Analysing the Impact of Microclimatic Variation on Urban Residential Environment: A Study of Dhaka City

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ABSTRACT: Rapid and unplanned urbanization in Dhaka has led to diverse microclimatic conditions across its residential neighbourhoods, with significant implications for thermal comfort, public health, and community resilience. This study investigates the impact of microclimatic variation on thermal comfort, health outcomes, and resilience capacity across three contrasting residential typologies in Dhaka: the planned neighbourhood of Dhanmondi, the dense mixed-use area of Chawkbazar, and the informal settlement of Korail Slum. Field-based micrometeorological measurements of air temperature, relative humidity, and wind speed were conducted across all three areas during April to June, supplemented by structured resident questionnaire surveys, Key Informant Interviews, and a Thermal Resilience Index. Thermal comfort was assessed through both objective indices, including Predicted Mean Vote (PMV) and Physiological Equivalent Temperature (PET), and a Subjective Thermal Comfort Index (STCI) derived from resident surveys. Outdoor mean temperatures ranged from 32.41°C in Korail to 33.19°C in Chawkbazar, while mean outdoor air speeds varied from 0.0816 ms^{-1} in Chawkbazar to 0.75 ms^{-1} in Dhanmondi, indicating that ventilation restriction is a more significant determinant of thermal discomfort than temperature alone in the denser areas. Chawkbazar recorded the highest mean PET of 42.64°C, classified as "Very Hot," while Korail recorded the highest subjective thermal discomfort with an STCI of 7. Thermal Resilience Index scores of approximately 13, 9, and 4 for Dhanmondi, Chawkbazar, and Korail respectively reveal a substantial resilience gap rooted in disparities in energy access, housing quality, and adaptive capacity rather than climatic exposure alone. Residents of Korail further reported perceived associations between thermal conditions and elevated rates of respiratory illness, dermatological infections, and heat exhaustion among children and the elderly. The findings indicate that thermal vulnerability in Dhaka is structurally determined, with informal settlements bearing the compounded burden of the most demanding thermal environments and the weakest capacity to cope with them. The findings provide empirical evidence to support urban heat adaptation planning in rapidly urbanising megacities of the Global South.

Keywords: Microclimate; Thermal Comfort; Thermal Resilience Heat; Vulnerability; Urban Morphology; Climate Adaptation

INTRODUCTION

Rapid and largely unplanned urbanization is fundamentally reshaping the thermal environments of cities across the Global South. As forests, wetlands, and open land give way to concrete and asphalt, cities trap heat in ways that their surrounding rural landscapes do not, a phenomenon widely known as the Urban Heat Island (UHI) effect (Oke, 1987; Gartland, 2008). The consequences extend well beyond discomfort. Elevated urban temperatures intensify health risks, strain energy systems, and deepen existing inequalities between residents who can afford to adapt and those who cannot. These pressures are felt most acutely in the densely packed, rapidly growing cities of South Asia, where planning deficits and resource constraints leave millions exposed (Tsoka et al., 2018; Sharmin and Steemers, 2020).

Among the cities bearing the heaviest burden of this urban thermal crisis, Dhaka stands out for both the scale and speed of its transformation. With a current population of 36.6 million, Dhaka has recently overtaken Tokyo to become the world's second largest megacity and is projected to reach 52.1 million by 2050 (UN DESA, 2025). This growth is fuelled not only by economic migration but increasingly by climate displacement, as communities from disaster prone rural areas relocate to the city in search of stability. An estimated 400,000 to 500,000 people from flood-prone and erosion-affected rural areas relocate to Dhaka each year, with Dhaka already having sheltered more than ten million climate migrants (Mayors Migration Council, 2023; Harvard Humanitarian Initiative, 2025).

This explosive, largely unplanned expansion has come

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at a severe environmental cost. Between 1980 and 2023, Dhaka lost 47% of its dense green cover, with healthy vegetation shrinking from 5,202 hectares in 1989 to just 612 hectares by 2020, while 72% of the city's wetlands disappeared between 1988 and 2016 (World Bank, 2025; Mongabay, 2024). The loss of these natural cooling systems has directly intensified the city's thermal environment. UHI intensity across Dhaka now ranges between 2.5°C and 7.5°C above surrounding rural zones, and seasonal mean temperatures have risen by up to 3.92°C over the past 25 years (Hussain et al., 2023; Uddin et al., 2021). The human cost of this thermal intensification became starkly visible in April 2024, when Bangladesh endured its worst heatwave in 76 years. Temperatures peaked at 43.8°C and schools shut down leaving 33 million children out of classrooms. Hospitals across the country reported overwhelming surges in heatstroke and dehydration, and fatalities were reported across districts spanning nearly every division of the country (ReliefWeb, 2024; Dhaka Tribune, 2024).

The health implications of this thermal intensification are both serious and unevenly distributed. Since 1980, Bangladesh's perceived or "feels-like" temperature has surged by 4.5°C, far outpacing the 1.1°C rise in actual maximum temperature, contributing to rising rates of dehydration, respiratory illness, and heat exhaustion (World Bank, 2025). Heat stress alone is currently estimated to cost Dhaka's economy approximately 8% of its city GDP annually (Ryhan and Kabir, 2023). Within the city, these burdens fall most heavily on the urban poor, as those who are most exposed are invariably those with the fewest means to cope (Islam et al., 2021; Shahid, 2023; UNICEF, 2024)

To understand how residents experience and respond to urban heat, this study draws on two closely related concepts: thermal comfort and thermal resilience. Thermal comfort refers to the condition in which a person perceives their surrounding environment as thermally acceptable, determined by environmental factors such as air temperature, humidity, air velocity, and radiant heat, as well as personal factors including metabolic rate and clothing insulation (ASHRAE, 2017; Fanger, 1970). It is commonly assessed through quantitative indices such as the Predicted Mean Vote (PMV), Predicted Percentage of Dissatisfied (PPD), and Physiological Equivalent Temperature (PET), each of which translates measured environmental conditions into estimates of human thermal experience (Matzarakis et al., 2010). Thermal resilience, on the other hand, refers to the capacity of communities and urban systems to withstand and recover from periods of extreme heat without significant harm to occupants or infrastructure. It encompasses energy security, adaptive capacity, and community preparedness, and is increasingly recognized as a critical dimension of urban sustainability under a changing climate (Hong et al., 2023; Loughnan et al., 2012).

Despite growing research on UHI effects and heat vulnerability in South Asian cities, much of it remains focused either on macro-scale remote sensing analyses or on single-site comfort assessments. Few studies have brought together field-based micrometeorological measurements, objective comfort indices, subjective resident perceptions, and community resilience metrics within a single, comparative framework across socioeconomically different neighbourhoods (Hussain et al., 2023; Sharmin and Steemers, 2020). Informal settlements, which house a large and growing share of Dhaka's population, remain particularly underrepresented in this literature despite being the most thermally vulnerable residential context (ESS Open Archive, 2024). Addressing these gaps is not only a matter of scientific completeness but carries direct policy relevance for achieving SDG 3 (Good Health and Well-being), SDG 7 (Affordable and Clean Energy), and SDG 11 (Sustainable Cities and Communities) in cities like Dhaka.

This study investigates the impact of microclimatic variation on thermal comfort, human health, and community resilience across three residential neighbourhoods in Dhaka: the planned area of Dhanmondi, the dense mixed-use quarter of Chawkbazar, and the informal settlement of Korail Slum. Using a mixed-methods approach that combines field-based micrometeorological measurements, PMV and PET assessments, subjective resident surveys, Key Informant Interviews, and a Thermal Resilience Index (TRI), it seeks to answer three questions: how do microclimatic conditions vary across these three areas, how do those variations shape thermal comfort and health, and what determines the capacity of each community to cope with extreme heat. The findings aim to offer evidence that is grounded in local conditions and directly useful for urban planners and policymakers working in rapidly growing cities of the Global South.

STUDY AREA

This study focuses on three residential neighbourhoods in Dhaka representing distinct urban typologies: the planned area of Dhanmondi, the dense mixed-use quarter of Chawkbazar, and the informal settlement of Korail Slum. Together they span the full spectrum of residential form found in a rapidly growing megacity, making them well-suited for a comparative analysis of microclimatic conditions and thermal resilience.

Dhanmondi is one of Dhaka's oldest planned residential areas, originally developed in the late 1940s with structured plot allocations, designated open spaces, and wide streets. It covers 4.34 km² with a population of 101,937 and a density of approximately 23,500 persons per km² (BBS, 2022). The presence of Dhanmondi Lake and scattered green spaces provides some natural thermal buffering, though rapid vertical development in recent decades has progressively eroded these advantages (Prothom Alo, 2020).

Chawkbazar, located in Old Dhaka, is one of the city's most historically dense mixed-use areas. It covers 2.07 km² and houses 123,053 residents at a density of approximately 75,433 persons per km², one of the highest across Dhaka's thanas (BBS, 2022). Narrow lanes, continuous building frontages, and a near-total absence of green space severely restrict ventilation and sunlight, producing a persistently warm and humid microclimate.

