CHAPTER 8

DISCUSSION AND CONCLUSIONS

This chapter discusses the findings mentioned in chapters 4 to 7, and their implications for achieving thermally comfortable cities in hot climates, exemplified by Chennai city. The first section deals with the impact of urbanization on historic climate and thermal comfort. The second and third section includes the discussion of the intensity of the UHI and the influence of land use / land cover. In the fourth section, the influence of urban built form at the micro-level is discussed. The fifth section contains the conclusions along with the recommendations for improving the outdoor thermal comfort. Also, suggestions for further research are provided in the last section.

8.1 IMPACT OF URBANIZATION ON HISTORIC CLIMATE

Urbanization, associated with the rapid transformation of the natural land cover to hard impervious surfaces, accelerates the thermal discomfort of a region. The study analyzed the 20 year air temperature trends in the CMA, and attempted to correlate the changes in climatic and comfort trends to urbanization. It was found that strong and statistically significant trends exist between thermal comfort and urbanization.

The changes in thermal comfort appear to be strong during the day in the “recent climate”, attributed to urbanization. The daytime thermal comfort trends at both the urban and rural stations, revealed a significant increasing trend in the discomfort level, with nearly 100% of the people
feeling either uncomfortably hot or distressed. The night time thermal comfort analysis revealed that the nights were comfortable in the CMA, but the urban changes in the recent years, have shown a significant increasing trend towards discomfort.

The study found a statistically significant increasing trend in the discomfort experienced during daytime, with fairly comfortable nights, and highlights the need to improve the daytime comfort conditions in the CMA, through a planned growth of urban areas.

8.2 INTENSITY OF THE UHI EVIDENT FROM URBAN-RURAL DIFFERENCES

The significant existence of an urban heat island is evident from the urban-rural temperature differences in the CMA, during both day and night. During the night, all the urban and suburban locations within the CMA were warmer than the rural locations, whereas during the day some locations were warmer and others cooler.

The study found the maximum nocturnalCLUHI during the calm, clear, winter periods in the CMA. The maximum daytime intensity was experienced by the SUHI when compared to the CLUHI. The urban rural differences revealed a significant cool island during the day, and the maximum cool island intensity was experienced during summer.

The study found a significant correlation between urban-rural differences and the urban built-up density, urban geometry, vegetation etc.; this indicates the significance of the development regulations that define the urban built form, in designing comfortable urban environments.
8.3 INFLUENCE OF THE LAND USE / LAND COVER ON THE UHI PROFILE

The urban growth pattern of the CMA was found to have a significant impact on the surface temperatures, and the sprawl of the hotspots corresponded to the degree of urban built-up in the last two decades. Hard surfaces such as the buildings, roads, parking lots etc., increased the surface temperatures significantly, while soft surfaces such as the green cover, and dense vegetated areas reduced the daytime surface temperatures.

The UHI profile in the CMA revealed a significant correlation between the thermal distribution pattern and the land use / land cover types. During the daytime, the study found the variation in surface temperatures from industrial, commercial, transportation nodes, residential and open spaces in a descending order. The industrial areas located within the city limits exhibited higher surface temperatures when compared to industries located in the periphery of the CMA, attributed to the dense urban built-up. The residential areas in the CMA were comparatively more comfortable than the commercial areas, attributed to the presence of vegetation within the residential plots of the detached houses. The open spaces experienced the least surface temperatures, attributed to the moisture availability of the natural ground cover.

However, at night time, the air temperatures varied from commercial, residential, transportation nodes, industrial and open spaces in a descending order. The street geometry in the urban areas was found to have a significant correlation with the nocturnal air temperatures in the CMA. The narrow urban canyons of the commercial and residential areas in the CMA experienced higher ambient air temperatures during the nights, compared to the shallow canyons of the transportation nodes and the industrial areas.
The land use /land cover types were found to influence the thermal distribution pattern in the CMA; this highlights the need to improve the comfort conditions by appropriate planning.

8.4 INFLUENCE OF URBAN BUILT FORM ON THERMAL COMFORT AT THE MICRO-LEVEL

The air temperature and the thermal comfort trends in the residential neighbourhoods of the CMA revealed that the nights were comfortable during both summer and winter. During the daytime in summer, all the residential sites were uncomfortably hot with the PET values well above the upper limit of the comfort zone, while in winter some sites were hotter and others cooler. As the daytime comfort was found to have a significant correlation with the street geometry and percentage of urban built-up, the study indicates the significance of improving the daytime comfort in residential areas, by stipulating appropriate urban built-form in the development regulations of the CMA.

8.4.1 Effect of the Percentage of Built-up Area and the H/W Ratio

The thermal comfort analysis of the residential areas during summer revealed, that the daytime comfort conditions can be improved significantly with an increase in the percentage of the built-up area and the H/W ratio. However, the increased aspect ratio and the urban built-up reduced the night time comfort conditions, and influences the energy demand for cooling during the nights. The H/W ratio influences the comfort conditions significantly when compared to the percentage of urban built-up area. Moreover, the study reveals that with increase in the H/W ratio, the daytime comfort increases and the night time comfort decreases. This indicates the need for arriving an optimum H/W ratio and percentage of built-up area in the CMA, in improving the outdoor thermal comfort. The study
also indicates that the medium rise and medium density with an aspect ratio of approximately 0.6 to 0.7 and built-up area of 30% (plot coverage) is found to provide optimum outdoor thermal comfort in the CMA. As the growth of the urban built form in the CMA is shifting from low rise to medium and high rise structures, it is possible to improve the outdoor comfort conditions by regulating the urban geometry.

