# EFFECTS OF URBAN FORM ON MICROCLIMATE AND THERMAL COMFORT IN THE CITY OF HYDERABAD

PLANNING PROJECT SUBMITTED IN PARTIAL FULFILMENT FOR THE AWARD OF DEGREE OF B.TECH PLANNING


**BY**

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## Certificate

I/We certify that the planning thesis entitled **"EFFECTS OF URBAN FORM ON MICROCLIMATE AND THERMAL COMFORT IN THE CITY OF HYDERABAD"** submitted by **R.SANJANA SINGH** bearing **Roll no: 11011BA023** on this 18th June 2015 in partial fulfilment of the requirements for the award of degree of **BACHELOR OF TECHNOLOGY (PLANNING)** of this university, is a bonafide work to the best of my/ our knowledge and may be placed before the examination board for their consideration.

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# **DECLARATION**

I hereby declare that the thesis entitled ***"*EFFECTS OF URBAN FORM ON MICROCLIMATE AND THERMAL COMFORT IN THE CITY OF HYDERABAD*"*** which I am submitting for the degree of bachelors in Urban and Regional planning of the Jawaharlal Nehru Architecture and Fine Arts University (formerly JNTU), Hyderabad, is the result of the work carried out by me in the School of Planning and Architecture. I worked under the guidance of Mrs. Praveena Reddy, faculty - Department of Urban & Regional Planning. I further declare that the work is original and has not been previously submitted for any degree, diploma in this or any other university.


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**DEDICATED TO**

*Maa, Paa, Sonu & Frosty*

# ABSTRACT

Urban climate, now a days has become a serious issue when concerning the urban environment.

Due to change in extreme weather conditions, the indoor and outdoor comfort zone has been creating an issue of concern.

The microclimate of a site area is largely influenced by many factors such as, urban morphology and density, the properties of urban surfaces and also vegetation cover.

As streets form a considerable part of urban spaces, the street geometry, orientation influence the amount of solar radiation received and the amount of wind flow in the street canyons.

Therefore, this research conducted proves that the street's geometry and orientation form key factors in providing a pleasant micro climate for pedestrians at street level.

## Contents

LIST OF FIGURES



LIST OF TABLES



LIST OF MAPS

Abbreviations

**AMT** – Annual Mean Temperature

**AMR**- Annual Mean Radiant

**APSDPS** – Andhra Pradesh State Disaster Planning Society

**AWS**- Automatic Weather Station

**H Avg** – Humidity Average

**PET** – Physiological Equivalent Temperature

**PMV** – Predicted Mean Vote

**RH** – Relative Humidity

**SET** – Standard Equivalent Temperature

**T Avg** – Temperature Average

**Tmrt** – The Mean Radiant Temperature

**UCL** – Urban Cool Island Effect

**UHI** – Urban Heat Island

**UNESCO** – United Nations Educational, Scientific and Cultural Organization

**Wd Avg** – Wind Direction Average

**Ws Avg** – Wind Speed Average

# 1. Introduction

Man-made environments can create microclimates of their own, deviating from the macro climate of the region to a degree depending on the extent of man's intervention. Such intervention with the natural environment is greatest in large towns or cities, thus it is justifiable to speak of an "urban climate".

Cites are responsive to urban climate instability and inconstancy and able to change their own climates. Urban climate is a critical factor which affects regional and global climates and consequently urban liveability. The microclimate of urban open spaces is influenced by several parameters such as the urban form and geometry, urban density, the vegetation, the water levels and the properties of surfaces.

As more than a quarter of the urban areas are usually covered by streets, designing urban streets plays an important role in creating the urban climate. The urban streets vary in geometry as defined by height/width ratio (H/W) and also the orientation that is defined by its long axis. These parameters directly influence the absorption and emission of solar radiation and also urban ventilation which have a significant impact on the temperature variations within the streets as well as the surrounding environment.

## 1.1 Background

The phenomenon of the rapid urbanization in cities has also become one of the important topics in urban planning and sustainable development. This is since the rapid urbanization often leads to negative environmental impacts, including modifications on the urban microclimate. Those particularly at risk include the elderly, low-income earners and residents in urban areas of high population densities with limited surrounding vegetation. Furthermore, the rapid urbanization with limited landscape negatively affects the human health due to the increased pollution (Harlan et al., 2006). This, in turn, has an impact on microclimate and thermal comfort for inhabitants.

A given urban density can result from independent design features, that affect urban microclimate in different ways such as fraction of urban land covered by buildings, distances between buildings, and average height of buildings (Givoni, 1998). These parameters affect the urban microclimate in terms of solar radiation, solar reflection, wind speed and wind direction, etc.

Urban microclimate and outdoor thermal comfort are generally given little importance in the urban design and planning processes (Eliasson, 2000; Johansson, 2006b). Moreover, few studies have dealt with the relationship between urban planning regulations and the local microclimate.

## 1.2 Aim

To assess the effect of urban forms on microclimate and thermal comfort.

## 1.3 Objectives

- To analyse the temperature trends in the city of Hyderabad.
- To determine two neighbourhood areas to conduct the study.
- To conduct a comparative analysis of the neighbourhood areas.
- To infer from the factors responsible for the temperature variations.
- To recommend the appropriate measures.

## 1.4 Scope & limitations:

The parameters of the urban microclimate are limited to the extent of vegetation cover, land use, street orientation, building heights and any landscaping elements. The study is only based on the data measurements recorded by AWS and not manually.

