22nd International Conference on Sustainable Energy Technologies
Kuala Lumpur, Malaysia, 13 to 15 August 2026 · ISBN 978-1-995850-00-9 · ISSN 2978-4387

CONFERENCE PAPER · URBAN & ENVIRONMENT

An evaluation framework to assess pedestrian comfort in relation to street design along Indira Gandhi Road corridor, Kozhikode

Akhil K[1]*, Deepa Rani R[1]

[1] Department of Architecture and Planning, College of Engineering Trivandrum, Thiruvananthapuram, Kerala, India

RECEIVED 31 May 2026 · REVISED 28 June 2026 · ACCEPTED 11 July 2026
PRESENTED 13 to 15 August 2026 · PUBLISHED 23 November 2026

ABSTRACT

In Kerala's tropical warm humid context, high humidity, intense solar radiation, and restricted airflow intensify heat stress, and pedestrian thermal discomfort particularly along dense commercial corridors where street design prioritises vehicular movement over climate responsiveness. Indira Gandhi Road in Kozhikode exemplifies this condition, with high pedestrian density, east-west orientation, minimal vegetation, and heat-retentive surfaces producing sustained thermal exposure. Despite growing research on urban microclimates, street-scale empirically validated frameworks that translate environmental performance into design action remain limited in warm-humid contexts. This study develops a design-driven, multi-layered evaluation framework to assess pedestrian thermal performance across ten spatial zones. The approach integrates in-situ microclimatic measurements (air temperature, relative humidity, globe temperature, wind velocity, CO_2), urban morphology parameters (aspect ratio, sky view factor), thermal imaging, and simulation modelling using UTCI and mPET indices, complemented by structured user perception surveys. Results show that urban design directly governs thermal exposure, with radiant heat as the dominant driver of discomfort. Mean Radiant Temperature reaches 43–60 °C, while mPET values (41–47 °C) indicate persistent strong to very strong heat stress. High Sky View Factor zones (0.79–0.82) correspond to peak exposure, and low wind speeds (<2 m/s) constrain convective cooling. User perception aligns with measured and simulated data, identifying solar radiation, reflected heat, and stagnant airflow as primary stressors. Simulation-based interventions demonstrate that integrated street design strategies can reduce Mean Radiant Temperature by 12–18 °C, significantly improving pedestrian-level thermal conditions. These results position urban design as a quantifiable microclimate regulator for climate-responsive street design in warm-humid urban environments.

KEYWORDS Pedestrian thermal comfort, Street morphology, Street aspect ratio (AR), Sky view factor (SVF), Physiological equivalent temperature (PET), Universal thermal climate index (UTCI)

1. Introduction

Rapid urbanisation and rising global temperatures have intensified outdoor thermal discomfort in cities, particularly in warm-humid climates where high humidity, intense solar radiation, and limited air movement restrict the human body's ability to dissipate heat. Commercial streets are especially vulnerable because extensive paved surfaces, continuous building frontages, limited vegetation, and high pedestrian activity increase exposure to radiant heat, thereby reducing walkability, discouraging outdoor activities, and negatively affecting public health and urban liveability (Oke 1988).

Street morphology is one of the principal factors governing pedestrian-scale microclimatic conditions. Urban form characteristics such as street orientation, aspect ratio (H/W), and Sky View Factor (SVF) regulate solar access, long-wave radiation exchange, wind movement, and shading,

* Corresponding author. Email address: akhilkaleekz@gmail.com (Akhil K)

© 2026 The Author(s).
Published by Caravel Press.

doi.org/10.65582/set.2026.040

thereby influencing pedestrian thermal comfort (Oke 1988). Investigating street canyon geometry, Jamei and Rajagopalan (2019) demonstrated that street configuration and shading substantially influence pedestrian thermal comfort, while Rodríguez-Algeciras *et al.* (2018) showed that asymmetrical street canyons significantly modify thermal conditions in warm-humid climates.

