Synopsis of Thesis entitled:

Redefining Urban Planning Process through Human Biometeorological approach for Sustainable Urban Development

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Statement of Problem

Urban areas in India and South Asia are going to face hotter summers, greater energy demand, lowering of ground water along with increasing population pressure. Risk of drought, flood, sea-level rise, tropical cyclone and subsidence will make the city more vulnerable to loss (IPCC, 2022). By 2050, 20 largest coastal cities will face flood losses. Of these, 9 in Asia, including Kolkata, is vulnerable to seal level rise, flooding and subsidence. Kolkata is also expected to see a rise in heat-related mortality. Impact of heatwaves at scenarios 1.5^0 C and 2^0C, show that Kolkata will experience heatwaves similar to 2015, every year. Kolkata has been mentioned as one of the megacities to be vulnerable to extreme climate change (IPCC,2022). In Kolkata, heatwaves and heat-related mortality similar to 2015 will be more recurrent, every year. Kolkata is also vulnerable to drought-risk.

The need for comfort in outdoor and indoor conditions have been recognised in the Delhi Master Plan for the year 2041. Until this report, there was a general lack of studies on microclimate, outdoor thermal comfort at pedestrian level and urban heat stress in respect to urban planning process such as in, Master Plans, City Development Plans, Block development plans, Climate action plans. In most reports, however, the need for open areas and Green-blue spaces have been stressed upon. Factors which act as constraints to adaptation can be due to economic and socio-cultural conditions, quality of governance, planning and policy making, lack of information, presence of physical barriers and biophysical and meteorologic conditions of the region. The same barriers can become limits that will not allow adaptive actions to secure the needs of the system. (Klein *et al.*, 2015).Human Biometeorology explains the relation between atmospheric conditions and importance in controlling the maintenance of health or spread of diseases. A single environmental parameter cannot account for conditions for thermal comfort. (Lin 2011). Microclimate parameters, surface cover characteristics and thermal perception of the people together contribute to objective and subjective assessment of the outdoor thermal conditions.

Study area

The study area is within the limits of Kolkata Municipal Area. The north-south arterial roads were selected as ventilation pathways and the cross sections of the roads with east-west arterial roads gives junctions or cross roads which are mostly the centre points for data collection. For some stations, the data points were taken close to natural surface cover to study the impact of natural surface. Few stations such as Dhapa, Bantola, Garden Reach are located on the eastern and western extreme ends of the east-west arterial limit in order to include the share of natural surface which is otherwise mostly absent in the city centre. 50 stations were selected from the intersections of the north-south and east west arterial roads of the city area. Based on the data collection of these stations, neutral mPET, acceptable range of mPET, and comfortable locations of the city were calculated. Stations have also been identified as dynamic potential or thermal load based on share of surface cover. For further analysis of the importance of dynamic potential and importance of water bodies, 10 stations were selected based on dynamic potential and thermal load.

Research Gap

- Insufficient studies on seasonal change in thermal comfort perception seasonally
- Insufficient studies on seasonal change in significance of surface cover on outdoor thermal comfort
- Insufficient studies on conditions for comfort based on comfort location
- Insufficient studies showingclassification of comfortable location
- Insufficient studies on use of Plan Area Fraction to describe study area
- Insufficient studies on planning at grassroot level with the involvement of people in climate-inclusive planning involves subjective assessment at microclimate scale.
- In SWOT analysis of City Development Plans in India, there is no mention of comfort and stress conditions of the city.

Research Questions

1. Is Kolkata Comfortable?
2. How does Outdoor Thermal Comfort change over space and seasons?
3. What are the causes for variations in Thermal Comfort?
4. How can people participate in Climate-Inclusive Urban Planning process?

Aim

To analyse and understand outdoor thermal comfort in different urban surface covers and microclimatic conditions

Objective of the study

1. To Study the influence of different surface covers such as water body, green area and open area on outdoor thermal comfort.
2. To Classify comfort locations of city based on microclimatic and thermal perception study.
3. To Calculate the Neutral mPET and acceptable range of comfort conditions in Kolkata
4. To Recommend the overall conditions of comfort for sustainable urban planning.

Research Hypothesis

Natural Landscape with Water Bodies, Vegetation and Open areas have a positive influence on Outdoor Thermal Comfort.

Scope of Work

- Assessment of Outdoor Thermal Comfort
- Importance of water bodies in outdoor thermal discomfort
- Importance of Vegetation surface cover on outdoor thermal comfort.
- Importance of Open surface cover on outdoor thermal comfort.
- Subjective assessment- Perception studies on outdoor thermal comfort.
- Role of Thermal Load and Dynamic Potential
- Application of Outdoor Thermal Comfort in future Climate-oriented City Development Plans.

The calculation of comfort location for the city includes statistical techniques such as factor analysis and raster calculation. Both subjective and objective assessment is essential in calculation of proposed Neutral mPET and proposed acceptable range of mPET. Stations with conditions closest to neutral and comfortable conditions are identified. With the help of this information, the proposed surface cover for every 100m diameter has been recommended.