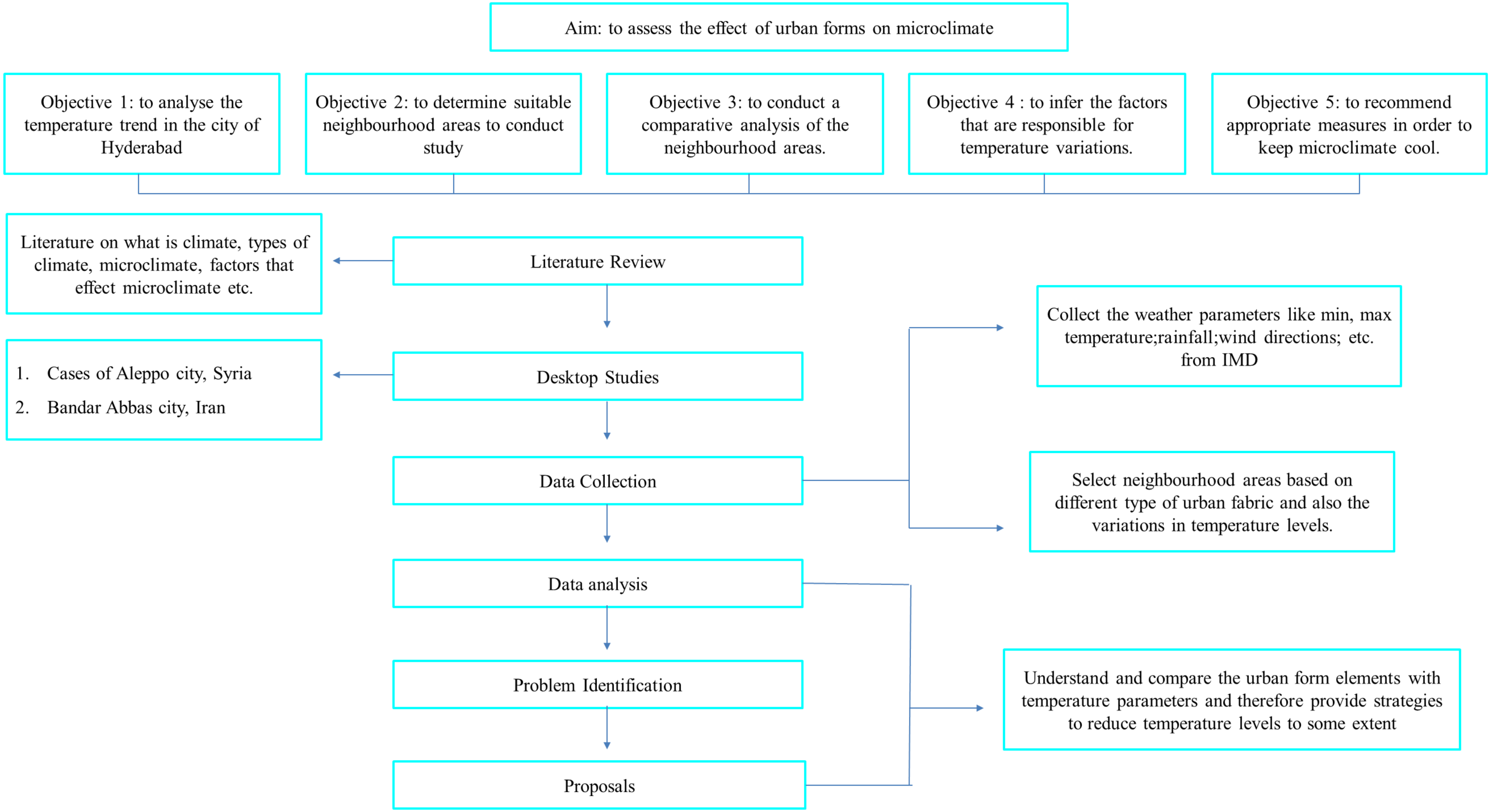
## 1.5 Need for the study:

The predictions of global emission models for Hyderabad clearly indicate the worsening of extreme rainfall events and heat waves in the future.

Urban form is a very important factor affecting the ecological impact of an urban system. The comparative analysis of different scenarios for transportation and buildings suggests that there are large gains from changing the way we design our cities.

Thus, there is a need to better understand the way in which small scale urban fabric structure contributes to heat island effects and how this information can be used to develop strategies for mitigating these effects on a local basis.

## 1.6 Methodology



# 2. Literature Review

2.1 Climate: is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.

### 2.1.1 Climate Classification:

The Köppen system recognizes five major climatic types:

A - Tropical Moist Climates: all months have average temperatures above 18° Celsius.

B - Dry Climates: with deficient precipitation during most of the year.

C - Moist Mid-latitude Climates with Mild Winters.

D - Moist Mid-Latitude Climates with Cold Winters.

E - Polar Climates: with extremely cold winters and summers.