Recent studies have further expanded the understanding of climate-responsive street design. Ben Ratmia *et al.* (2023) demonstrated that street configuration and building envelope characteristics jointly influence outdoor thermal conditions, while Necira *et al.* (2024) highlighted the combined effects of street asymmetry, surface albedo, and shading on pedestrian thermal comfort. In addition, Lai *et al.* (2025) identified street geometry and orientation as key determinants of thermal performance in dense urban environments. Collectively, these studies emphasise that pedestrian comfort depends on the interaction between urban morphology, surface materials, vegetation, and local climatic conditions rather than on any single design parameter. Nevertheless, relatively few investigations have integrated street morphology, field measurements, thermal comfort assessment, and pedestrian perception into a unified evaluation framework for warm-humid Indian cities. Consequently, evidence-based guidance for climate-responsive street design remains limited in this climatic context.

The Indira Gandhi Road corridor in Kozhikode represents a typical high-density commercial street characterised by continuous building frontages, extensive asphalt paving, limited tree cover, and an east-west orientation. These characteristics create prolonged daytime exposure to solar radiation and contribute to significant pedestrian heat stress, making the corridor an appropriate case study for investigating the influence of street design on outdoor thermal comfort.

Accordingly, this study evaluates pedestrian thermal comfort by integrating field-based microclimatic measurements, street morphology analysis, thermal comfort indices, thermal imaging, and pedestrian perception surveys. The research examines the relationship between urban form and pedestrian thermal conditions and proposes practical climate-responsive street design strategies that can reduce heat stress while improving walkability in warm-humid urban environments.

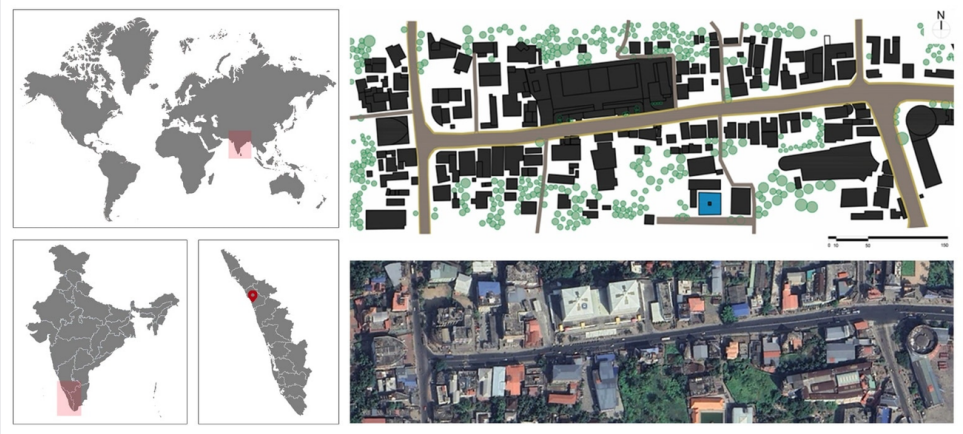

Figure 1. Location of the study area (Kozhikode city and Indira Gandhi Road Corridor).

2. Methodology

The study was conducted along the Indira Gandhi Road corridor in Kozhikode, Kerala, a major commercial street characterised by continuous mixed-use development, high pedestrian activity, and an east–west orientation. The approximately 1.8 km study corridor was divided into ten representative observation zones (A–J) to capture variations in street geometry, building height, land use, pedestrian density, and vegetation cover. This zoning enabled systematic comparison of thermal conditions across different urban settings within the corridor.

Field investigations were carried out during representative daytime periods under comparable weather conditions. Pedestrian-level microclimatic variables, including air temperature, relative humidity, globe temperature, wind velocity, surface temperature, and carbon dioxide concentration, were measured using calibrated field instruments. Thermal images were simultaneously captured to identify surface heat distribution and localised thermal hotspots. Street morphology was documented through field measurements and photographic surveys, with particular emphasis on street aspect ratio (H/W), street orientation, and Sky View Factor (SVF) because these parameters strongly influence solar exposure and pedestrian thermal conditions.