8.5 CONCLUSION

The climate aspects in planning regulations are generally ignored due to the lack of scientific assessments. This study provides the scientific knowledge on the link between thermal comfort and urban built form, and aids in evolving climate-responsive design guidelines.

Rapid urbanization in the Chennai Metropolitan Area, in terms of the increase in the population growth rate, housing demand, residential land use zones and the transportation demand, changes the urban built form, and leads to significant alterations in the climate variables. This affects the environmental quality and standard of life. The changing urban climate receives little attention from architects, planners, environmentalists and decision-makers, and has been ignored in the preparation of the second master plan for the CMA.

The Chennai Metropolitan Development Authority (CMDA) governs the developments in the CMA through the “Second Master Plan for the CMA, 2026”. The “Development Regulations” (DR) for the CMA, specifies the zoning of different land uses and determines the urban built form in the CMA. According to the second master plan of the CMA, the proposed increase in the residential and industrial land use categories is 18.66% and 3.65% respectively, and the proposal is based on the demand in the housing sector, and to improve the economy of the city through developments in the
industrial sector. The observations of the present study can be used as a scientific base in defining the urban planning guidelines for the above developments in the CMA. Also, the UHI profile and thermal mapping of the CMA from the present study can be used as the primary data for climate studies by the Regional Meteorological Centre, Chennai.

This study is the first of its kind in investigating the relation between urbanization, urban built form, the temperature distribution pattern and comfort conditions in the Chennai Metropolitan Area. The results of the study highlight the significance of interdisciplinary research in the field of urban climate, where architects, urban planners, decision-makers, climatologists, geographers, and environmentalists come together for a holistic approach in tackling the urban problems.

8.5.1 Recommendations for a Thermally Comfortable City in a Hot Humid Climate

Based on the results of the study in the Chennai Metropolitan Area, a low-rise city, representing a hot humid climate, recommendations pertaining to some of the aspects of land use and development guidelines for built form have been given from the macro to the micro level, in order to improve the outdoor thermal comfort.

1. The study revealed that the presence of vegetation in the medium-rise urban built form improved the daytime thermal comfort conditions significantly. Vegetation can improve thermal comfort by providing shade to the pedestrians significantly; however, care has to be taken to see that it does not reduce the sky view factor, which would otherwise block the re-emission of the long wave radiation during the nights. The study also indicated that the areas with dense vegetation
remained warmer during the nights in summer, when compared to the rural areas, attributed to the reduced sky view factor.

2. The industrial areas situated away from the city core have been found to reduce the surface temperatures during the daytime. The industries located away from the dense urban built-up with vegetation shading, can reduce the surface temperatures. This would also assist in reducing the pollution from industries, which would otherwise increase the warming of the surrounding residential neighbourhood.

3. The study also suggests that medium-rise medium density and high-rise low density are desirable in improving the thermal comfort conditions, when compared to the low-rise high density, low-rise low density, and high-rise high density developments. The medium-rise and medium density developments increase the thermal comfort conditions by providing optimum shading during the daytime and an optimum sky view factor during the night. The high-rise low density developments provide sufficient shading from buildings during the daytime, and do not reduce the sky view factor.

Based on the micro-level study in the residential neighbourhoods of the CMA, the following recommendations have been given:

4. The desirable percentage of built up ratio (plot coverage) in residential neighborhoods that could improve the thermal comfort conditions is 25% to 30%. The current development guideline of the CMA allows plot coverage of 70% to 75% for residential land use. An increase in the plot coverage results
in low-rise urban built form, and reduces the shade from buildings.

5. The optimum height-to-width ratio that can improve the thermal comfort conditions in residential neighbourhoods is 0.6 to 0.7. Owing to the low-rise profile of the CMA, a majority of the developments have an aspect ratio of less than or equal to 0.5.

8.6 FURTHER RESEARCH

The present study includes an analysis of the urban built form only in terms of the percentage of built-up area and the H/W ratio; investigations of other parameters at the building level in terms of setbacks, street width, building heights, plot coverage, floor space index, vegetation shading etc., can aid in arriving at specific planning guidelines. Street orientation has not been included in the present study and further studies can include a detailed analysis of different street orientations in residential neighbourhoods.

The urban built up has a significant impact on thermal comfort trends and it is necessary to take up further research, specific to the simulation of different street geometries in improving pedestrian comfort at the street level. The relationship between the urban built form and the aerodynamic effects can also aid in arriving at optimum design solutions with improved outdoor thermal comfort.

In future studies, it would be interesting to investigate the impact of building materials (albedo) on urban temperatures, to identify suitable materials for construction. Also, the implications of the urban built form on thermal comfort and energy use in buildings needs to be studied in detail, and can prove to be effective in reducing the energy demand.
The present study finds that green cover reduces surface temperatures significantly. Therefore, further investigation on landscaping in particular, the size and location of the green cover at the neighbourhood level can help in mitigating the urban heat island effect.