**Climate of India**: India has 'Tropical Monsoon' type of climate.

Tropical Rain Forest

- west coastal plain and Sahyadris and in parts of Assam

Tropical savanna

- Most of the plateau of peninsula, Only central eastern Tamil Nadu falls under this tract

Tropical Semi-Arid Steppe Climate

- The rain-shadow belt, running southward from central Maharashtra to Tamil Nadu

Tropical and Sub-Tropical Steppe

- from Punjab to Kachchh between the Thar Desert to its west and the more humid climates of the Ganga Plain and the Peninsula to its east and south respectively

Tropical Desert

- The western part of Barmer, Jaisalmer and Bikaner districts of Rajasthan and most of the part of Kachchh form the sandy wastes of the Thar

Humid Sub-Tropical With Winter

- A large area to the south of the Himalayas, east of the tropical and sub-tropical steppe and north of the tropical savanna running in a long belt from Punjab to Assam with a south-westward extension into Rajasthan east of the Aravalli Range

Mountain Climate

- The Himalayan and Karakoram ranges

Drought in India

- The dry areas of Rajasthan and the adjoining part of Haryana and Gujarat

## 2.2 Microclimate:

Is a local atmospheric zone where the climate differs from the surrounding area. The term may refer to areas as small as a few square feet or as large as many square miles.

### 2.2.1 What factors effects microclimate?

- Topography – slope, orientation, exposure, elevation, hills or valleys, at or near the site.
- Ground surface – natural or man-made, its reflectance, permeability and the soil temperature, as these affect vegetation and this in turn affects the climate.
- Three dimensional objects – trees, or tree belts, fences, walls and buildings, as these may influence air movement, may cast a shadow and may sub divide the area into smaller units with distinguishable climatic features.

### 2.2.2 Microclimate in Urban Regions

The factors causing deviations of the urban climate from the regional macroclimate are the following:

a) Changed surface qualities (pavements and buildings) – increase absorbance of solar radiation, reduced evaporation.
b) Buildings – casting a shadow and acting as barriers to winds, but also channelling winds possibly with localised increase in velocity or by storing absorbed heat in their mass and slowly releasing it at night.
c) Energy seepage – though walls and ventilation of heated buildings; the output of refrigeration plants and air conditioning; heat output of internal combustion engines and electrical appliances; heat loss from industry; especially furnaces and large factories.
d) Atmospheric pollution – waste products of boilers and domestic and industrial chimneys, exhaust from motor cars; fumes and vapours, which both tend to reduce direct solar radiation but increase the diffuse radiation and provide a barrier to outgoing radiation.

### 2.2.3 Urban Heat Islands:

It is a metropolitan area which is significantly warmer than its surrounding rural areas. Many urban and suburban areas experience elevated temperatures compared to their outlying rural surroundings; this difference in temperature is what constitutes an Urban Heat Island.

*Image 1 Urban Heat Island Profile*

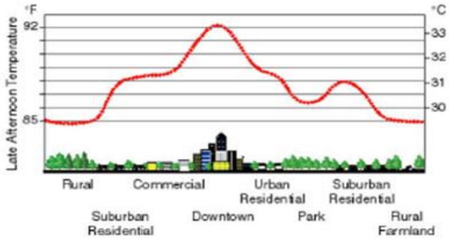
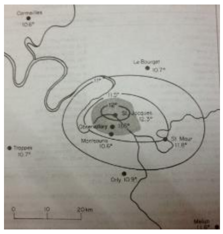



*Image 2 mean annual temperature of Paris and vicinity*

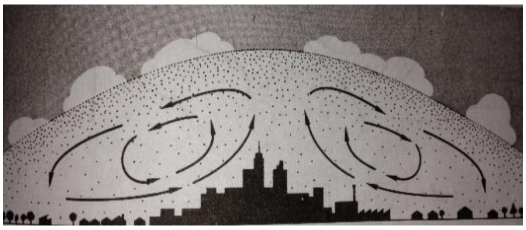


Temperatures are normally highest near the city centre and decline gradually towards the suburbs, beyond which there is a steep downward temperature gradient a t the rural margin.

### 2.2.4 Urban precipitation:

The distribution of rainfall over a town or city is very much influenced by topography However, other factors also play a major role, especially the heat islands.

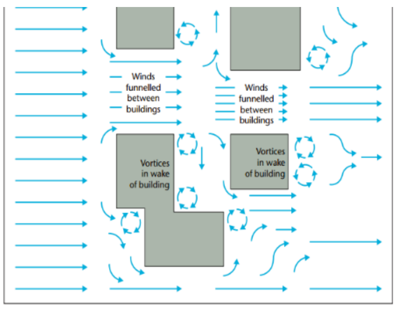
*Image 3 Schematic cross section of circulation generated by heat island in an urban aerosol*



A strong heat island generates its own circulation system. The tendency of air to rise above the heat island is a possible explanation of greater cloudiness over cities and may account in part for greater precipitation.

### 2.2.5 Urban winds:

*Image 4 Winds around offices in a city showing the vortices created by the buildings.*




Tall buildings can significantly disturb airflows over urban areas, and e even a building 100 metres or so high can deflect and slow down the faster upper-atmosphere winds. The net result is that urban areas, in general, are less windy than surrounding rural areas.

### 2.2.6 Impacts of Urban microclimate:

*Energy Consumption*- Elevated summertime temperatures in cities increase energy demand for cooling. This peak urban electric demand increases 1.5 to 2 percent for every 0.6°C increase in summertime temperature.

*Air Quality and Greenhouse Gases* –higher temperatures can increases energy demand, causes higher levels of air pollution and greenhouse gas emissions. Pollutants from most power plants include sulphur dioxide (SO2), nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and mercury (Hg). Further, fossil-fuel-powered plants emit greenhouse gases, particularly carbon dioxide ($CO_2$), which contribute to global climate change.

*Human Health and Comfort* – Increased daytime surface temperatures, reduced night-time cooling, and higher air pollution levels can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality. Sensitive populations, such as children, older adults, and those with existing health conditions, are at particular risk from these events.