Korail Slum lies on the edge of Gulshan and Banani and is one of Dhaka's largest informal settlements, covering approximately 90 acres and housing an estimated 200,000 residents at a density of around 87,606 persons per km² (Huq and Shafique, 2023). Nearly all residents are rural migrants displaced by flooding and river erosion (Mayors Migration Council, 2023). Tin-roofed, poorly ventilated structures, virtually no green cover, and no formal cooling infrastructure make Korail the most thermally vulnerable of the three study areas.

Dhanmondi is broadly representative of Dhaka's upper-middle-income planned residential stock. Chawkbazar represents the city's dense, unplanned mixed-use typology where residential and commercial functions overlap with little regulatory control. Korail represents the most thermally vulnerable residential typology in Dhaka, where extreme environmental exposure combines with the weakest adaptive capacity of any of the three study areas.

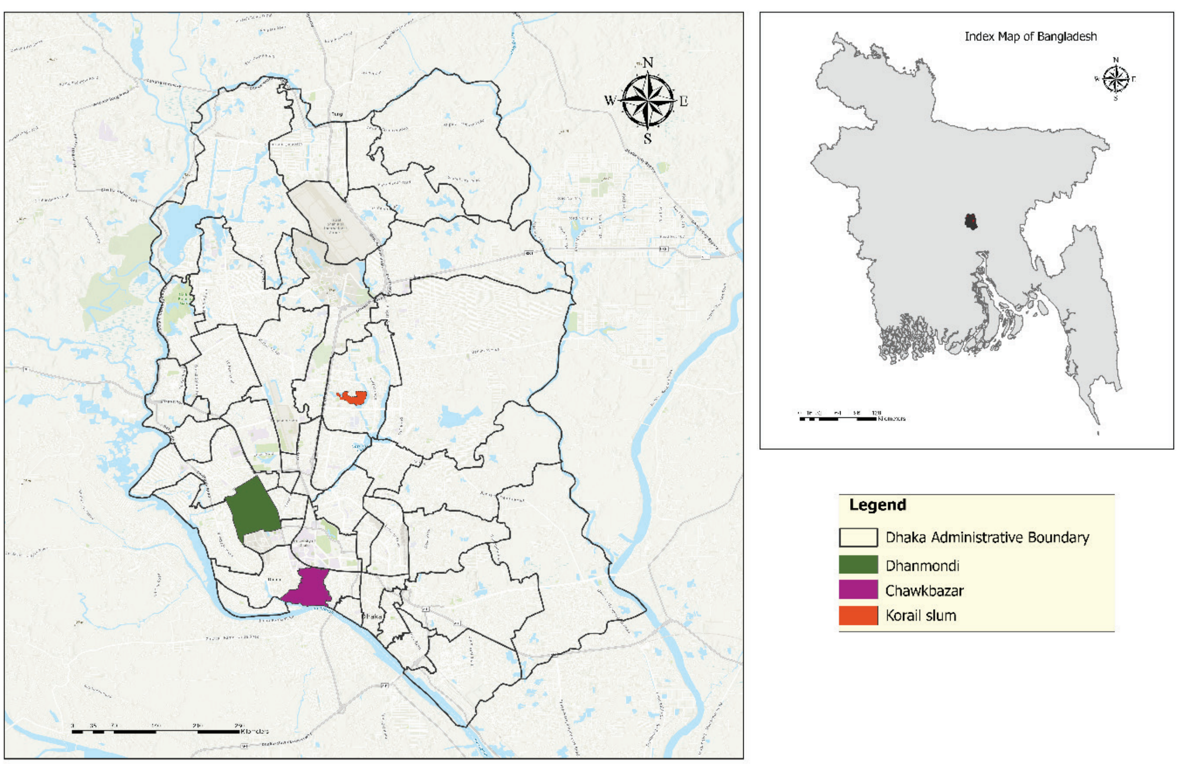


Figure 1: Study Area Map

METHODS AND MATERIALS

Research Design and Methodological Approach

The assessment of outdoor thermal comfort in urban environments has traditionally relied on one of two distinct approaches: field-based meteorological measurements analysed through objective indices, or resident surveys that capture subjective thermal perceptions. While both approaches have advanced understanding of urban heat environments, each has recognised limitations when used in isolation. Studies relying solely on environmental measurements and indices such as PMV and PET can document physical thermal conditions with precision, but existing comfort models are not fully developed to capture the effects of both environment-based and human-based parameters together, and most such studies remain neutral to individual differences such as age, gender, and socioeconomic background (Aghamolaei et al., 2023). Survey-based approaches, in turn, lack the environmental grounding needed to explain why perceptions differ across urban contexts. It is now widely accepted that thermal comfort cannot be fully understood through objective parameters alone and that subjective responses must also be considered (Nikolopoulou and Lykoudis, 2006).

In cities where informal settlements coexist with planned neighbourhoods, this limitation becomes even more consequential. Research in comparable urban contexts across Africa and South Asia has found that quantitative approaches consistently underrepresent the lived experience of heat stress in low-income communities, and that understanding how residents perceive, experience, and respond to thermal discomfort requires qualitative data that physical measurements cannot provide (Baruti et al., 2024; Loughnan et al., 2012). As one recent review concluded, the experience of vulnerabilities and adaptive capacities of vulnerable groups remains an under-researched topic precisely because single-method studies cannot bridge the gap between what is measured and what is lived (Laue et al., 2022).

This study therefore adopts a mixed-methods research design, integrating field-based micrometeorological measurements, objective thermal comfort indices (PMV and PET), structured questionnaire surveys, Key Informant Interviews, and a Thermal Resilience Index derived from survey data. This approach allows the study to document what the thermal environment is across three contrasting urban typologies, understand how residents perceive and experience those conditions, and assess how well different communities are equipped to cope with extreme heat. Both primary and secondary data were collected. Primary data were gathered through field measurements and resident surveys, while secondary data were drawn from published literature, government documents, and institutional reports.

Conceptual Framework

The conceptual framework guiding this study was developed by integrating insights from existing literature on microclimatic variation, thermal comfort, and urban resilience. It is structured around two analytical phases. Phase I examines thermal comfort as a function of three interacting sets of factors: environmental conditions (air temperature, relative humidity, and wind speed), individual characteristics (age, gender, perception, and awareness), and activity-related factors (metabolic rate and clothing insulation). Thermal comfort is assessed through both subjective indicators and objective indices including PMV, PPD, PET, and the Subjective Thermal Comfort Index (STCI). Phase II extends the analysis to health impacts and thermal resilience, linking occupant vulnerability — as revealed through Phase I — to systemic factors including energy access, backup power capacity, financial capacity for adaptation, and community preparedness. Together, the two phases provide a comprehensive basis for assessing how microclimatic conditions translate into differential thermal experiences and resilience capacities across Dhaka's contrasting residential typologies (Fig. 2).

Sampling Technique and Sample Size

Participants were selected using a purposive sampling strategy from Dhanmondi, Chawkbazar, and Korail, targeting resident's representative of each neighbourhood's socioeconomic and physical character. Sample size was determined using the Cochran formula (Cochran, 1977):

$$n = (Z^2Pq) / e^2$$

Where n is the required sample size, Z is the critical value for the desired confidence level, P is the estimated proportion of the attribute present in the population, $q = 1 - P$, and e is the desired level of precision. Assuming maximum variability ($P = 0.5$), a 90% confidence level, and ±10% precision, the formula yielded a sample size of 97. This was adjusted to 90 to maintain equal distribution across the three areas, with 30 respondents per area, which was considered sufficient for descriptive and comparative statistical analysis.

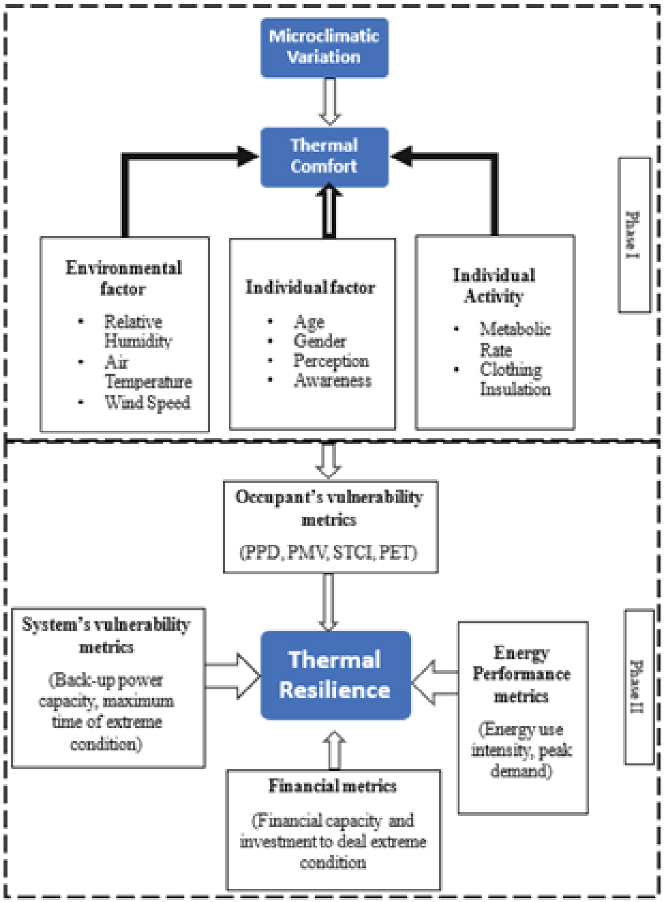


Figure 2: Conceptual Framework for Assessing Thermal Comfort and Resilience

Field Survey for Micro-Meteorological Data Acquisition

Micrometeorological data including air temperature, relative humidity, and wind speed were collected across all three study areas during April, May, and June, covering the pre-monsoon and early monsoon period when thermal stress in Dhaka is at its peak. To minimise the effect of diurnal temperature variation and ensure comparability across sites, all measurements were conducted between 12:00 pm and 1:00 pm, the period of highest ambient temperature during the day. Both indoor and outdoor measurements were taken at each site. Air temperature and relative humidity were recorded using a digital thermometer, and wind speed was measured using a digital anemometer. The instruments used for data collection are shown in Figure 3.