Thermal comfort conditions were evaluated using Mean Radiant Temperature (MRT) and modified Physiological Equivalent Temperature (mPET), which integrate the combined effects of air temperature, humidity, wind velocity, and radiant heat to quantify pedestrian heat stress. The thermal comfort indices were interpreted according to established thermal stress classifications to assess pedestrian exposure under existing street conditions (Walther and Goestchel 2018).

To complement the quantitative measurements, a structured pedestrian perception survey was conducted among corridor users, including pedestrians, commuters, shopkeepers, street vendors, and other frequent users. The questionnaire investigated perceived thermal sensation, comfort level, preferred walking periods, and the environmental factors contributing to thermal discomfort. These responses were compared with the measured microclimatic conditions to improve the interpretation of the field observations.

The collected datasets were subsequently analysed to examine the relationships between street morphology and pedestrian thermal comfort. Comparative analysis of the measured environmental variables, morphological parameters, thermal comfort indices, thermal imaging observations, and user perception data was undertaken to identify the dominant factors influencing pedestrian heat stress and to formulate climate-responsive street design strategies for warm-humid urban environments.

Table 1. Summary of measurement parameters.

Parameter	Instrument / Method	Purpose
Air Temperature	Kestrel Weather Meter	Ambient thermal condition
Relative Humidity	Kestrel Weather Meter	Moisture content of air
Globe Temperature	Black Globe Thermometer	Mean Radiant Temperature calculation
Wind Velocity	Kestrel Weather Meter	Convective cooling assessment
CO_2 Concentration	Testo Air Quality Meter	Outdoor air quality assessment
Sky View Factor	Fisheye Photography	Urban enclosure analysis
Aspect Ratio	Field Survey	Street geometry evaluation
Surface Temperature	Thermal Camera	Heat-retaining surface identification
UTCI & mPET	Autodesk Forma / Thermal Comfort Analysis	Pedestrian thermal comfort evaluation

