surfaces is the higher than the rest of the orientations. The building with 33 meters high shows thehighest□□whereasthebuildingwith84metershighshowsthe lowest □□, this coincides with the study (Berardi & Wang,2016).

$Tmrt$ increases till 11 am, during noon time the $Tmrt$level was observed to be constant, but as the day progresses it increases. At 3 pm the maximum value could be observed. The maximum variation in different directions and different heights could be observed in the latter part of the day.

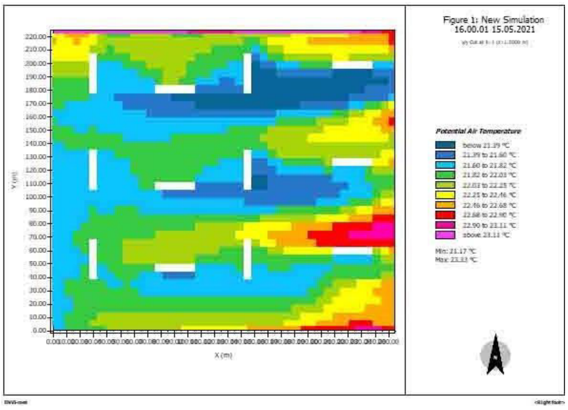
Figure 3(b) shows the spatial variation of $Tmrt$ during the harshest hour (3 pm) of the day. The difference could be observed between shaded and non-shaded spaces. Higher the building, the area covered on the ground by the lower $Tmrt$ level is higher. In the case of the buildings-oriented East- west, a lower value of $Tmrt$ was observed on the east side but a higher value was observed on the west side. It shows the importance of shade and the direction from which the open space is enclosed.

Since the shadow pattern depends on the direction of the vertical surfaces enclosing them and the time of the day, it is important to know the vertical surfaces that cast the shade for the maximum duration of the day.

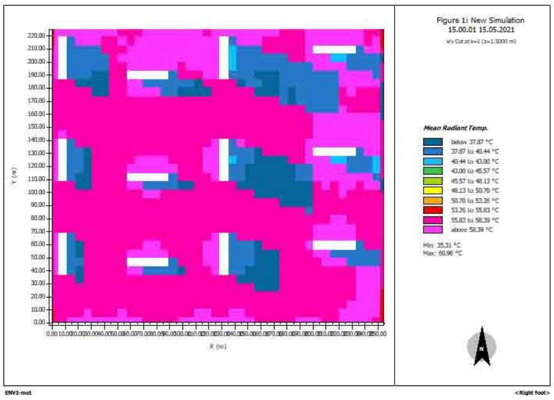
|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |



(a)



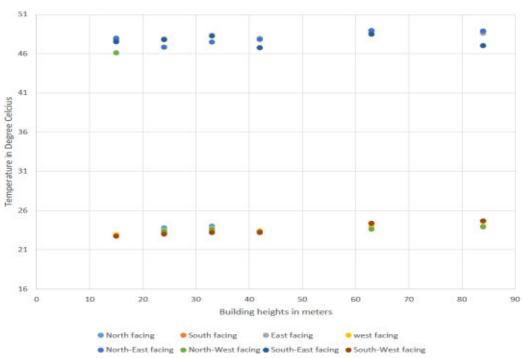
(b)

Figure3:Spatialvariationof(a)Ta(b)Tmrt

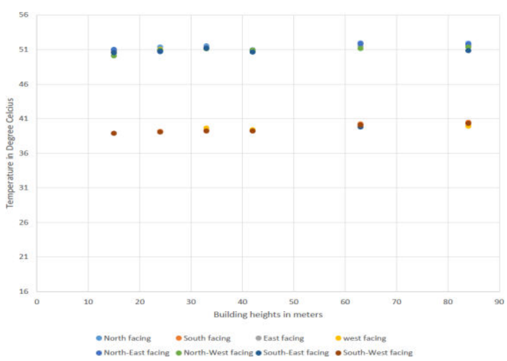
Correlation of shade, orientation, and Tmrt:

Figure 4 shows the variation of $Tmrt$ at all the morphologies for different times of the day. The effect of shade could be observed in the simulated values. A maximum variation could be seen at 9 am and 3 pm whereas at noon the variation is minimum. At 9 am, the vertical surfaces facing the direction having shade could be seen with the temperature less than 26 degrees. the drastic difference is seen for the surfaces facing the direct solar radiation with the $Tmrt$ more than 46 degrees. a similar pattern was observed in the latter part of the day at 3 pm when the ambient temperature is at its peak. At noon when the altitude of the sun is high and the amount of shade observed on the ground as well as on the building surfaces is negligible. It thus shows that the impact of vertical building surfaces on $Tmrt$ and eventually on the thermal comfort can be reduced if the maximum shade is achieved. The study (Huang, Lin & Lien, 2015) achieved similar results.