*Water Quality* - Surface UHI degrade water quality, mainly by thermal pollution. Pavement and rooftop surfaces that reach temperatures 27 to 50°C higher than air temperatures transfer this excess heat to storm water. Water temperature affects all aspects of aquatic life, (especially the metabolism and reproduction) of many aquatic species.

One of the impact of the urban microclimates is on human health and comfort through rise in the temperature causing heat waves.

## 2.3 Urban form:

It can be defined as

- The "general pattern of building height and development intensity"
- The "structural elements" that define the City physically, such as natural features, transportation corridors, open space, public facilities, as well as activity centres and focal elements.

It can also be defined as the spatial configuration of fixed elements (Anderson et al., 1996).

### 2.3.1 Elements of urban form:

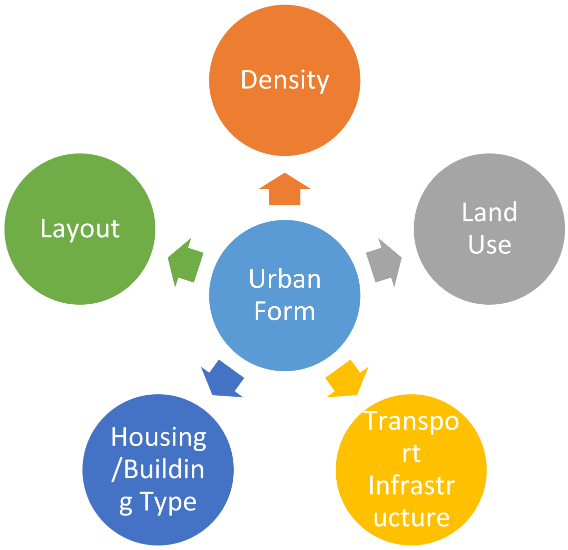



*Figure 1 elements of urban form*

## 2.4 Urban configuration:

From the thermal performance point of view, historically four different types of overall urban forms have developed for different climates.

2.4.1 Compact urban form: outcome of historical indigenous settlement is the compact city form. Compact city morphology responded positively to the stressful climate, as seen in human settlements in Mediterranean, the Middle East and Asia for more than 5000 years.

The compact city is concentrated and firmly unified with consolidation of land uses in a close and tight physical relationship with each other and the structures within themselves. The residential area, is arranged in a neat and orderly form in a smaller interval space between dwelling units.

The most stressful climate cities, especially those in hot dry zones have evolved as compact settlements in particular response to the environmental stress.

Advantages:

- Responds to and eases the problems faced by stressful climates, such as intense radiation, extreme diurnal temperature fluctuation, intense dryness, cold or hot winds and dust storms.
- Consumes less energy for cooling and heating.
- Reduces the cost of design, construction, maintenance and operation of all infrastructure networks.

- Saves commuting time and energy.
- Has minimal impact on delicately sensitive environment.

#### 2.4.2 Dispersed urban form
: It is characterized by low population density per urban unit, low rise individual detached housing, and provision of generous space within urban land. Disperse pattern extends utilities, roads and infrastructures and consumes financial resources for its design, construction and operation.

#### 2.4.3 Clustered form
: is an aggregate of land use or housing in relatively small urban units integrated within close proximity of each other. This form potentially responds favourably to stressful conditions of cold dry or hot dry climates.

These forms can carry within them an integrated land use or segregated land use a while. Integrated land use is a combination of different land uses that have a reciprocal relation to each other and is usually common in cities. The inner city is developed as an economic activity centre and pushes residences, uses services and many jobs to the periphery.

#### 2.4.4 Combined form:

This is an aggregate of different forms brought together to establish a type of dispersed form and becomes a cohesive part of urban pattern.

## 2.5 Climate and design response:

Hot humid

- Excessive heat
- High humidity

- Ventilation: open ends and dispersed
- Widely open streets
- Extensive shadow
- Dispersion of high rise buildings to support ventilation
- Wide, yet shadowed open spaces.
- Planned tree zones

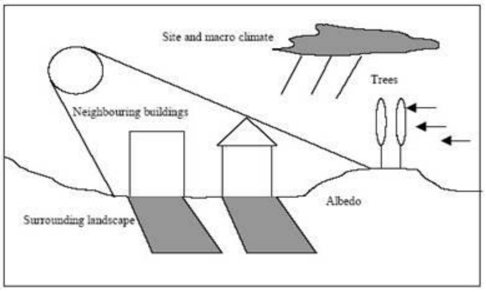
Hot dry

Excessive dryness combined with high day temperatures

- Shadowing
- Mix of building height to shadow the city
- Small, dispersed and protected public spaces

### 2.5.1 Residential Design Pattern:

a) Street orientation – streets designed straight and parallel to each other will support air movement into and within the city, the wind blowing through the unpaired sections with no vegetation cover cause dust turbulence and garbage accumulation in addition to intense heat or cold.




b) Street width – narrow, winding and zigzagging alleys are protective against cold and hot winds, receive minimum sunshine, establish shadowed space throughout the day – this pattern provides a cool and comfortable microclimate. In hot-humid climate, wide streets help ventilate the city but with proper vegetation.

c) Vegetation – trees in the centre or along the streets absorb dust and pollution, minimize the effect of solar radiation and establish shadowed areas.

d) Open public spaces – open space near the city, has its own microclimate and plays an important role. In hot-dry climate, a large open space (covered with asphalt) in the city has a negative impact.