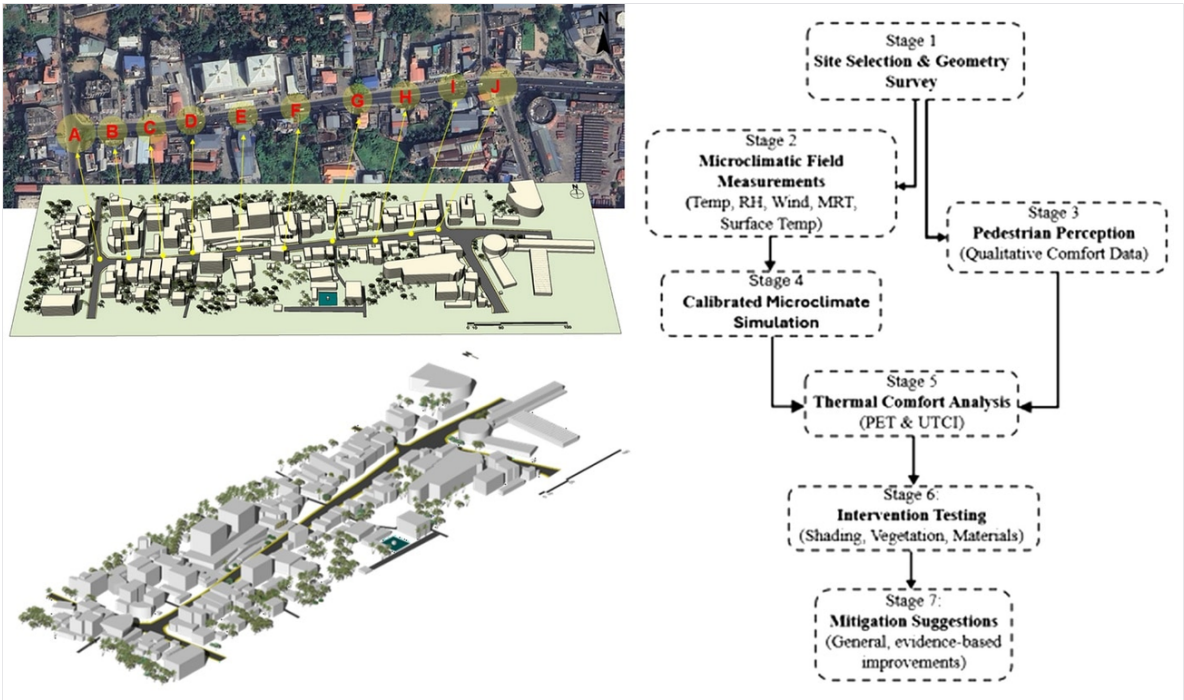

Figure 2. Location of the study area and methodological framework for pedestrian thermal comfort assessment.

3. Results and discussion

The field measurements revealed considerable spatial variation in pedestrian thermal conditions along the Indira Gandhi Road corridor, primarily resulting from differences in street geometry, solar exposure, vegetation cover, and surface characteristics. The measured street aspect ratio (H/W) varied from 0.29 to 0.54, indicating generally shallow street canyons with limited vertical enclosure. As shown in Table 2, the higher aspect ratio sections provided greater shading than the wider street segments; however, the overall aspect ratio of the corridor remained insufficient to substantially reduce pedestrian exposure to direct solar radiation.