The vertical surfaces can be designed in such a way that the duration of the direct solar exposure is reduced as much as possible to improve the microclimate of the open spaces. A strong correlation could be observed between the orientation of the building surface and the $Tmrt$. At the harshest hour of the day between 3 pm to 6 pm, the vertical surfaces facing south, south-west, and north-west resulted in the highest $Tmrt$ in front of them. To reduce the $Tmrt$ during the harshest duration of the day, the number of vertical surfaces for buildings for these directions can be reduced or can be designed in such a way that those will have lesser solar exposure. A very slight and gradual increase in the $Tmrt$ was observed as the building height increased. Thisgives freedom to the designers to design buildings having minimum restrictions for building heights when it comes to the effect on the microclimate. this also shows that the higher height-to-width ratio will help in achieving the maximum shade but it will not help decrease the $Tmrt$.



(a)



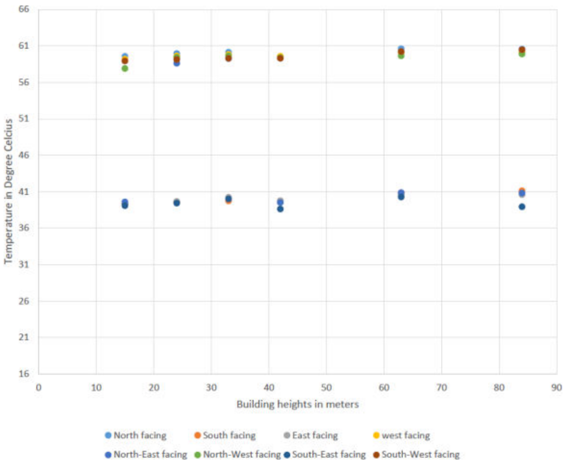
(b)

International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)

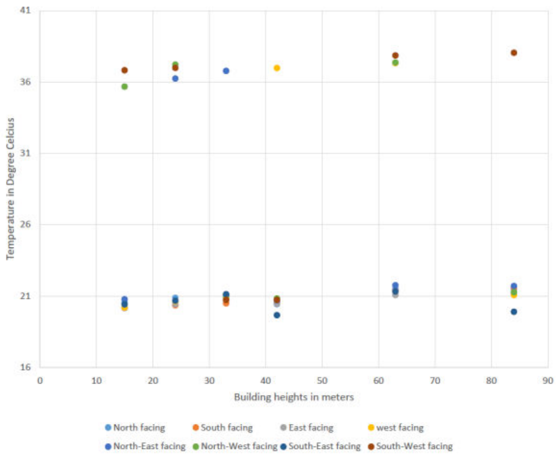
|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |



(c)



(d)

Figure4:Variation of Tmrtat (a) 9am(b)12pm(c)3pm(d)6pm

IV. CONCLUSION

The study focused on understanding the various morphologies available in the urban neighborhoods of Addis Ababa and analyzed the effect of vertical surface geometry on the microclimate of adjacent open spaces. The results were obtained from the 'ENVI-met 5.0.2' simulation out- puts. Results were analyzed for the summer season when the temperature is closer to the limit of the human thermal comfort level. From the study, it is evident that the vertical surfaces, their geometry, and orientation have high effects on outdoor thermal comfort.
The variation in the urban geometries can result in varying levels of microclimate. with the small modifications within the height and the orientation, the difference in the adjacent microclimate could be observed.

The existence of a south-facing vertical surface of the building may not help in achieving the required shade instead it will affect the microclimatic level by increasing the start, due to its exposure to direct solar radiation. building surfaces facing northeast, east, and southeast directions may help reduce the impact on the microclimate.

Shade from the building surfaces is an important factor for microclimatic improvement. The building surfaces can so be designed that they get maximum shade for the maximum duration of the day; the better the microclimate the user spending time in the outdoor environment will be higher.

Although the effect of the shade could be observed on the level that it does not drastically affect the Ta. the difference between Ta for various directions is negligible, the same output could be seen for shaded and non-shaded spaces.

Currently, the microclimate for the city is easy to maintain, which also becomes the challenge for urban designers and architects in the future to design in such a way that the microclimate is either maintained or improved and make sure due to the future development the deterioration in the micro-climate does not occur.

There are certain limitations of this study. Simulated values of temperature can be much different from the actual values of temperature since only vertical surfaces are considered for the simulations. The impact on the microclimate can occur due to horizontal entities in the built environment. further research should focus on the other entities in the built environment and studied individually to understand the impact created by them on the microclimate.

The wind speed was also studied in this paper, but a negligible impact was observed on the level of micro-climate at various times of the day. A similar result was seen in terms of relative humidity. For this reason, these parameters are not discussed further in the results.