In design pattern of stressful climate city should avoid large open spaces and instead provide small dispersed green spaces.

### 2.5.2 Comprehending nature of urban and built form:

- The planning and designing of overall and component parts of the city can indicate its eco – friendliness.
- The design primarily calls for low height, horizontally sprawling built form amidst Mother Nature.
- New concepts on eco-architecture can be explored even through appropriate skyscrapers, saving green land at the ground level and reducing aggregate negative impacts on the biosphere.
- Orientation of built form, façade design, roofscape, and use of transitional spaces, atrium, and sun shading devices, design of windscoop and service cores – all may intelligently reflect ecological inclination.

- Besides multilevel landscaping, natural lightning systems, electromechanical systems, energy utilisation - these too can be planned for both tall and short buildings in ecological responsive ways.

### 2.5.3 Deriving climatic design for eco-city:

Bio climatic design for human habitat includes orientation of buildings and street layouts according to sun path diagram and wind flow, building forms either to allow sun penetration or reduce solar heat gain, space planning to increase or decrease wind speed and govern microclimatic conditions, modulation of natural light, use of passive solar gain technologies, etc.

SOURCE – PLANNING FOR ECO – CITIES: URBAN DESIGN GUIDELINES FOR SUSTAINABLE DEVELOPMENT

### 2.5.4 Street Canyon Design and Urban Microclimate

A street canyon refers to the space which is formed by two typically parallel rows of buildings separated by a street and it creates the basic unit of modern cities.

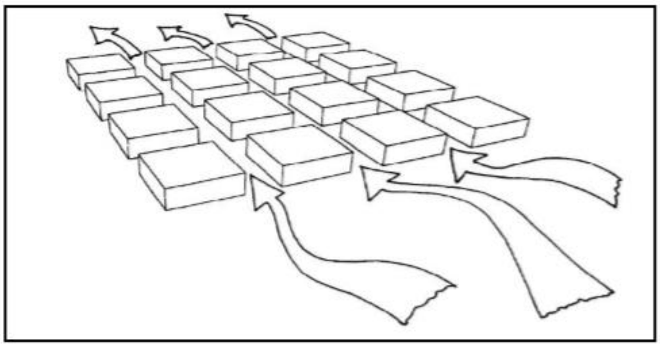
The geometry of a street canyon are expressed by its ‘aspect ratio’ including the ratio of the height of the building (H) to width of the street (W). If the canyon has an aspect ratio of around equal to 1 with no major openings on the walls it is called a uniform street canyon. A canyon with an aspect ratio below 0.5 is a shallow street canyon; and the aspect ratio of 2, represents a deep street canyon.

It has been proved that the geometry and orientation of the street canyon affect outdoor and indoor environments, solar access inside and outside the buildings, the permeability to airflow for urban ventilation, as well as the potential for cooling of the whole urban system.

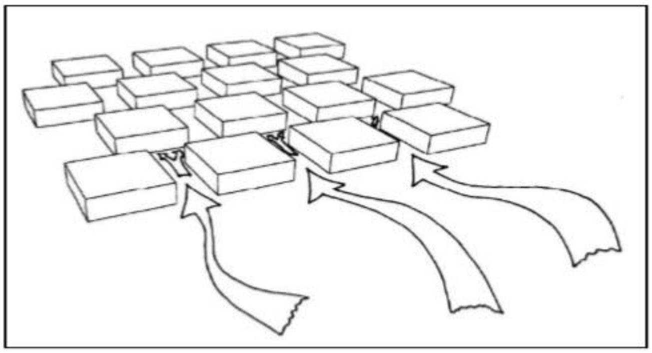
Therefore, the street design influences the thermal comfort at pedestrian level as well as the global energy consumption of urban buildings.

## 2.6 Impact of street design on airflow and solar access

- A wider street provides better mixing of air and consequently better airflow in the urban canyon. In addition, better ventilation could be occurred in a street with various building heights.



Straight and parallel streets improve airflow into and within a city



Narrow and winding streets make airflow slow

- Moreover, the H/W ratio affects the quantity of solar energy obtained by street surfaces (facades, roofs and ground).
- Decrease of the H/W ratio increases solar access in the street. Street orientation hardly influences the amount of solar radiation of the canyon; it causes differences in the distribution of the total radiation over the different street surfaces.
- Street orientation significantly influences the diurnal and seasonal pattern of irradiation of the street surfaces and it is more affective on the vertical surfaces of the street.

Therefore, in order to provide a pleasant microclimate in urban areas, designing urban streets in a way which brings about appropriate airflow and utilize solar access is vital and essential. This could affect global climate and energy consumption of buildings.

# 3 Desktop Study

## 3.1 Influence of Urban Form on the Microclimate and Thermal Comfort in the City Of Aleppo

- Aleppo is the largest city in Syria with a population of 2,132,100.
- Area – 190 sq. km
- The city of Aleppo was selected to conduct this study in it due to its unique urban fabric.
- The ancient city of Aleppo, which has been inscribed on the World Heritage List by UNESCO since 1986, dates back to the Roman-Hellenistic era and there is the modern city of Aleppo, which has its roots in the late period of the Ottoman Empire and French colonialism.