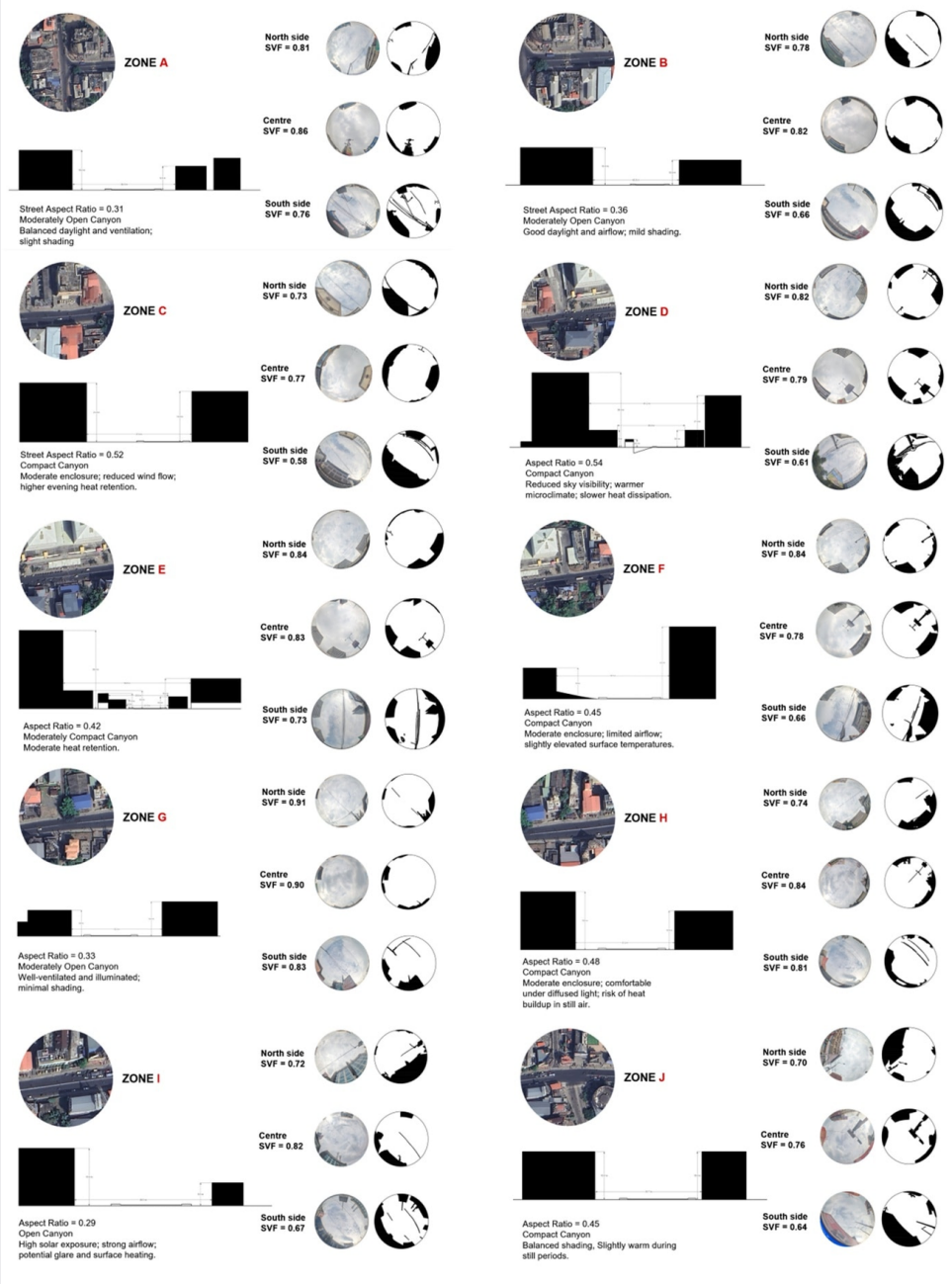

Figure 3. Spatial distribution of street aspect ratio (H/W) and sky view factor (SVF) across the ten observation zones along the Indira Gandhi Road corridor.

Table 2. Street aspect ratio (H/W) values for the observation zones.

Zone	Left Height (m)	Right Height (m)	Width (m)	Avg. Height (m)	Aspect Ratio (H/W)
A	15.0	9.0	39.3	12.0	**0.31**
B	18.0	12.0	42.0	15.0	**0.36**
C	21.0	18.0	37.8	19.5	**0.52**
D	39.0	27.0	61.2	33.0	**0.54**
E	39.0	15.0	64.6	27.0	**0.42**
F	9.0	21.0	33.3	15.0	**0.45**
G	9.0	12.0	32.0	10.5	**0.33**
H	18.0	12.0	31.2	15.0	**0.48**

Table 2. (continued)

Zone	Left Height (m)	Right Height (m)	Width (m)	Avg. Height (m)	Aspect Ratio (H/W)
I	15.0	6.0	36.5	10.5	**0.29**
J	15.0	15.0	33.7	15.0	**0.45**

Sky View Factor (SVF) analysis further demonstrated the influence of urban morphology on thermal exposure. The northern footpath exhibited the highest SVF values (0.79–0.82), indicating extensive sky exposure, whereas comparatively lower SVF values were recorded in sections with greater building enclosure and vegetation cover (Table 3). These findings indicate that increased sky openness was associated with greater solar exposure and elevated pedestrian heat stress. Similar relationships between SVF and outdoor thermal comfort have been reported in previous studies on climate-responsive street design and urban vegetation (Lai *et al.* 2025; Ben Ratmia *et al.* 2023).

Table 3. Summary of SVF results for north, central, and south street sections.

Zone	Avg. SVF	Visual Enclosure	Thermal Implication	Suitability
North	0.79	Semi-open	Hotter, high solar gain	Needs shading & vegetation
Central	0.82	Balanced	Comfortable, well-ventilated	Ideal microclimate zone
South	0.29	Highly enclosed	Cooler, low solar gain	Suitable for shade & rest areas

Thermal comfort assessment showed that Mean Radiant Temperature (MRT) ranged between 43 °C and 60 °C, while modified Physiological Equivalent Temperature (mPET) varied from 41 °C to 47 °C, corresponding to strong to very strong heat stress throughout most observation periods (Table 4). These results demonstrate that radiant heat, rather than air temperature alone, was the dominant factor influencing pedestrian thermal discomfort. Comparable observations were reported by Jamei and Rajagopalan (2019), who emphasised that urban geometry and solar exposure substantially affect radiant heat exchange and pedestrian comfort.