Figure 3: Thermometer and Anemometer Used for the Purpose of Data Collection

Thermal Comfort Assessment

Thermal comfort was assessed through both subjective and objective methods. For subjective assessment, three indicators were used: Thermal Sensation, Thermal Comfort Level, and Temperature Preference. Average scores for each indicator were calculated per area and summed to produce the Subjective Thermal Comfort Index (STCI), where higher values indicate greater thermal discomfort. For objective assessment, the Predicted Mean Vote (PMV) was calculated using the CBE Thermal Comfort Tool for indoor conditions. The seven-point PMV scale used for interpreting indoor thermal comfort levels is presented in table 1.

Questionnaire Survey and Key Informant Interviews

A structured questionnaire survey was conducted alongside the micrometeorological measurements. The survey assessed residents' thermal sensations, comfort levels, and temperature preferences using a seven-point scale ranging from cold (−3) to hot (+3). Humidity, wind, and solar sensations were similarly assessed on equivalent scales. Clothing insulation was evaluated using checklists based on ASHRAE Standard 55 (ASHRAE, 2017). A separate questionnaire was used to assess thermal resilience, covering monthly electricity consumption, experience of power outages during extreme weather, access to backup power, and individual and structural adaptation strategies. To assess health impacts in Korail, Key Informant Interviews were conducted with three informants: a student coordinator, a landowner, and a clinical in-charge, using separate structured interview guides for each.

Table 1: PMV Scale (Source: ASHRAE Standard 55, 2017)

THERMAL SENSATION	very cold	cold	cool	slightly cool	neutral comfortable	slightly warm	warm	hot	very hot
PMV	-4	-3	-2	-1	0	1	2	3	4
PHYSIOLOGICAL STRESS LEVEL	extreme	strong	moderate	slight	no stress	slight	moderate	strong	extreme
		coldstress					heatstress		

For outdoor thermal comfort, Physiological Equivalent Temperature (PET) was computed using RayMan 1.2, developed at the Meteorological Institute of the University of Freiburg (Matzarakis et al., 2010). The PET classification scale used for outdoor thermal comfort assessment is presented in table 2.

Table 2: PET Scale (Source: Matzarakis et al., 2010)

PET	Thermal perception	Grade of physiological stress
4 °C	Very cold	Extreme cold stress
8 °C	Cold	Strong cold stress
13 °C	Cool	Moderate cold stress
18 °C	Slightly cool	Slight cold stress
23 °C	Comfortable	No thermal stress
29 °C	Slightly warm	Slight heat stress
35 °C	Warm	Moderate heat stress
41 °C	Hot	Strong heat stress
>41 °C	Very hot	Extreme heat stress

Metabolic rate was standardised at 1.2 met across all respondents, corresponding to a seated or light activity level, to ensure a valid and consistent comparison across the three study areas. Clothing insulation values were derived individually from the ASHRAE-based checklists completed during the survey.

Thermal Resilience Assessment

The Thermal Resilience Index (TRI) was used in this study to calculate the thermal resilience of each residential community. It measures resilience by combining a number of important elements: preparedness, which measures the community's awareness and readiness for climate-related challenges; energy security, which includes the dependability of access to electricity and the availability of backup power systems; and adaptive capacity, which includes structural and individual adaptations used to control indoor heat. The TRI for each community was calculated using responses to survey questions about energy use, perceptions of climate change, and adaptation tactics. It was calculated as:

$$TRI = (W_1 . E + W_2 . P + W_3 . A) / (W_1 + W_2 + W_3)$$

Where E is the Energy Security Score, P is the Preparedness Score, and A is the Adaptive Capacity Score. Weights were assigned as $W_1 = 0.4$, $W_2 = 0.2$, and $W_3 = 0.4$, reflecting the relatively greater measurable influence of energy access and adaptive capacity on overall resilience outcomes in low-income urban contexts, consistent with approaches adopted in comparable resilience assessment frameworks (Hong et al., 2023; Sharma et al., 2021). Higher TRI scores indicate greater capacity to cope with and recover from thermal stress.

Data Analysis

PMV and PET values were subjected to statistical and comparative analysis using SPSS Statistics 25.0. Survey data from all 90 respondents were entered into a structured dataset and processed in MS Excel for additional comparative analysis. Spatial analysis was conducted using GIS, with Inverse Distance Weighting (IDW) interpolation used to generate continuous surface maps illustrating temperature distribution across the study areas. It should be noted that IDW interpolation assumes spatial continuity and does not account for physical barriers such as dense building blocks; the resulting heat maps are therefore best interpreted as spatial approximations rather than definitive thermal gradients. Key Informant Interview data were analysed qualitatively, with responses described and interpreted thematically to contextualise the health impacts of thermal stress in Korail.

RESULTS

Field measurements and resident surveys conducted across Dhanmondi, Chawkbazar, and Korail Slum during April to June reveal consistent and measurable differences in microclimatic conditions, thermal comfort, and resilience capacity across the three study areas. The results are presented below across four thematic areas: outdoor and indoor microclimate, spatial heat distribution, thermal comfort, and thermal resilience.

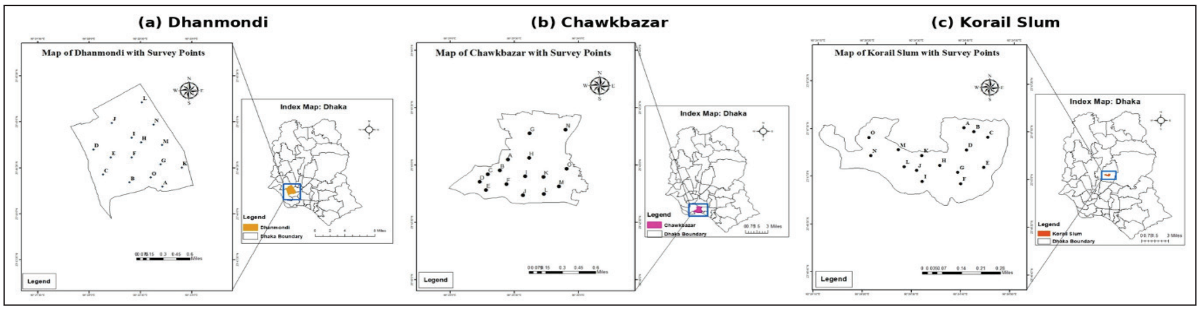


Figure 4: Survey Point Maps of the Three-Study Area

Microclimatic Variation Across the Three Study Areas

Outdoor Microclimatic Variation

Outdoor microclimatic measurements reveal notable differences across the three areas. Dhanmondi recorded a mean outdoor temperature of 32.79°C with a relative humidity of 85.20% and a mean air speed of 0.75 ms^{-1}. The presence of Dhanmondi Lake and scattered green spaces contributes to relatively moderate outdoor conditions, with air movement providing partial thermal relief. Chawkbazar recorded the highest mean outdoor temperature of 33.19°C, with relative humidity at 86.87% and a mean air speed of just 0.0816 ms^{-1}. The area's dense mixed-use built fabric, near-total absence of open space, and minimal vegetation result in restricted airflow and persistently warm, humid outdoor conditions. Korail Slum recorded a mean outdoor temperature of 32.41°C, relative humidity of 85%, and a mean air speed of 0.0875 ms^{-1}. Despite a slightly lower mean temperature than Chawkbazar, the near-stagnant airflow and tightly packed informal structures create outdoor conditions that are similarly oppressive in terms of felt heat and humidity.