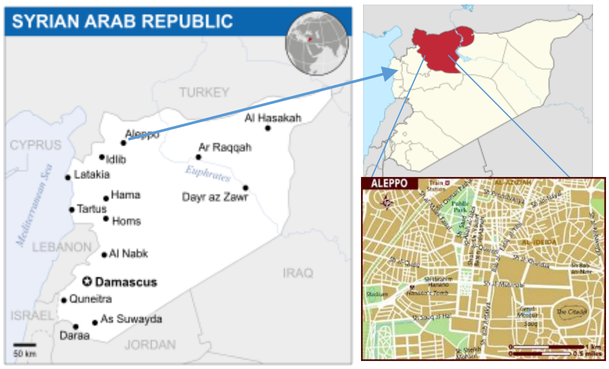



*Image 5 location Map of Aleppo, Al – Jedeideh and Engineers' Society*


### 3.1.1 Study area: The site selection considered two neighbourhoods, one in old Aleppo - "Al-Jdeideh" and the other in the new area -"Engineers' society"

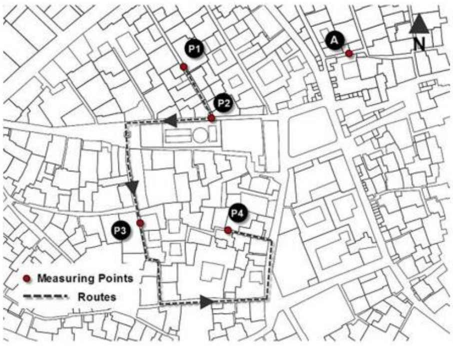
### 3.1.2 Field Measurements: Method of Investigation

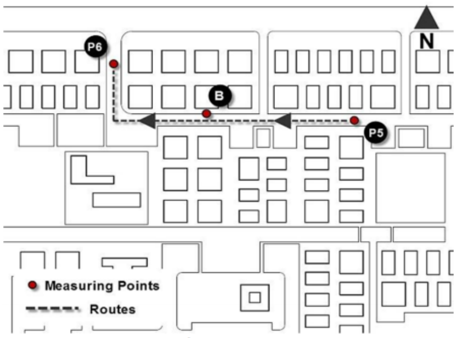
*Table 1 Measurement Parameters and Instruments*

| Site | Measured Parameters | Instruments |
|---|---|---|
| P1,P2,P3,P4,P5 &P6 | Air temperature<br>Relative humidity<br>Air velocity<br>Surface temperatures | Kestrel 4500 weather meter<br>Kestrel 4500 weather meter<br>Kestrel 4500 weather meter<br>Supco infrared thermometer L1T12LT |
| A and B | Air temperature<br>Relative humidity | Tinytag ultra 2 data logger TGU 4500<br>Tinytag ultra 2 data logger TGU 4500 |

*Table 2 the geometric parameters of the measurement locations in old and new Aleppo*

| Area | Location | Average Building Heights H (M) | Distance Between Buildings W (M) | Aspect Ratio H/W | Orientation (Angle From N) |
|---|---|---|---|---|---|
| Old | P1 | 8 | 2.1 | 3.81 | SE-NW |
| | P2 | 14 | 2.3 | 6.09 | E-W |
| | P3 | 9 | 2.3 | 3.91 | N-S |
| | P4 | 7 | 1.8 | 3.89 | E-W |
| New | A | 10 | 3 | 3.33 | E-W |
| | P5 | 13 | 28 | 0.46 | E-W |
| | P6 | 13 | 26 | 0.50 | N-S |
| | B | 13 | 28 | 0.46 | E-W |




The aspect ratios (H/W) of old Aleppo locations vary from 3.3 to 6.1, all canyons are almost oriented in two main directions, three oriented east-west, and other two north-south. Whereas, the aspect ratios of new Aleppo locations are nearly 0.5 and they are oriented in two different directions, east-west and north-south

### 3.1.3 Measurement Process:

- The instantaneous measurements were carried out on one summer day in July (19 July 2012).
- Measurements were conducted consecutively from 9:00 to 18:00 LST with 5-10 minutes average at each site.

- Air temperature, relative humidity and air velocity measurements were taken at nearly 1.7 m above ground level, using weather meters.
- Surface temperatures were taken at a height 1.5 m above ground level using Supco infrared thermometer.

### 3.1.4 Estimation of Sky View Factor (SVF):

Both neighbourhoods were modelled in detail using AutoCAD software, then digital SVF images were generated considering that the viewpoints, which represent the measurement locations, are located at 1.7 m above ground level.

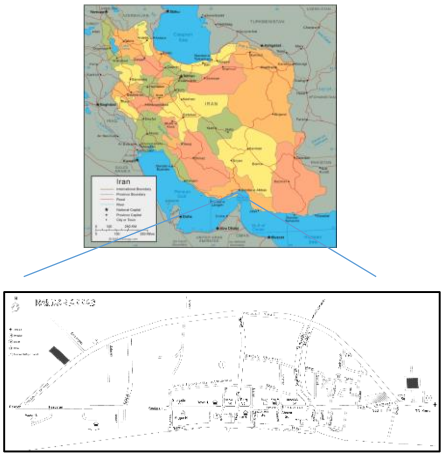
### 3.1.5 Thermal Comfort Analysis:

In order to calculate Tmrt and PET, recorded data for the day of measurements (19 July 2012), were used in the thermal assessment process using RayMan software. The average of PET values at the hottest period of the day (12 pm - 3 pm) shows that the PET is significantly correlated with SVF (R2 = 0.834) whereas PET increased with SVF values. This confirms the effect of the geometry of urban street canyon represented by the SVF on the outdoor thermal comfort expressed by the PET index.

