8.1 Introduction

Works that were briefly covered due to various limitations of time, resources and nonavailability of reliable data, need to be addressed with fresh and dedicated initiatives in the future. This thesis, more specifically, dwelt on redefining and re-examining Sustainable Architecture within the Urban Canopy Layer at Neighbourhood Scale for Warm-Humid Climate of Tropical areas. The thesis focussed on the importance of Urban Geometry modifications for achieving desired level of thermal comfort in urban residential streets. The aspects of Urban Built Form which could play an important role in the process sustainable development were suggested and expressed in its quantifiable terms. The proposed sustainable measures were also validated and analysed by primary data sources from the case study areas. However, while many new ideas were presented, some areas are yet to be covered, which will create further avenues to the future researcher. All these avenues are to be explored by future researchers. It is hoped that the present exercise would make them available the appropriate methodology for such studies and also be helpful to formulate their problem, possibilities and guidance for development, deployment and dissemination of knowledge to the future generation.

8.2 Parallel challenges

A complex, diverse and multi-dimensional subject like sustainable architecture has many shades and interpretations to it that can hardly be completely contained. The followingspecific areas are being envisaged as some parallel challenges that need to be integrated with the base-line analysis presented in this thesis, since these could not be dealt in details for thereasons cited above. These are:

8.2.1 Shadow Umbrella and Shading Potential of Built Form Types

Solar exposure of buildings has been a primary concern of many planners in climates with cold winters to allow for passive solar heating. It has sometimes been investigated in isolation from other aspects of urban climatology because it only requires knowledge of geometry. The so-called solar envelope also has been the subject of numerous studies by architects, with the aim of ensuring appropriate solar exposure of buildings (Knowles, 1981) or of open space
(Yezioro et al, 2006). Littlefair (1996) surveyed a variety of graphic methods to establish solar exposure, though a substantial number of computer-aided design (CAD) programmes now perform the task automatically, given a geographical location and time of year. In tropical climates, exposure to solar radiation is generally undesirable. Planners in such locations are therefore concerned with creating urban geometries that maximize shade. Narrow streets and a dense urban matrix sometimes are often recommended for desert locations, although they restrict ventilation; but designs for warm-humid locations must maximize airflow while providing shade in public spaces too (Emmanuel, 1993), so tropical cities may be less dense. The solar envelope is a concept which tries to bring in solar radiation, but shadow umbrella is a concept developed by Emmanuel which tries to restrict the incident solar radiation to minimum in tropical areas, where shading is more important. He has also developed techniques to create shadow umbrella for residential and commercial areas. The author has also suggested the incorporation of these concepts for modifying the urban geometry of the built forms to achieve desirable thermal comfort in warm-humid tropical areas. The figures below shows some initiatives by the author, which would be dealt in further research works.

8.2.2 Urban Density and its impact on Microclimatic Aspects

The density of a city is generally determined by economic considerations, reflected in the price and availability of land. It is also influenced, and in turn has an effect upon, the overall form of the town. Architects and planners typically measure urban density by means of the number of dwellings per unit area of the site (Knowles, 2003) or by the ratio of the total built floor area to the area of the site, an index more suited to non-residential development. Urban climatologists, on the other hand, refer to density by different measures: the plan area density, which is the ratio of the building’s footprint to the total area of the site; or the frontal area density, which is the ratio of its (windward) elevation to the site area (Grimmond and Oke, 1999). Density has a direct effect on the exposure of urban surfaces to direct solar radiation. Such exposure may be considered beneficial in cold climates or detrimental in hot conditions, where shade is considered desirable. However, whereas the latter objective is fairly easy to achieve – for example, by the addition of specialized shading elements such as pergolas and blinds – the former imposes stringent limitations on the overall built volume that can be constructed in a given site, as well as upon its geometry. So research work which would focus on using density as a positive aspect in modifying the urban built geometry for achieving the desired level of thermal comfort would be an important contribution in this field of research.
8.2.3 Built Form type, Vegetation and its impact on Microclimatic Aspects