In this study, the importance of thermal perception of the people has been stressed upon. Without this information, the comfort location, neutral conditions and acceptable conditions cannot be calculated. People's survey for thermal perception will also ensure grass-root participation in micro-climate inclusive urban planning process.

Research Methodology

For first and second objectives, primary data was collected through instruments and questionnaire schedule. The secondary data was collected from Google Earth and satellite images that helped analyse the surface cover of the study area. Plan Area Fraction methodology was applied to identify the thermal load and dynamic potential of each station.

For the third objective the Outdoor thermal comfort values for each station was calculated using the Outdoor Thermal Index. Statistical techniques were used to calculate the Neutral mPET, acceptable range of comfort and the comfortable locations of the city.

Recommendations were based on the the overall conditions of comfort and the missing link in the climate inclusive-urban planning process that is showcased in the literature review.

Research Outcome

i. Microclimate-The microclimate distribution in four seasons of the year 2019, show that areas that have high values of Air Temperature (Ta), correspond with areas having high values of Globe Temperature (Tg) and Mean Radiant Temperature (Tmrt). Areas with high recorded windspeed at 1m level has low Ta, Tg, Tmrt. Summer has the highest temperatures compared to the other seasons. Wind speed is lowest in winter. Air temperature and mean radiant temperature is most significant parameter affecting mPET causing discomfort Ta or Tmrt increases. Wind speed significantly increases comfort in Spring, Autumn, Winter by reducing Ta and Tmrt. In summer, Ta is the most important parameter, built surface, water, vegetation contributes to discomfort during daytime. Clo value significantly increases mPET values in winter during daytime.

ii. Surface cover-Unsupervised classification show that 61% of KMC area is Built and Impermeable surface. The remaining 39% has natural landscape including open areas, water bodies and vegetation. NDBI, NDVI, NDWIshow that the central part of the city and along the north-south arterial road way, there is dense built surface and the same area has low vegetation and low water bodies; the same central and northern part of the city have high values of Ta and high values of Tmrt. Based on Plan Aera Fraction, areas with thermal load

will have higher share of built surface and impermeable surface. Areas with high dynamic potential will have high share of natural surface cover such as water surface, vegetation surface and open surface. The north and central part of KMC area that has high Ta, Tmrt, Tg, high built surface, low vegetation cover and low water bodies, also have high PET and high mPET values. Accordance with mPET values, Spring conditions are mostly comfortable, summer conditions are uncomfortable to very uncomfortable, Autumn is comfortable and Winter is comfortable to slight uncomfortable. Higher share of Built surface reduces comfort in spring, autumn, winter. Higher share of Water surface gives comfort by reducing Ta, Tmrt in all seasons except in summer. In summer, water surface reduces comfort. Higher share of Vegetation surface increases Ta in Summer.Natural surface cover such as open areas and vegetation surface did not show significant correlation with mPET conditions. Water surface has shown to have significant positive correlation with Ta and Tmrt in Correlation analysis

iii. Seasonal variation in Outdoor thermal comfort conditions- In spring, Ta, Tmrt significantly reduces comfort; in spring, higher share of built surface increases Tmrt; and Va increases comfort in spring. In summer, Tmrt reduces comfort higher share of vegetation surface increases Ta in summer but higher share of water surface increases comfort by reducing Ta and Tmrt. In Autumn, Ta, Tmrt reduces comfort. Built surface and Impermeable surface increases Ta, Tmrt; in autumn, higher share of Water surface reduces Ta, but Va increases comfort. In winter higher share of built surface increases Ta and Tmrt, higher share of impermeable surface reduces Ta and Tmrt. higher share of water reduces Ta. In winter, Ta, Ts, Tmrt reduces comfort, Va and RH increases comfort.

iv. Inference from Hypothesis testing and analysis of role of dynamic potential

It is concluded that natural surface cover as a combination of open areas, vegetation surface and water bodies taken together will have influence on thermal comfort conditions. Ther is significant difference in Outdoor Thermal comfort conditions due to difference in share of Dynamic Potential. Waterbodies show significant impact on mPET values. The stations with more than 60% built surface have higher mPET values. Higher mPET values reflect low levels of comfort. Share of water fraction is important for outdoor thermal comfort. The water breeze from water bodies improves outdoor comfort conditions.

v. Thermal perception study- Summer has the most unacceptable conditions with minimum votes on comfort, satisfaction and tolerance of outdoor thermal conditions. There is empirical note of adaption with changes in clothing patterns in winter season. at 28.16 ^{o}C people feel neutral, comfortable and prefer neither warmer nor cooler conditions. The

proposed acceptable range is 23^{o} C to 29^{o} C. Neutral range is within the acceptable range of temperature. There should be a combination of natural surface and built surface in surface cover characteristics for a place to have comfortable outdoor thermal conditions. People's perception of weather conditions is extremely important to calculate the neutral and acceptable outdoor thermal conditions. Without the Thermal Perception Study, such calculations cannot be performed. The mean thermal sensation vote implies the need for people's participation in climate inclusive planning process.