### 3.1.6 Conclusions:

- Day-time air temperatures in old neighbourhoods are consistently lower than those found in new neighbourhoods, i.e. urban cool island effect (UCL).
- The urban street canyons with high aspect ratios were more capable in lowering the air temperatures.
- The lowest PET values were consistently noticed in canyons with low SVF (high aspect ratio). This is mainly due to the effect of shading on mean radiant temperature which drops significantly with the decrease in solar (short-wave) radiation.
- The wide canyons in the new part of the city are less comfortable with maximum values for Tmrt and PET, compared with narrow walkways in old Aleppo.

## 3.2 Microclimate and Thermal Comfort of Urban Forms and Canyons in Traditional and Modern Residential Fabrics in Bandar Abbas, Iran



- Bandar Abbas is a port city and capital of Hormozgān Province on the southern coast of Iran.
- Population: 435751
- Climate: the city is located at the hot and humid region. It has been regarded as the city which has eight months' time of harsh conditions of heat.

### 3.2.1 Built Form and Microclimate:

There are three types of built form in Bandar Abbas urban area: high rise towers, mid- rise blocks and low-rise compact courtyard houses.

### 3.2.2 Urban Canyon Analysis:

The main focus of this part is to describe the details of selected urban canyons and particularities of these canyons regarding to physical, microclimate and thermal comfort specifications of two prevailing typologies of selected traditional and modern fabrics of residential districts.

South Golshahr

- Starting from the middle of 80's to build up by private owners, mainly one story houses.
- After year of 2000 especially the street sides of area built as commercial and residential medium and high rise buildings.
- In recent 10 years, interior empty areas also started to construction in multi-story buildings.
- The selected canyon in modern fabric has a H/W ratio of 0.5

Nakhl-e-Nakhoda

- The history of this quarter back to a separated fisherman's village, 8km away from Bandar Abbas historical city centre.
- During recent 40 years and rapid development of urban areas especially in 1980's have, has included to urban area but still has traditional form
- Canyons are belonging to traditional forms with narrow lanes and sandy pathways and mainly North-South direction.

*Table 3 Inventory of street canyons*

| Site | Type Of Canyon | H/W Ratio | Orientation | Vehicle Traffic | Ground Cover | Distance From Sea(M) | Distance Between Two Site | Fabric Specification |
|---|---|---|---|---|---|---|---|---|
| South Golshahr (M) | Residential | 0.5 | WSW-ENE | Medium | Asphalted | 438 | 955 | New Development |
| Nakhl – E-Nakhoda (T) | Residential | 1.0 | N-S | Low | Sandy | 380 | | Traditional |

### 3.2.3 Results:

The result indicates remarkable differences of building layout between the traditional fabric and modern fabric of the old area and new residential developments.

1) Canyon Orientation was found out to be the first contributor of thermal comfort in the selected area whereby causes proper shading condition and conducive ventilation. Since H/W ratio in traditional fabrics is higher than modern fabric therefore, the traditional fabric was found out to be more thermally comfortable than the modern fabric.
2) Vegetation was revealed to have a positive effect in providing cooling benefits particularly during daytimes, when there is a high altitude of sun with high solar radiation in summer. The traditional fabric has more conducive vegetation layout rather than modern fabric in terms of thermal comfort.
3) According to investigations of microclimate situation and computation of thermal comfort indices (PET, PMV, SET*), the calculated values of thermal comfort indices show higher ratio in modern fabrics than traditional area, this is the effect of lower H/W ratio and inadequate wind circulation and shading.

Therefore there is a need to device:

- Higher H/W ratio
- Increasing vegetation cover
- Considering urban canyon orientation
- According to prevailing wind in design process of new development areas.