Table 4. Measured mean radiant temperature (MRT) and modified physiological equivalent temperature (mPET).

Day one, 15 October 2025

Zone	T_g (°C)	T_a (°C)	RH (%)	V_{avg} (m/s)	MRT (°C)	mPET (°C)
A	40	36.6	61.2	0.433	43.44	42.9
B	41	35.1	62.4	0.666	49.18	43.3
C	41	35.3	62.5	1	49.96	42.8
D	39	36.4	62.3	1.733	46.79	41.6
E	39	34.4	64.9	1	47.79	41.3
F	39	35.1	63.5	0.833	44.25	40.9
G	40	35.1	62.4	0.966	47.47	41.7
H	41	35.9	61.7	1.433	51.45	43
I	41	35.7	56.4	1.033	51.57	43.1
J	40	34.8	60.3	1.1	51.13	42.3

The east–west orientation of the corridor further intensified thermal stress by limiting effective daytime shading over extended periods of the year. Combined with the high Sky View Factor and shallow street geometry, this orientation exposed pedestrians to prolonged solar radiation, particularly during midday. Similar findings were reported by Rodríguez-Algeciras *et al.* (2018) and

Ben Ratmia *et al.* (2023), who demonstrated that street orientation strongly influences pedestrian thermal conditions in warm climates by modifying solar access and shading duration.

Thermal imaging observations (Figure 4) revealed that asphalt pavements, exposed concrete surfaces, and building façades functioned as major heat reservoirs, absorbing and re-radiating solar energy throughout the day. The spatial distribution of thermal hotspots closely corresponded with the measured MRT values, confirming that heat-retentive surface materials substantially increased pedestrian radiant heat exposure. The observed influence of heat-retentive pavement and façade materials is consistent with previous studies investigating the relationship between urban morphology, surface characteristics, and pedestrian thermal comfort (Ben Ratmia *et al.* 2023; Necira *et al.* 2024).