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2023 ||

| DOI:10.15680/IJIRSET.2023.1203001 |

The morphology of an urban neighborhood depends primarily on the design of interior spaces, for this reason, while designing the holistic approach should be followed which will focus not only on indoor spaces but also on outdoor spaces.

REFERENCES

1. Abdollahzadeh, N., & Biloria, N. (2020). Outdoor thermal comfort: Ana- lyzing the impact of urban configurations on the thermal performance of street canyons in the humid subtropical climate of Sydney. *Frontiers of Architectural Research*, . URL: https://doi.org/10.1016/j.foar.2020.11.006. doi:10.1016/j.foar.2020.11.006.
2. Ahmed, H. (2006). Addis Ababa University. *Cahiers d'études africaines*,
3. *46*, 291–312. doi:10.4000/etudesafricaines.5928.
4. Ali-Toudert, F., & Mayer, H. (2006). Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. *Building and Environment*, *41*, 94–108. doi:10.1016/j.buildenv.2005.01.013.
5. Ali-Toudert, F., & Mayer, H. (2007). Erratum to "Numerical study on the
6. effects of aspect ratio and orientation of an urban street canyon on out- door thermal comfort in hot and dry climate" [Building and Environment 41 (2006) 94-108] (DOI:10.1016/j.buildenv.2005.01.013). *Building and*
7. *Environment*, *42*, 1553–1554. doi:10.1016/j.buildenv.2005.12.013.
8. Allegrini, J., Dorer, V., & Carmeliet, J. (2015). Influence of morpholo- gies on the microclimate in urban neighbourhoods. *Journal of Wind Engineering and Industrial Aerodynamics*, *144*, 108–117. doi:10.1016/ j.jweia.2015.03.024.
9. ASHRAE-55 (2010). Thermal Environemental Condition for Human
10. Occupancy.
11. Auttarat, M. S., & Sudarat (2015). Thermal Comfort Conditions of Urban Spaces in a Hot-Humid Climate of Chiang Mai City , Thailand Manat Srivanit and Sudarat Auttarat. *iCUC9*, -, 1–30.
12. Baruti, M. M., Johansson, E., & Åstrand, J. (2019). Review of studies on outdoor thermal comfort in warm humid climates: challenges of informal urban fabric. *International Journal of Biometeorology*, *63*, 1449–1462. doi:10.1007/s00484-019-01757-3.
13. Berardi, U., & Wang, Y. (2016). The effect of a denser city over the urban
14. microclimate: The case of Toronto. *Sustainability (Switzerland)*, *8*, 1– 11. doi:10.3390/su8080822.
15. Bruse, M., & Fleer, H. (1998). Simulating surface-plant-air interac-
16. tions inside urban environments with a three dimensional numerical model. *Environmental Modelling and Software*, *13*, 373–384. doi:10.1016/S1364-8152(98)00042-5.
17. Carfan, A. C., Galvani, E., & Nery, J. T. (2012). Study of thermal
18. comfort in the city of são paulo using ENVI-met model. *Investigaciones Geograficas*, *78*, 34–47.
19. Chen, L., Yu, B., Yang, F., & Mayer, H. (2016). Intra-urban dif- ferences of mean radiant temperature in different urban settings in Shanghai and implications for heat stress under heat waves: A GIS- based approach. *Energy and Buildings*, *130*, 829–842. URL: https://linkinghub.elsevier.com/retrieve/pii/S037877881630812X. doi:10.1016/ j.enbuild.2016.09.014.
20. Crank, P. J., Sailor, D. J., Ban-Weiss, G., & Taleghani, M. (2018). Eval-
21. uating the ENVI-met microscale model for suitability in analysis of targeted urban heat mitigation strategies. *Urban Climate*, *26*, 188– 197. URL: https://doi.org/10.1016/j.uclim.2018.09.002. doi:10.1016/ j.uclim.2018.09.002.
22. Delpak, N., Sajadzadeh, H., Hasanpourfard, S., & Aram, F. (2021).
23. The Effect of Street Orientation on Outdoor Thermal Comfort in a Cold Mountainous Climate, . URL: www.preprints.org. doi:10.20944/preprints202105.0654.v1.
24. Fröhlich, D., & Matzarakis, A. (2018). Spatial Estimation of Thermal
25. Indices in Urban Areas—Basics of the SkyHelios Model. *Atmo- sphere*, *9*, 209. URL: http://www.mdpi.com/2073-4433/9/6/209. doi:10.3390/atmos9060209.
26. Gaffar, V., Yuniawati, Y., & Ridwanudin, O. (2019). A Study of Outdoor
27. Recreation Motivation and Activity Preferences. *Journal of Southwest Jiaotong University*, *54*. doi:10.35741/issn.0258-2724.54.3.23.
28. Huang, K. T., Lin, T. P., & Lien, H. C. (2015). Investigating thermal comfort and user behaviors in outdoor spaces: A seasonal and spatial perspective. *Advances in Meteorology*, *2015*. doi:10.1155/2015/423508.
29. Kakon, A. N., Nobuo, M., Kojima, S., & Yoko, T. (2010). Assessment of
30. Thermal Comfort in Respect to Building Height in a High-Density City in the Tropics. *American Journal of Engineering and Applied Sciences*, *3*, 545–551. doi:10.3844/ajeassp.2010.545.551.
31. Kántor, N., & Unger, J. (2011). The most problematic variable in
32. the course of human-biometeorological comfort assessment — the mean radiant temperature. *Open Geosciences*, *3*. URL: https:
33. //www.degruyter.com/document/doi/10.2478/s13533-011-0010-x/html.
34. doi:10.2478/s13533-011-0010-x.