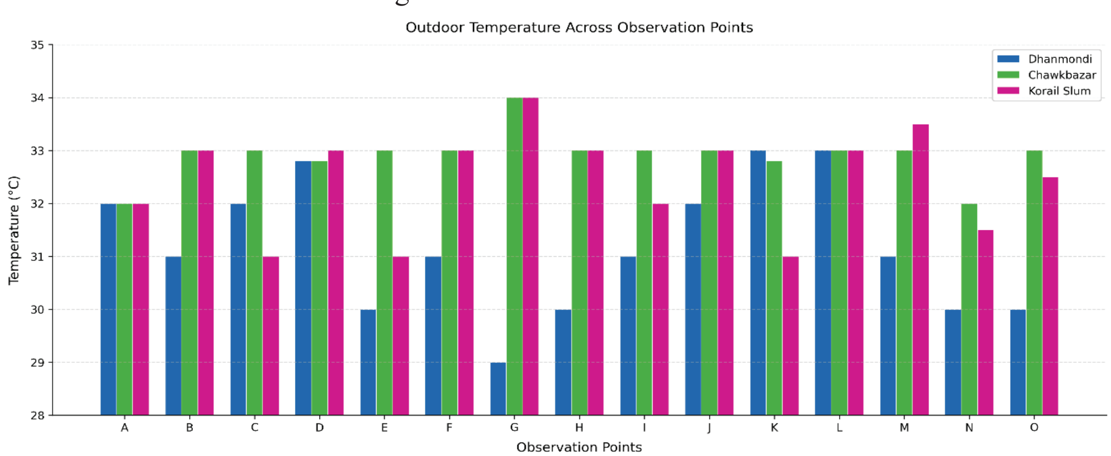


Figure 5: Bar Graph of Outdoor Temperature Across Areas

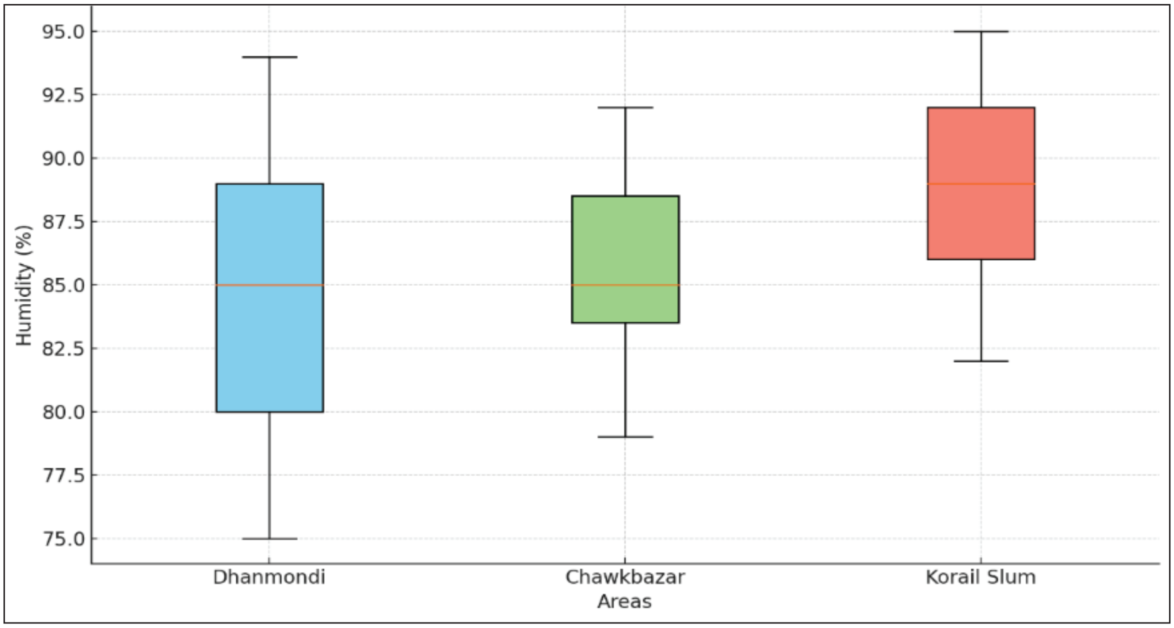


Figure 6: Boxplot of Outdoor Humidity Across Areas

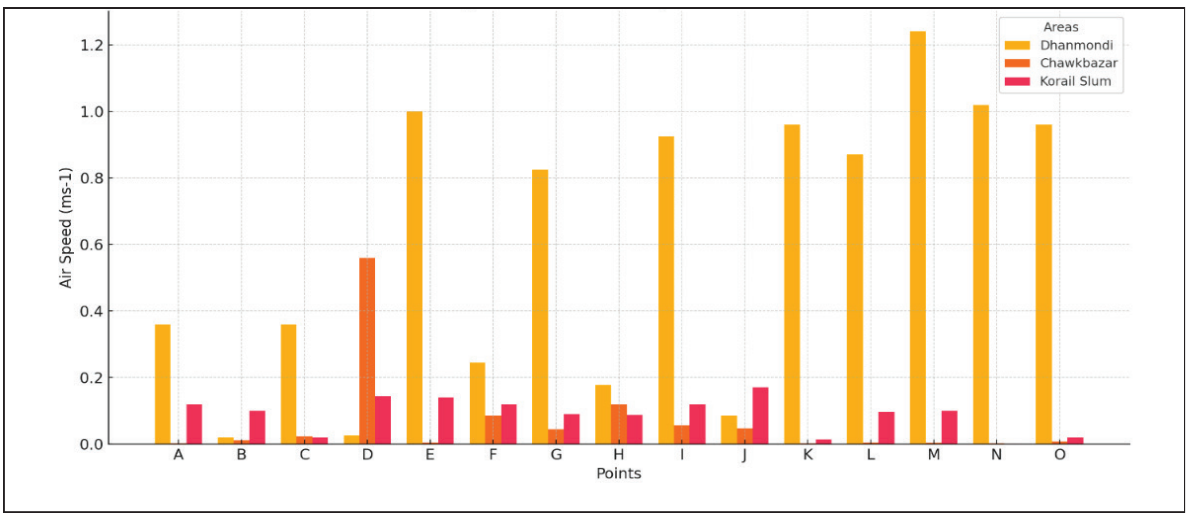


Figure 7: Bar Graph of Outdoor air Speed Across Areas

Indoor Microclimate

Indoor measurements follow a broadly similar pattern. Dhanmondi recorded a mean indoor temperature of approximately 31°C, relative humidity of 85%, and a mean air speed of 1.02 ms^{-1}, reflecting the relatively better ventilation that planned building layouts in the area afford. Chawkbazar recorded higher mean indoor temperatures of 33°C and relative humidity of approximately 88%, with a mean air speed of 0.0816 ms^{-1}. The dense building stock and minimal setbacks in this area restrict cross-ventilation, trapping heat and moisture within residential and commercial spaces. Korail Slum recorded mean indoor temperatures of around 32°C with humidity averaging 88% and the lowest mean air speed of all three areas at 0.0501 ms^{-1}. The combination of tin-roofed single-room structures, high occupant density, and virtually no natural ventilation results in near-stagnant indoor air and the most severe indoor thermal conditions across the three study areas.