It is a known fact that the effect of trees and other plants in the urban area can modify the urban temperature, the urban wind conditions and the solar exposure of buildings and of pedestrians in the streets, in public parks and other open spaces. The urban “green” areas, in public open spaces like parks as well as in private planted areas around buildings, can have a marked effect on the climatic conditions to which an individual building is exposed and on the urban climate at large. The type and details of the plants around a building can affect its exposure to the sun and the wind, its indoor comfort conditions and energy use. Leaves of plants absorb most of the solar radiation that strikes them but transform a very small part of the radiant energy into chemical energy by photosynthesis. Most of the absorbed solar radiation is transformed into latent heat by diffusion and evaporation of water from the leaves (a process known as evapotranspiration). The evaporation significantly cools the leaves and the air in contact with them and at the same time increases the humidity of the air. The importance and desirability of this factor depends on the local humidity and temperature conditions. As a result of the evapotranspiration process, the air near the ground in green areas is cooler than the air in built-up areas covered by asphalt or concrete or over land bare of plants. Furthermore, as a result of their lower temperature, the longwave radiation emitted from leaves is lower than that emitted from the surrounding walls and other hard surfaces. The effect of vegetation on wind conditions depends to a great extent on the type of the plants and on the details of the planting pattern. Grassy areas pose the least friction (resistance) to the wind and allow for the best ventilation conditions. Bushes impede the wind near the ground surface and above their foliage. The type and density of trees, in particular, have a noticeable impact on the wind speed near the ground. A densely planted row of trees may serve as a windbreak. A grove of trees lowers significantly the wind speed within it and downwind from the grove. Blockage of the wind by plants is desirable in cold regions and seasons, but is undesirable in hot climates and seasons, especially in hot, humid regions.

8.2.4 Urban Albedo and its impact on the Microclimatic Aspects.

The urban energy balance and temperature depends on the amount of solar radiation absorbed within the urban fabric. This, in turn, depends on the average urban albedo. Albedo is defined (Taha et al. 1988) as the ratio of reflected-to-incident radiation at a particular surface over the whole solar radiation spectrum. It depends mainly on the color of the surface. Dark colors have low albedo while a white color has a very high albedo. The average urban albedo depends on the color of the roofs, walls and roads, parking areas and so forth. The land fraction covered by vegetation affects the urban temperature but this effect is not due to the albedo of the plants, as the solar absorptivity of leaves is rather high, but to the evaporation from the leaves. The urban albedo is the main factor determining the amount of solar radiation absorbed in the urban area. The color of the built urban elements,
especially the building’s roofs, is controllable by urban design. Because the roofs comprise a large fraction of the urban area in a densely built town, the radiation balance in such cases can be controlled and thus may have a pronounced effect on urban air temperature.

8.3 Concluding Remarks:

The study of urban built forms and its microclimatic aspects is an important area of research where researcher from various disciplines like urban climatology, architecture, urban design, urban planning, geography, etc can contribute and their findings can be of great use in the process of sustainable development. The scope of work in this thesis was limited to outdoor thermal comfort in street canyons with fixed canyon ratio, but there are also various other aspects mentioned above, which could be integrated with these findings to substantiate the research outcomes.

A number of interesting questions arise in the course of this study:

1. The numerical results need to be validated with more field measurements and the mean radiant temperature which mostly effects the outdoor thermal comfort need to be measured at site by using instruments like globe thermometer, etc.
2. The impact of urban geometry modifications on the nocturnal heat island effect can be studied for warm humid climates. In ENVI-met the heat storage capacity of the building materials is not considered, so this study could not analyse the nocturnal heat island effect.
3. The study of human comfort is very complex which combines various aspects like physical, physiological and psychological dimensions. Social survey is needed for better understanding of the human comfort and the methods and approaches may vary from case to case, but an universal approach need to be developed for studying the human thermal comfort.
4. The study also raises the concern that for making any intervention in urban areas, the aspects both at architectural level and urban building level need to be kept in mind. The impact of any architectural intervention is generally seen in outdoor environments, so keeping in mind the outdoor spaces, its use, activities and thermal comfort the study and research of building geometry at urban scale is of utmost importance.