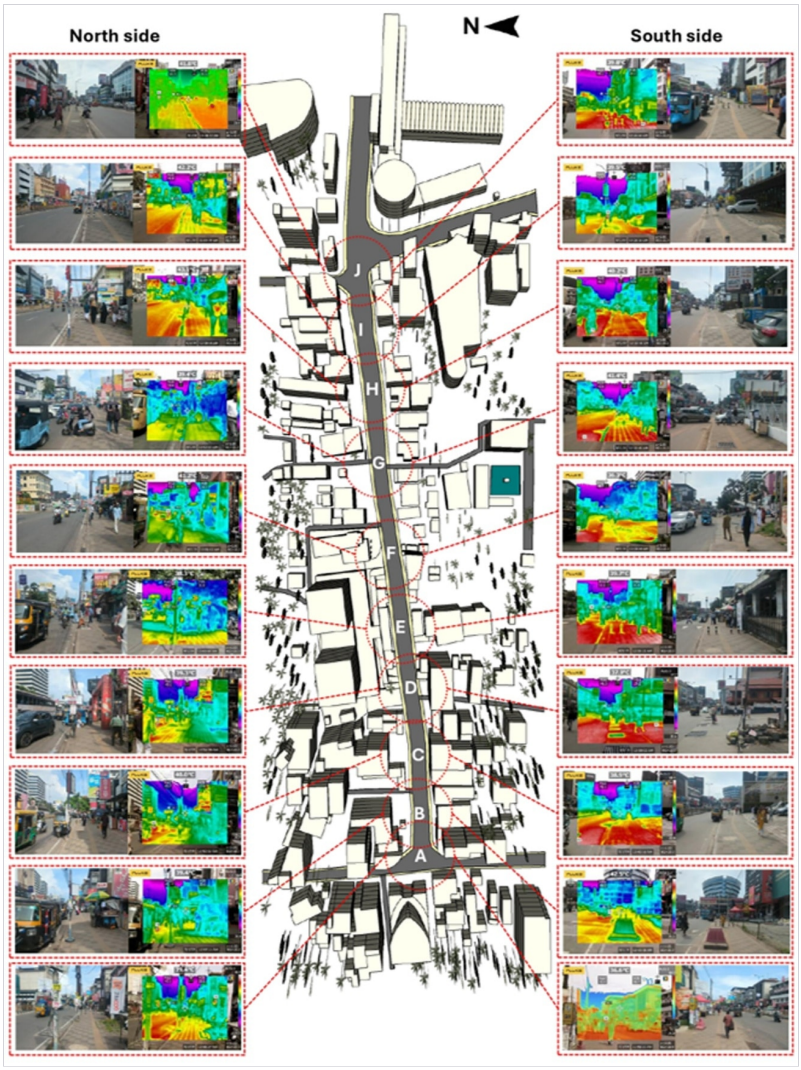

Figure 4. Thermal images showing surface temperature distribution along the study corridor.

User perception surveys strongly supported the measured environmental conditions. Respondents consistently identified direct solar radiation, reflected heat from paved surfaces, inadequate shading, and stagnant airflow as the principal causes of outdoor thermal discomfort. The close agreement between measured environmental variables and pedestrian perception strengthens the reliability of the field observations and demonstrates the importance of integrating subjective responses with quantitative thermal assessment.

Among all observed environmental characteristics, roadside vegetation exhibited the greatest cooling potential. Globe temperature measurements beneath mature tree canopies showed reductions of approximately 4.5–6.5 °C compared with adjacent exposed locations. Behavioural

observations further indicated that pedestrians naturally preferred shaded locations for resting, waiting, and informal commercial activities, confirming the effectiveness of continuous tree canopy in reducing radiant heat exposure while improving street usability (Figure 5). Comparable cooling benefits associated with urban vegetation have been reported in previous studies on climate-responsive street design and urban vegetation (Lai *et al.* 2025; Ben Ratmia *et al.* 2023).



Figure 5. Existing roadside trees providing pedestrian shading along the corridor.

Overall, the results demonstrate that pedestrian thermal comfort along the Indira Gandhi Road corridor is primarily governed by radiant heat exposure, resulting from excessive sky openness, prolonged solar exposure associated with the east–west street orientation, heat-retentive surface materials, limited vegetation cover, and inadequate airflow. The strong agreement between field measurements, thermal imaging, street morphology analysis, and pedestrian perception confirms that reducing Sky View Factor through continuous tree canopies, introducing additional shading structures, optimising pavement materials, and preserving natural ventilation are effective climate-responsive strategies for improving pedestrian comfort in warm-humid urban streets.

4. Conclusion

This study evaluated pedestrian thermal comfort along the Indira Gandhi Road corridor in Kozhikode by integrating field-based microclimatic measurements, street morphology analysis, thermal comfort assessment, thermal imaging, and pedestrian perception surveys. The findings demonstrate that pedestrian thermal discomfort within the corridor is primarily governed by excessive radiant heat exposure resulting from high Sky View Factor, prolonged solar exposure associated with the east–west street orientation, heat-retentive surface materials, limited vegetation cover, and inadequate airflow rather than by air temperature alone.

The analysis established a clear relationship between street morphology and pedestrian thermal conditions. Higher Sky View Factor values corresponded with increased Mean Radiant Temperature and modified Physiological Equivalent Temperature, indicating that urban geometry strongly influences outdoor thermal comfort. Thermal imaging further confirmed the contribution of asphalt

pavements and exposed building façades to surface heat accumulation, while field observations demonstrated the measurable cooling benefits provided by mature roadside vegetation.

The study also showed strong agreement between quantitative field measurements and pedestrian perception, confirming that direct solar radiation, reflected heat, inadequate shading, and stagnant airflow are the dominant factors affecting thermal comfort along the corridor. Integrating environmental measurements with user perception therefore provides a comprehensive framework for evaluating pedestrian-scale microclimates.