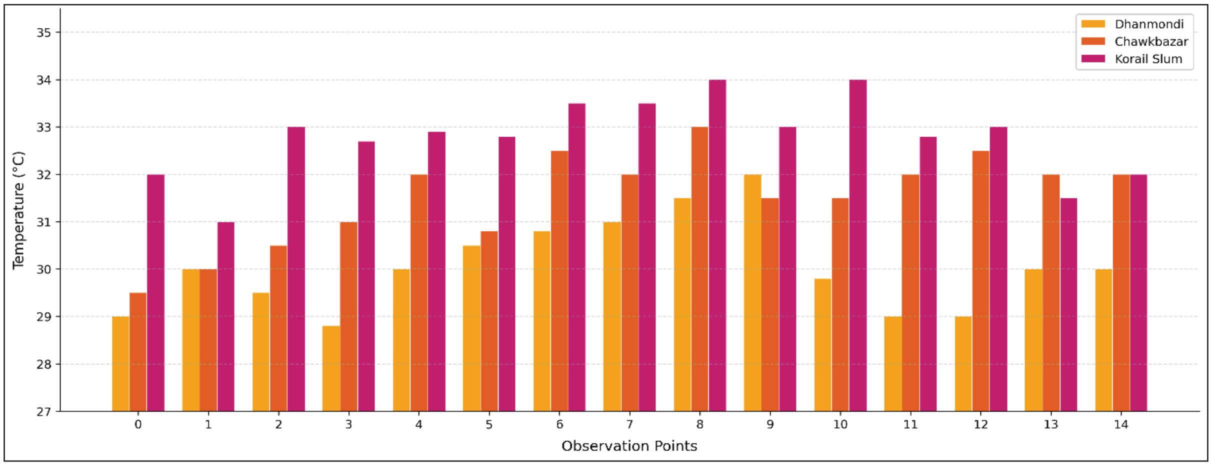


Figure 8: Indoor Temperature Variation Across Three Areas

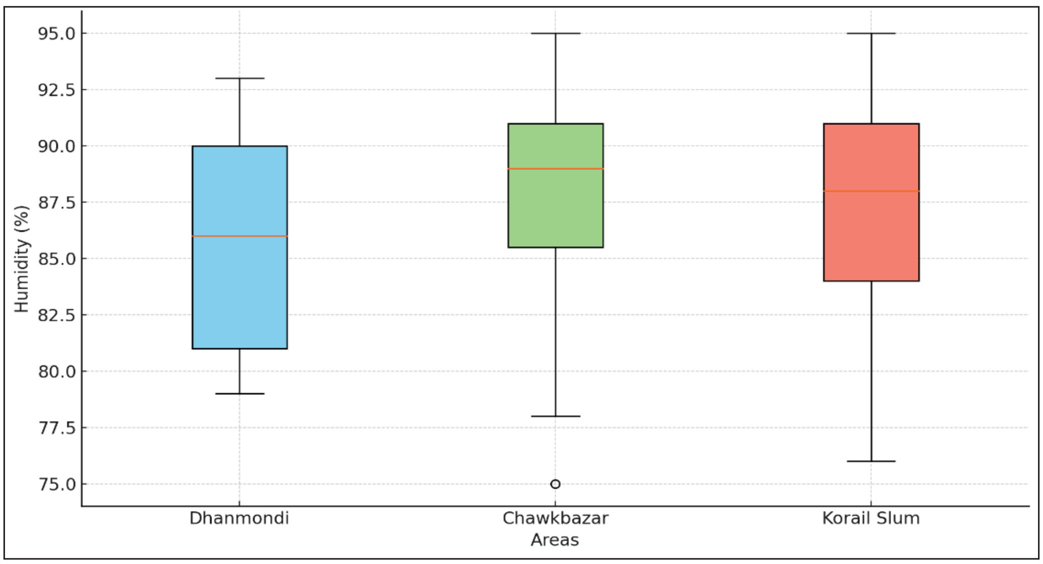


Figure 9: Boxplot of Indoor Humidity Across Three Areas

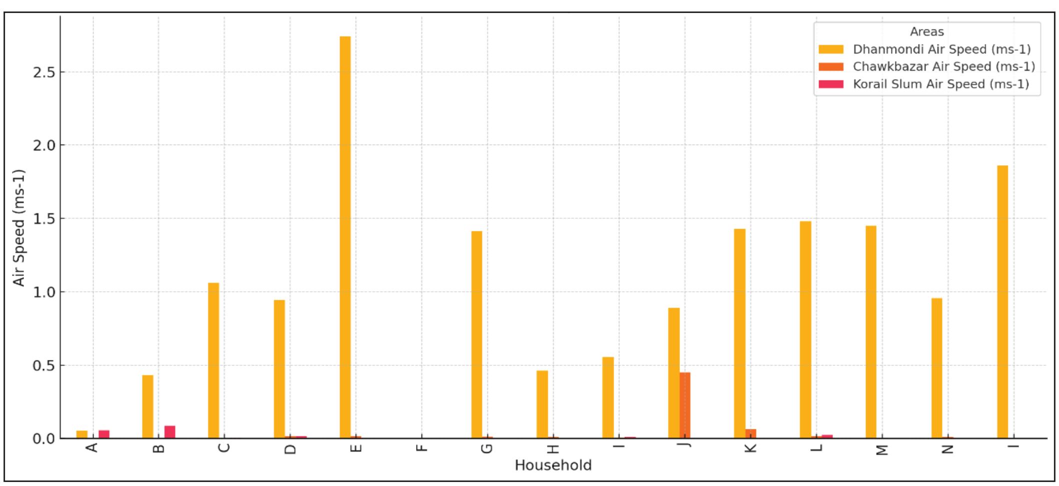


Figure 10: Household-Wise Air Speed Across Areas

Spatial Analysis of Heat Distribution Across the Three Areas

GIS-based spatial analysis using Inverse Distance Weighting interpolation was used to map temperature distribution across the three study areas (Fig. 11). In Dhanmondi, temperature across measurement points ranges from 29°C to 33.9°C, with the hottest zones concentrated at points L, D, and K, and cooler pockets at points G and A, corresponding to areas with greater vegetation cover. In Chawkbazar, temperatures range from 31.5°C to 34°C, with the highest values concentrated in the northern and southwestern portions of the area where building density is greatest and green cover is absent. In Korail Slum, temperatures range from 30°C to 34°C, with the highest concentrations in the central and southern portions of the settlement where population density and structural crowding are most intense. Cooler pockets are found near water bodies and open spaces at the settlement's periphery.

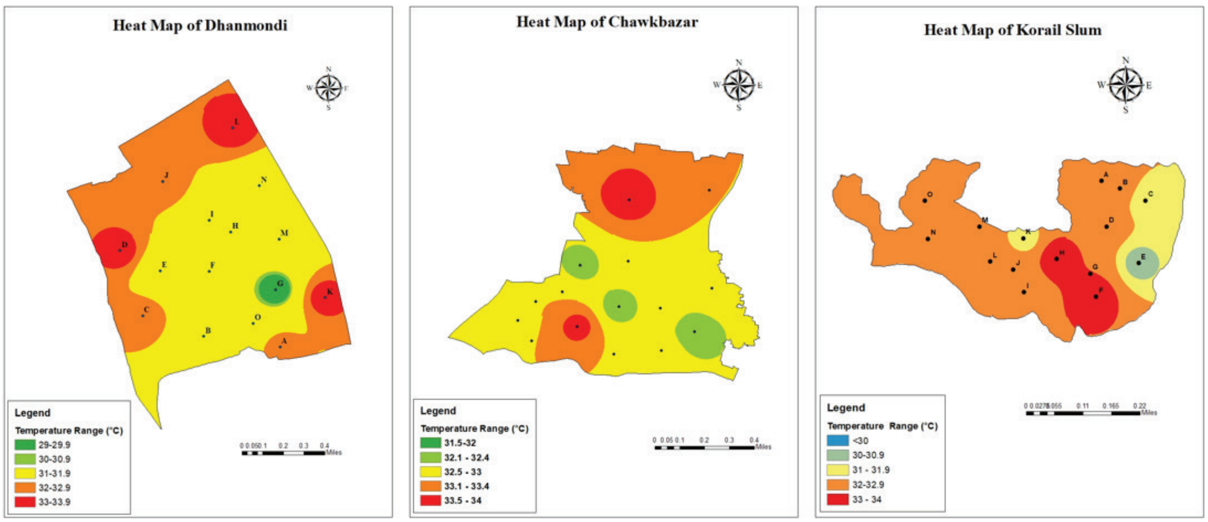


Figure 11: Spatial Heat Distribution Maps of Dhanmondi, Chawkbazar and Korail Slum

These field observations are broadly consistent with secondary climatic data for Dhaka in 2024. According to Meteoblue (n.d.), daily mean maximum temperatures in Dhaka peak at 33°C between April and June, with prevailing wind speeds of 5 to 10 km/h year-round and stronger winds of 20 to 30 km/h during summer months (Fig. 12). The peak temperature period recorded in the secondary data aligns directly with the field measurement window of this study, lending further credibility to the observed spatial thermal patterns across the three neighbourhoods.

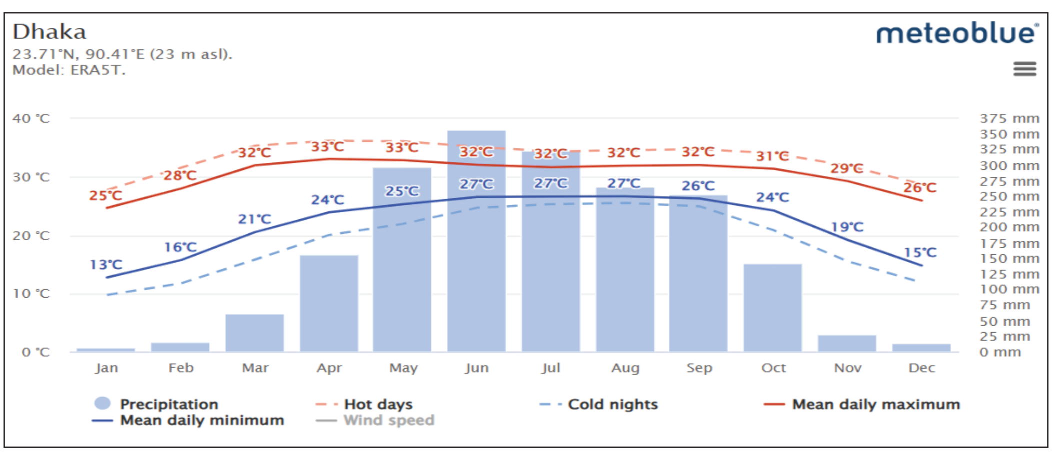


Figure 12: Seasonal Variation of Temperature, Precipitation, and Wind Speed in Dhaka, 2024

Source: Meteoblue (n.d.)