35. Köppen, W. (2011). The thermal zones of the Earth according to the duration of hot, moderate and cold periods and to the impact of heat on the organic world. *Meteorologische Zeitschrift*, *20*, 351–360. URL: http://www.schweizerbart.de/papers/metz/detail/20/76135/The_thermal_zones_of_the_Earth_according_to_the_du?af=crossref. doi:10.1127/0941-2948/2011/105.
36. Matzarakis, A. (2012). RayMan and SkyHelios model - two tools for urban
37. climatology. *Proceedings MettoolsVIII, 8. Fachtagung des Ausschusses Umweltmeteorologie der Deutschen Meteorologischen Gesellschaft*, *5*, 1–6. URL: http://www.urbanclimate.net/matzarakis/pub2012.php.
38. Matzarakis, A., & Matuschek, O. (2011). Sky view factor as
39. a parameter in applied climatology rapid estimation by the SkyHelios model. *Meteorologische Zeitschrift*, *20*, 39–45. URL: http://www.schweizerbart.de/papers/metz/detail/20/75681/Sky_ view_factor_as_a_parameter_in_applied_climatol?af=crossref. doi:10.1127/0941-2948/2011/0499.
40. Mayer, H., & Hoppe, P. (1987). Thermal comfort of man in different urban environments. *Theoretical and Applied Climatology*, *38*, 43–49. URL:
41. http://link.springer.com/10.1007/BF00866252. doi:10.1007/BF00866252.
42. Nasrollahi, N., Namazi, Y., & Taleghani, M. (2021). The effect of urban shading and canyon geometry on outdoor thermal comfort in hot climates: A case study of Ahvaz, Iran. *Sustainable Cities and Society*, *65*, 102638. URL: https://doi.org/10.1016/j.scs.2020.102638. doi:10.1016/j.scs.2020.102638.
43. Perera, N. G. R., & Weerasekara, W. M. S. B. (2014). The Effect of Street Canyon Geometry on Outdoor Thermal Comfort in Colombo.
44. *International Conference on 'Cities, People and Places'- ICCPP-2014*,
45. .
46. Sharmin, T., Kabir, S., & Rahaman, M. (2012). A study of thermal comfort in outdoor urban spaces in respect to increasing building height in Dhaka. *AIUB Journal of Science and Engineering*, *11*.
47. Sharmin, T., & STEEMERS, K. (2013). Effect of Canyon Geometry on Outdoor Thermal Comfort. *Plea*, .
48. Sodoudi, S., & Cubasch, U. (2014). Using the ENVI-MET program to
49. simulate the micro climate in new Town HASHTGERD YoungCities View project CORDEX-East Asia View project, . URL: https://www.researchgate.net/publication/265550643. doi:10.13140/2.1.1739.2005.
50. Sophia, S., & Hyatt, R. (2019). The Effects of Outdoor Activity on
51. Concentration, .
52. Teferi, E., & Abraha, H. (2017). Urban Heat Island Effect of Addis Ababa City: Implications of Urban Green Spaces for Climate Change Adaptation. *Climate Change Management*, (pp. 539–552). doi:10.1007/ 978-3-319-49520-0_33.
53. Thorsson, S., Rocklöv, J., Konarska, J., Lindberg, F., Holmer, B., Dousset,
54. B., & Rayner, D. (2014). Mean radiant temperature - A predictor of heat related mortality. *Urban Climate*, *10*, 332–345. URL: http://dx.doi.org/10.1016/j.uclim.2014.01.004. doi:10.1016/j.uclim.2014.01.004.
55. World Meteorological Organisation (). World Weather Information Service
    – Addis Ababa.
56. Yahia, M. W., Johansson, E., Thorsson, S., Lindberg, F., & Rasmussen, M. I. (2018). Effect of urban design on microclimate and thermal comfort out- doors in warm-humid Dar es Salaam, Tanzania. *International Journal of Biometeorology*, *62*, 373–385. doi:10.1007/s00484-017-1380-7.

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.118

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 6381 907 438 ijirset@gmail.com

Scan to save the contact details

www.ijirset.com