Based on these findings, the study recommends climate-responsive street design strategies that prioritise continuous tree canopy, additional shading structures, improved pavement materials, and the preservation of natural ventilation. These interventions have the potential to reduce pedestrian heat stress, improve outdoor comfort, and enhance walkability in warm-humid commercial streets.

Although the study is limited to a single urban corridor and specific observation periods, the methodology provides a practical framework for assessing pedestrian thermal comfort in similar tropical coastal cities. The proposed evaluation framework provides a practical decision-support tool for climate-responsive street design in warm-humid tropical cities.

Declarations

Author contributions. Akhil K: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing (original draft), Writing (review and editing), Visualization, Validation, Resources, Software. Deepa Rani R: Conceptualization, Methodology, Writing (review and editing), Supervision, Project administration.

Funding. This research received no specific funding.

Conflicts of interest. The authors declare no competing interests.

Data availability. All data generated or analysed during this study are included in this paper.

References

Ben Ratmia, Fatima Zahra; Ahriz, Atef; Santi, Giovanni; Bouzaher, Soumia; Mahar, Waqas Ahmed; Ben Ratmia, Mohamed Akram Eddine; Matallah, Mohamed Elhadi (2023) 'Street Design Strategies Based on Spatial Configurations and Building External Envelopes in Relation to Outdoor Thermal Comfort in Arid Climates', *Sustainability*, 16(1), pp. 221. Available at: https://doi.org/10.3390/su16010221

Jamei, Elmira; Rajagopalan, Priyadarsini (2019) 'Effect of street design on pedestrian thermal comfort', *Architectural Science Review*, 62(2), pp. 92-111. Available at: https://doi.org/10.1080/00038628.2018.1537236

Lai, Bin; Fu, Jian-Ming; Guo, Cheng-Kai; Zhang, Dan-Yin; Wu, Zhi-Gang (2025) 'Street Geometry Factors Influencing Outdoor Pedestrian Thermal Comfort in a Historic District', *Buildings*, 15(4), pp. 613. Available at: https://doi.org/10.3390/buildings15040613

Necira, Hakima; Matallah, Mohamed Elhadi; Bouzaher, Soumia; Mahar, Waqas Ahmed; Ahriz, Atef (2024) 'Effect of Street Asymmetry, Albedo, and Shading on Pedestrian Outdoor Thermal Comfort in Hot Desert Climates', *Sustainability*, 16(3), pp. 1291. Available at: https://doi.org/10.3390/su16031291

Oke, T.R. (1988) 'Street design and urban canopy layer climate', *Energy and Buildings*, 11(1-3), pp. 103-113. Available at: https://doi.org/10.1016/0378-7788(88)90026-6

Rodríguez-Algeciras, José; Tablada, Abel; Matzarakis, Andreas (2018) 'Effect of asymmetrical street canyons on pedestrian thermal comfort in warm-humid climate of Cuba', *Theoretical and Applied Climatology*, 133(3-4), pp. 663-679. Available at: https://doi.org/10.1007/s00704-017-2204-8

Walther, E.; Goestchel, Q. (2018) 'The P.E.T. comfort index: Questioning the model', *Building and Environment*, 137, pp. 1-10. Available at: https://doi.org/10.1016/j.buildenv.2018.03.054

HOW TO CITE THIS PAPER

K, A. and R, D. R. (2026). An evaluation framework to assess pedestrian comfort in relation to street design along Indira Gandhi Road corridor, Kozhikode. In: *Proceedings of the 22nd International Conference on Sustainable Energy Technologies (SET2026)*, Kuala Lumpur, Malaysia, 13 to 15 August 2026. Caravel Press, pp. 496–505. ISBN 978-1-995850-00-9. ISSN 2978-4387. https://doi.org/10.65582/set.2026.040

COPYRIGHT AND LICENCE

© 2026 The Author(s). This is an open access paper distributed under the terms of the Creative Commons Attribution (CC BY 4.0) licence, which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

WSSET World Society of Sustainable Energy Technologies Organised by the World Society of Sustainable Energy Technologies. Published by Caravel Press.