Thermal Comfort in Urban Residential Environments

Indoor Thermal Comfort

Indoor thermal comfort was assessed using the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) indices. In Dhanmondi, the mean PMV of 1.2 falls within the "slightly warm" range, with relatively low PPD values indicating that most residents experience only mild indoor thermal discomfort. In Chawkbazar, PMV values are predominantly in the "warm" to "hot" range, with a higher proportion of residents reporting dissatisfaction, reflecting the area's poor ventilation and elevated indoor temperatures. Korail Slum records the highest PMV values across all three areas, predominantly in the "hot" category, with nearly all surveyed households experiencing conditions that exceed acceptable thermal comfort thresholds (Fig. 13a).

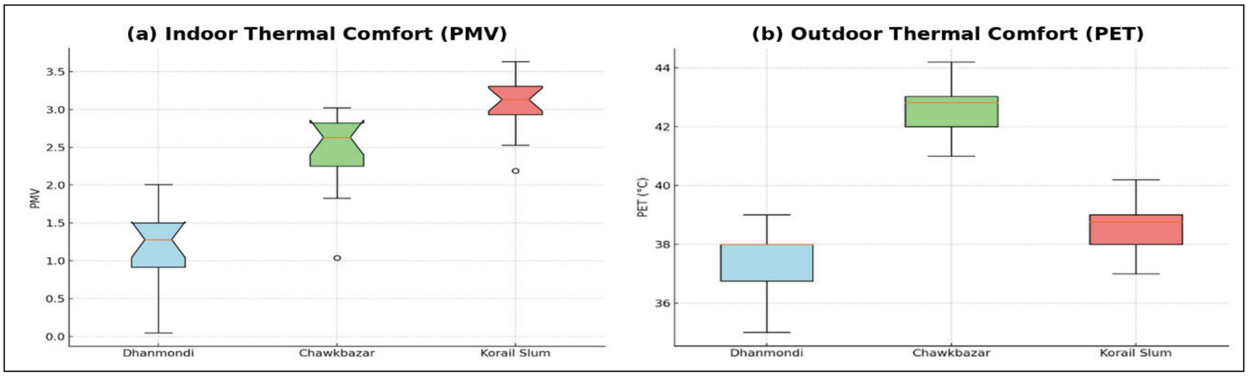


Figure 13: Thermal Comfort Across the Three Study Areas: (a) Indoor PMV and (b) Outdoor PET

Outdoor Thermal Comfort

Outdoor thermal comfort was assessed using the Physiological Equivalent Temperature (PET). Dhanmondi recorded a mean PET of 37.4°C, classified as "Warm" on the PET scale, indicating moderate outdoor thermal stress. Chawkbazar recorded the highest mean PET of 42.64°C, classified as "Very Hot," reflecting the combined effect of high temperatures, humidity, and severely restricted airflow in the dense built environment. Korail Slum recorded a mean PET of 38.5°C, classified as "Hot." While marginally lower than Chawkbazar, this value still represents significant outdoor thermal stress and indicates conditions well beyond the thermal neutral range (Fig. 13b).

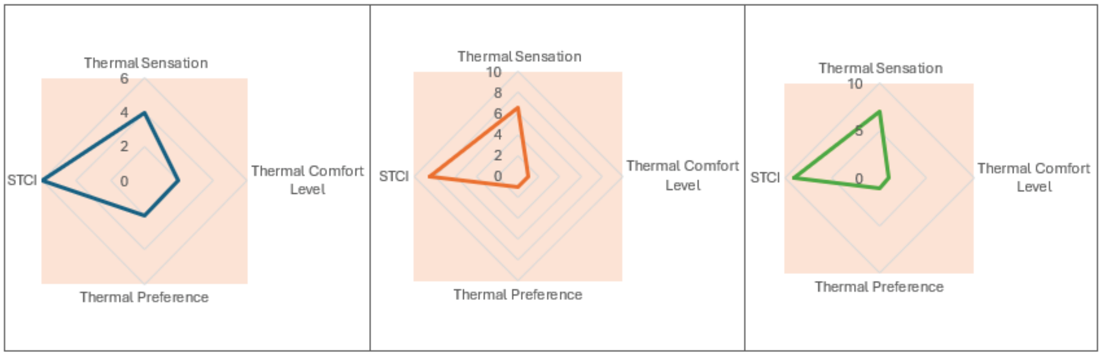
Subjective Assessment of Thermal Comfort: STCI

Subjective thermal comfort was measured using the Subjective Thermal Comfort Index (STCI), which aggregates scores for Thermal Sensation, Thermal Comfort Level, and Thermal Preference. In Dhanmondi, residents recorded a Thermal Sensation score of 4, a Comfort Level of 2, a Thermal Preference score of 1, and an overall STCI of 4, indicating moderate but manageable discomfort. In Chawkbazar, the Thermal Sensation score rose to 7, the Comfort Level to 3, and the Thermal Preference to 2, yielding an STCI of 6 and reflecting considerably higher perceived heat stress among residents. Korail Slum recorded the highest values across all indicators, with a Thermal Sensation score of 8, a Comfort Level of 3, a Thermal Preference of 3, and a peak STCI of 7, indicating the most severe subjective thermal discomfort of the three areas.

Overall, Korail Slum experiences the most thermal stress, followed by Chawkbazar, with Dhanmondi showing the most favorable conditions. And the findings highlight the need for targeted infrastructure improvements and sustainable housing strategies to address urban heat vulnerability.

Thermal Resilience

Thermal resilience across the three study areas was assessed using the Thermal Resilience Index (TRI), which combines three weighted components: Energy Security (E, weight = 0.4), Preparedness (P, weight = 0.2), and Adaptive Capacity (A, weight = 0.4). Higher TRI scores indicate a greater capacity to maintain thermal comfort and recover from periods of extreme heat.



(a) (b) (c)

Figure 14: Subjective Thermal Comfort Index for a) Dhanmondi, b) Chawkbazar and c) Korail Slum

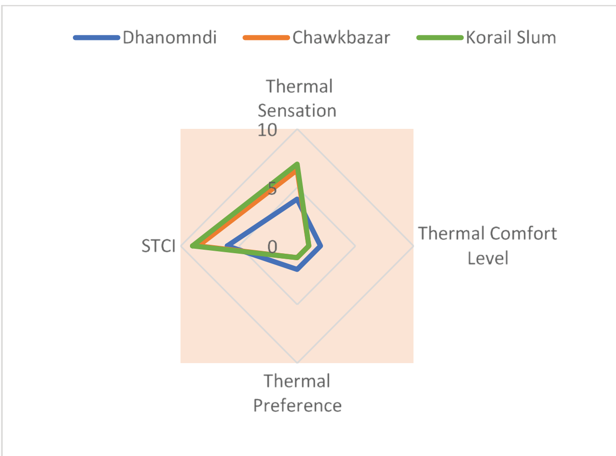
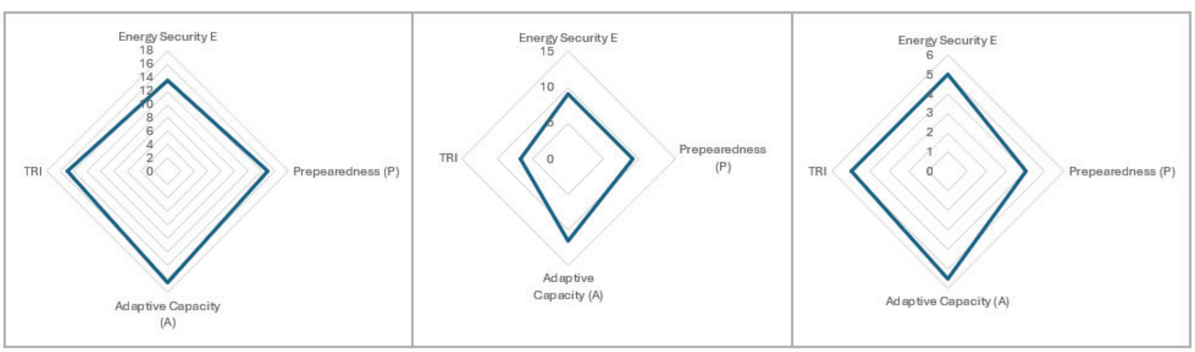


Figure 15: Overall Subjective Thermal Comfort

Energy Security

Energy security varies markedly across the three areas. Dhanmondi records the highest Energy Security score of approximately 14, reflecting reliable electricity access, monthly energy expenditure ranging from 5,000 to 15,000 BDT, and widespread availability of backup generators that ensure uninterrupted cooling during heatwaves. Chawkbazar records a mid-range Energy Security score of approximately 10. Residents spend an average of 1,500 to 2,000 BDT monthly on electricity and experience frequent power outages of two to three hours occurring multiple times daily, with only a small proportion of households relying on inverters or battery-powered fans as backup. Korail Slum records the lowest Energy Security score of approximately 5. Electricity costs average just 200 to 300 BDT per month, power cuts occur five to six times daily, and no backup infrastructure exists. During outages, residents have no recourse beyond hand fans.



(a) (b) (c)

Figure 16: Thermal Resilience Index (TRI) of a) Dhanmondi, b) Chawkbazar, and c) Korail Slum

Preparedness

Preparedness scores reflect community awareness of heat risks and readiness to respond to extreme heat events. Dhanmondi records a Preparedness score of approximately 12, with residents demonstrating awareness of heat-related health risks and actively adjusting cooling behaviour in response. Chawkbazar records a score of approximately 8, with residents acknowledging thermal discomfort but showing limited awareness of heat stress as a climate-driven phenomenon requiring systemic response. Korail Slum records the lowest Preparedness score of approximately 4, with most residents treating heat adaptation as a purely individual challenge and expressing little expectation of community or institutional support.

Adaptive Capacity

Adaptive capacity captures the behavioural, infrastructural, and financial resources available to residents to cope with extreme heat. Dhanmondi records the highest Adaptive Capacity score of approximately 13, with residents drawing on air conditioning, HVAC systems, cold beverages, access to shaded parks, and the financial flexibility to absorb higher energy costs. Chawkbazar records a score of approximately 9, with residents relying primarily on fans and natural ventilation, constrained by dense infrastructure and lower incomes. Korail Slum records an Adaptive Capacity score of approximately 4, the lowest of the three areas. Residents depend on low-powered fans, makeshift shaded areas, and cold tube-well water for relief. The presence of earthen cooking stoves indoors adds a further heat load to already poorly ventilated spaces, compounding thermal stress and narrowing available adaptive options considerably.

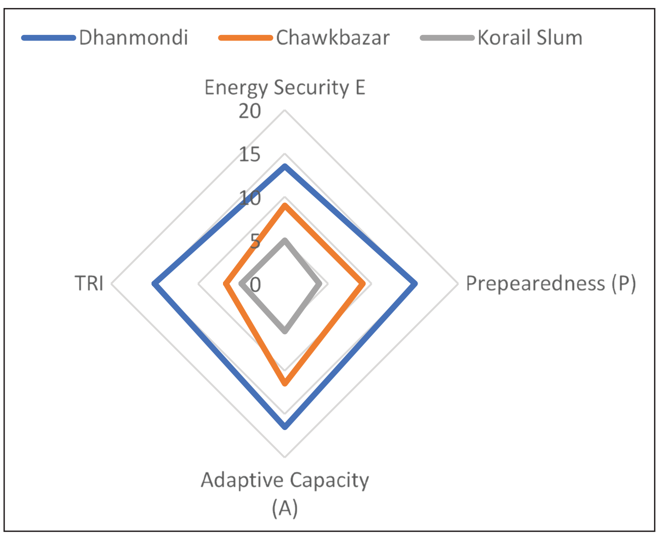


Figure 17: Overall TRI for the Three Areas

TRI results place Dhanmondi as the most thermally resilient area with an overall TRI of approximately 13, followed by Chawkbazar at approximately 9, and Korail Slum at approximately 4. The scale of this disparity reflects not simply differences in thermal exposure but fundamental inequalities in infrastructure, income, and resource access that determine how well different urban communities can withstand and recover from extreme heat events.

DISCUSSION

The findings of this study reveal systematic and measurable differences in microclimatic conditions, thermal comfort, and resilience capacity across three residential typologies in Dhaka, and these differences align with and extend patterns documented in existing literature on urban heat environments in tropical megacities.

Microclimatic Differentials and Urban Morphology

While the three areas differed only modestly in absolute air temperature, they diverged sharply in air movement, and it is this difference that best explains the contrasting thermal experiences observed across the neighbourhoods. The near order-of-magnitude gap in outdoor air speed between planned Dhanmondi and the denser fabric of Chawkbazar and Korail indicates that ventilation, rather than ambient temperature, is the decisive control on thermal discomfort in Dhaka's compact urban forms. This interpretation is supported by research on urban canyon geometry in dense tropical cities, which has shown that high building aspect ratios and low sky view factors simultaneously restrict wind penetration and trap outgoing radiation near ground level, producing near-stagnant and heat-retentive microclimates even where background air temperatures remain moderate (Peng and Huang, 2022; Laue et al., 2022). Chawkbazar exemplifies this mechanism: its narrow lanes, continuous building frontages, and near-zero sky view factor jointly suppress airflow and concentrate radiant heat, so that residents experience conditions considerably more oppressive than the recorded air temperature alone would suggest. The practical implication is that heat mitigation in such areas cannot rely on reducing temperature directly, but must instead restore airflow through morphological interventions, a point we return to in the recommendations.

Conversely, the relatively more moderate conditions recorded in Dhanmondi are at least partly attributable to the presence of Dhanmondi Lake and scattered green spaces, which provide natural thermal buffering through shading and evapotranspiration. A decade-long systematic review of urban green space cooling effects synthesising findings from 84 peer-reviewed studies found that urban green spaces can reduce local temperatures by 1 to 7°C, with cooling intensity shaped by vegetation density, spatial configuration, and surrounding urban morphology (Saud et al., 2025). The cooler measurement points in Dhanmondi's heat map at locations G and A correspond directly to areas of greater green cover, reinforcing this finding at the neighbourhood scale. The near-total absence of vegetation in Chawkbazar and Korail eliminates this buffering effect entirely, leaving both areas fully exposed to the thermal load of their built environments.

The findings of Sharmin et al. (2015), who studied microclimatic conditions across residential, commercial, and educational areas in Dhaka, offer a useful point of comparison. Their study found that traditional areas with variable, irregular plot sizes and building heights tend to respond more favourably to the synoptic climate, whereas planned areas with uniform plot sizes and heights are more prone to developing daytime UHI conditions. The present study qualifies this expectation by showing that the thermal performance of a planned area is not determined by its regular morphology alone: in Dhanmondi, the presence of water bodies and green space substantially moderates microclimatic conditions despite its planned, uniform layout. Taken together with the present findings, this suggests that the most severe thermal conditions arise not from planned urban form per se, but from the combination of extreme built density and the absence of natural cooling elements that characterises the mixed-use and informal typologies of Chawkbazar and Korail.

Thermal Comfort Patterns Across Urban Typologies

The PMV and PET results confirm a clear hierarchy of thermal stress across the three areas, with Korail recording the highest indoor discomfort with PMV values predominantly in the "hot" range, and Chawkbazar the highest outdoor discomfort with a mean PET of 42.64°C classified as "Very Hot." These values are considerably higher than the PET neutral range of 24 to 26°C generally accepted for hot and humid climates (Matzarakis et al., 2010; Sharmin et al., 2015), indicating that all three areas experience outdoor conditions well beyond thermal neutrality during the measurement period.

The subjective STCI results add an important dimension that the objective indices alone cannot capture. Korail Slum records the highest STCI of 7 despite a mean outdoor temperature slightly lower than Chawkbazar, suggesting that subjective thermal stress in informal settlements is shaped not only by measured environmental conditions but also by housing quality, material heat retention, and the complete absence of any cooling recourse. This divergence between objective measurement and subjective perception has been documented in comparable informal settlement contexts. A study deploying a sensor network across 12 informal settlements in Makassar, Indonesia found that informal settlement residents experience chronic heat stress conditions that are consistently underestimated by conventional weather stations, with wet bulb temperatures approaching the uppermost limits of human survivability both indoors and outdoors (Ramsay et al., 2021). Research specifically focused on Dhaka confirms that lower-income residents, particularly those in informal settlements, face greater risks of heat-induced health issues than their counterparts in formal residential areas, driven by the combination of higher exposure and weaker adaptive capacity (Rahman et al., 2022). The STCI results from this study reflect the same dynamic, where the gap between Dhanmondi and Korail in subjective comfort is considerably wider than the gap in measured outdoor temperature.

Thermal Resilience and Structural Inequality

The TRI results reveal the most pronounced contrasts of the study, with Dhanmondi scoring approximately 13, Chawkbazar approximately 9, and Korail Slum approximately 4 across the combined energy security, preparedness, and adaptive capacity dimensions. These findings are consistent with a growing body of literature identifying structural and socioeconomic conditions, rather than thermal exposure alone, as the primary determinants of urban heat vulnerability. Research in informal settlements in South Africa found that while dwellings in both affluent and poor neighbourhoods employ at least one passive heat amelioration strategy, only the wealthier households can afford active cooling measures such as air conditioning, making effective passive cooling strategies essential for the urban poor (Hugo, 2023). The same pattern is evident in this study, where Dhanmondi residents draw on air conditioning, backup generators, and the financial flexibility to sustain high energy expenditure, while Korail residents depend entirely on hand fans and makeshift shade.

The energy poverty dimension is particularly severe in Korail, where electricity costs of 200 to 300 BDT per month, five to six daily power cuts, and the complete absence of backup infrastructure mean that residents are left without any mechanised cooling during the periods of greatest heat stress. This constitutes what Mazzone et al. (2024) term "systemic cooling poverty," a condition in which structural barriers including inadequate housing, energy insecurity, and income constraints combine to deny access to the basic thermal protection that higher-income residents take for granted. Their study of comparable informal urban communities in Rio de Janeiro found that systemic cooling poverty encompasses multiple layers of physical, social, and infrastructural deficiencies that impede the provision of essential services necessary to ensure thermal safety during extreme heat episodes that apply with equal force to the conditions documented in Korail Slum.

Health Vulnerability and Adaptation

Key Informant Interviews conducted with a student coordinator, a landowner, and a clinical in-charge in Korail Slum consistently identified a range of heat-related health conditions perceived to be associated with the settlement's thermal environment. Reported conditions included respiratory illness, dermatological complaints such as scabies and heat rash, heatstroke, and chronic heat exhaustion. Informants noted that children were particularly vulnerable, citing the combination of overcrowded sleeping conditions, inadequate ventilation, and heat-retaining tin roofing as contributing factors to disturbed sleep and increased illness frequency during the summer months. Elderly residents were identified as the most at-risk group for heat exhaustion, with limited mobility restricting their ability to seek relief during peak heat periods.

The KII data reflect the perceptions and experiences of community members and frontline health workers rather than epidemiological evidence, and interpret indication of perceived health risks rather than established causal relationships. These perceptions are nonetheless consistent with findings from comparable informal settlement contexts. Mukhopadhyay et al. (2021), studying indoor heat stress in Kolkata slum dwellings and rural West Bengal housing, found that most slum dwellings exceed safe indoor temperature thresholds at some point during the day, and that the urban heat island effect is materially intensified within informal housing, producing heat stress conditions considerably greater than those experienced by residents in rural areas under equivalent outdoor conditions. The health conditions reported in Korail reflect a comparable pattern, in which the physical characteristics of informal housing translate ambient thermal stress into a direct and sustained risk to resident health and wellbeing.

The adaptation strategies documented across the three areas reflect the inverse relationship between thermal vulnerability and adaptive capacity that characterizes the study's findings as a whole. In Dhanmondi, access to air conditioning, backup generators, green parks, and financial flexibility provides a robust adaptive system. In Chawkbazar and Korail, adaptation is reactive and resource-constrained, relying on fans, hand-fans, minimal clothing, makeshift shade, and cold water, strategies that provide marginal relief but cannot adequately offset the thermal loads generated by the built environments these residents inhabit. Recent experimental evidence from informal settlements in Bihar, India found that low-cost structural interventions such as radiant foil insulation and Mylar blankets can lower indoor temperatures by 0.97 to 1.24°C, demonstrating that even modest, scalable structural improvements can meaningfully improve thermal conditions for informal settlement residents who lack access to mechanical cooling (Ang et al., 2026). These findings point to a practical pathway for thermal adaptation in Korail that does not depend on energy access or financial capacity, and that warrants serious consideration by urban planners and policymakers in Dhaka.

The findings of this study suggest that thermal vulnerability in Dhaka is best understood as the product of the intersection between the physical thermal environment and the socioeconomic and infrastructural conditions that determine whether residents can respond to it. Planned neighbourhoods like Dhanmondi benefit from a combination of environmental moderation and resource access that substantially reduces effective thermal stress, while informal settlements like Korail face the dual burden of the most demanding thermal environments and the least capacity to cope with them.

CONCLUSION

This study examined microclimatic variation, thermal comfort, and community resilience across three contrasting residential typologies in Dhaka: the planned neighbourhood of Dhanmondi, the dense mixed-use area of Chawkbazar, and the informal settlement of Korail Slum, during the peak heat period of April to June. The findings demonstrate that thermal vulnerability in Dhaka is not determined by climate alone but by the intersection of urban morphology, green infrastructure, housing quality, energy access, and socioeconomic resources that collectively shape how different communities experience and respond to extreme heat.

Dhanmondi, with a mean outdoor air speed of 0.75 ms^{-1}, a mean PET of 37.4°C, and a TRI of approximately 13, benefits from a combination of planned layout, green spaces, water bodies, and reliable energy access that substantially moderates both its physical thermal environment and its residents' capacity to cope with heat stress. Chawkbazar, recording the highest mean PET of 42.64°C and a TRI of approximately 9, demonstrates that extreme building density and the absence of natural cooling infrastructure can produce outdoor thermal conditions classified as "Very Hot" even where ambient temperatures remain within a comparable range to those of planned residential areas. Korail Slum presents the most severe conditions across every dimension assessed, with a peak STCI of 7, PMV values predominantly in the "hot" range, a TRI of approximately 4, and resident-reported health complaints spanning respiratory illness, dermatological conditions, and heat exhaustion among children and the elderly. The difference between a TRI of 13 in Dhanmondi and 4 in Korail does not reflect a difference in climate but a difference in infrastructure, income, and access to resources.

Three findings from this study show particular significance for urban planning and policy in Dhaka. First, ventilation restriction is a more decisive driver of thermal discomfort in dense tropical neighbourhoods than ambient temperature alone, and urban design interventions that restore natural airflow through street setbacks, building height regulations, and canyon geometry standards can deliver meaningful thermal benefits without requiring energy consumption. Second, green spaces and water bodies provide measurable and cost-effective thermal buffering even within a dense megacity context, and their continued loss in Dhaka has direct consequences for the thermal comfort of urban residents across all income groups. Third, the thermal resilience gap between formal and informal residential typologies in Dhaka is sufficiently large to constitute a public health concern and cannot be adequately addressed through individual adaptation strategies alone.

RECOMMENDATIONS

The findings of this study support a set of targeted recommendations across different levels of intervention. At the household level, low-cost passive cooling interventions represent the most immediately accessible pathway for improving thermal conditions in informal settlements such as Korail. Solar-reflective cool roof coatings have been shown to reduce roof surface temperatures by 12 to 31°C and indoor air temperatures by 2 to 4°C in comparable South Asian informal settlement contexts (RMI, 2024), and a pilot programme in Dhaka applying reflective paint to rooftops recorded indoor temperature reductions of more than 7°C (PreventionWeb, 2021). Radiant foil insulation and reflective blanket interventions trialled in informal settlements in Bihar, India reduced indoor temperatures by up to 1.24°C using low-cost, rapidly deployable materials (Ang et al., 2026).These interventions are particularly relevant for Korail, where tin-roofed structures generate severe indoor heat loads and where residents lack the financial capacity for mechanical cooling.

At the neighbourhood level, the finding that ventilation rather than ambient temperature is the decisive control on thermal discomfort in dense areas points to urban form itself as a primary target for intervention. In areas such as Chawkbazar, where narrow lanes and continuous building frontages suppress airflow, building regulations should incorporate minimum street setbacks, controls on building height-to-width ratios, and the preservation of ventilation corridors to restore natural air movement at street level. These morphological measures should be paired with mandatory green buffer requirements, incentives for rooftop greening, street-level tree planting, and the creation of shaded communal spaces, all of which simultaneously improve airflow and provide radiant shading. Bangladesh's National Adaptation Plan (2022) identifies urban heat as an emerging policy priority, and the 2024 Heatwave Warning Portal launched by RIMES and Save the Children provides a practical tool for communicating localised heat risk to communities (Urbanet, 2025). These national instruments provide a policy foundation that local urban planning in Dhaka should actively build on. Community cooling hubs, which are publicly accessible, shaded, and ventilated spaces designed to provide relief during peak heat hours, represent a practical and low-cost intervention for the most vulnerable residents, including the elderly and children identified in this study as bearing the heaviest burden of heat-related health impacts.

At the city planning level, the findings of this study reinforce the need for Dhaka's urban development frameworks to treat thermal resilience as a spatial equity issue. Dhaka, Khulna, Chattogram, and Gazipur have been identified as having the highest proportions of residents in informal settlements with medium to high climate vulnerability (Urbanet, 2025), and addressing this vulnerability requires integrating heat resilience criteria into land use planning, building approval processes, and slum upgrading programmes. Participatory planning processes that incorporate the lived experiences and priorities of informal settlement residents are essential to ensure that interventions are both contextually appropriate and effectively implemented. Recent initiatives such as the Dhaka Thrive Project, launched in 2024 through a collaboration between the Open Mapping Hub Asia-Pacific and World Vision Bangladesh, demonstrate the value of community-engaged data generation in building the geospatial evidence base needed to support such planning (HOTOSM, 2025).

FUTURE RESEARCH

This study focused on three neighborhoods during a single seasonal window, and its findings should be interpreted within these boundaries. Future research would benefit from longitudinal designs tracking changes in thermal conditions and resilience capacity over time, particularly in response to infrastructure upgrades or climate adaptation programs. The gendered dimensions of heat vulnerability in informal settlements, where women's household responsibilities expose them to prolonged indoor heat stress, remain underexplored and warrant dedicated investigation. Simultaneous multi-season measurements across a larger sample of Dhaka's residential typologies would strengthen the generalisability of the findings, and interdisciplinary research integrating urban planning, public health, and climate science would provide a stronger evidence base for the policy recommendations advanced here.

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