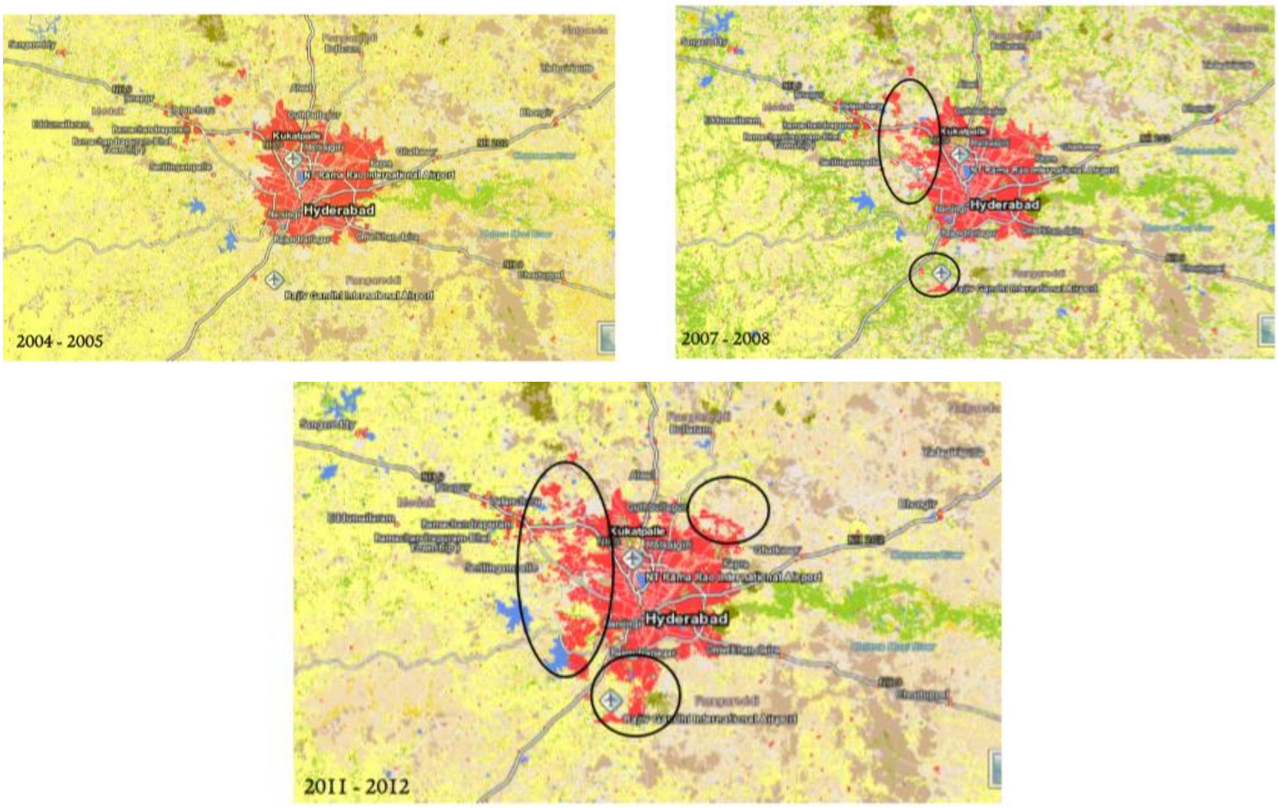
# 4 Case Study


- Hyderabad is the capital of the Southern Indian state of Telangana.
- Fourth most populous city and sixth most populous agglomeration in India.
- Area – 625 sq. km
- Hyderabad is situated on hilly terrain around artificial lakes.
- Height above the sea level – 536 m.

*Table 4 Hyderabad Decadal Growth*

| Year | Population | % Decadal Growth |
|---|---|---|
| 1991 | 3145939 | - |
| 2001 | 3829753 | 17.8 |
| 2011 | 4010238 | 4.71 |

*Image 6 land use cover map of Hyderabad*




An overall increase of built-up area has been observed since 2007 to 2012.

Mir Jumla Tank, Ma Sahab Tank, Batkamma Kunta are the water bodies that has been lost forever due to increase in urbanisation since past decades.

## 4.1 Climate of Hyderabad

*Table 5 Hyderabad Climate Scenario*

| Climate of Hyderabad: tropical wet and dry climate | |
|---|---|
| Annual mean temperature | $26^0$C |
| Monthly mean temperature | 21-$32^0$C |
| Summers ( march – June) | Average highs in the mid-30s Celsius |
| Maximum temperatures | Exceed 40 °C between April and June |
| Winter | the lowest temperature occasionally dips to 10 °C in December and January |
| May is the hottest month | temperatures range from 26 to 38.8 °C |
| January, the coldest | temperatures varying from 14.7 to 28.6 °C |
| Heavy rain from the south- west summer monsoon falls between June and September | annual rainfall of 812.5 mm |

- Heaviest rainfall recorded in a 24-hour period was 241 mm - 24 August 2000
- Highest temperature ever recorded was 45.5 °C - 2 June 1966
- Lowest was 6.1 °C - 8 January 1946

## 4.2 Temperature trends in Hyderabad

- An increasing trend shows impact of urbanisation in form of increase in built up area.
- Increasing warming trends in night-time temperatures reflect the contribution of changing land use patterns and anthropogenic heat.

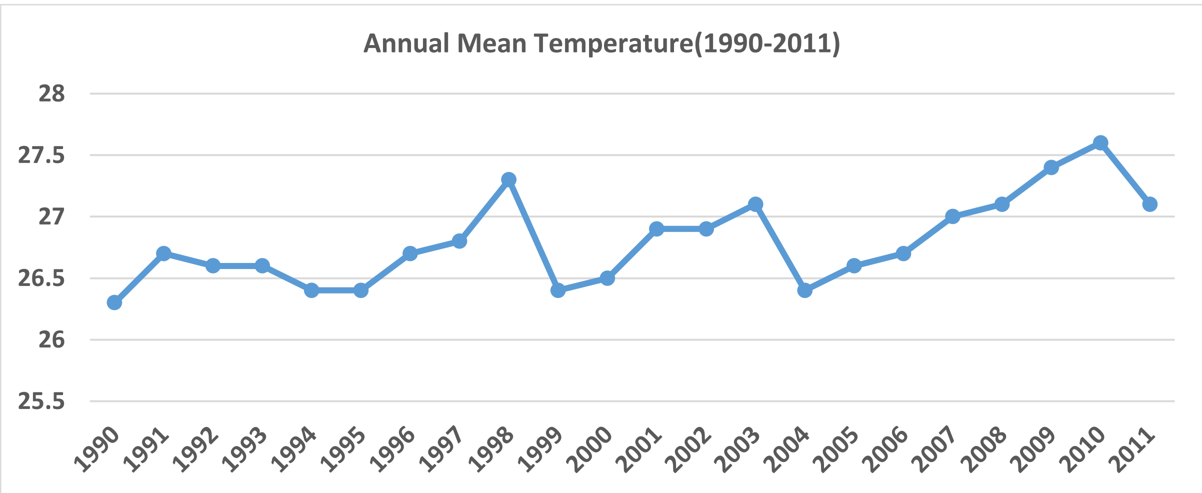
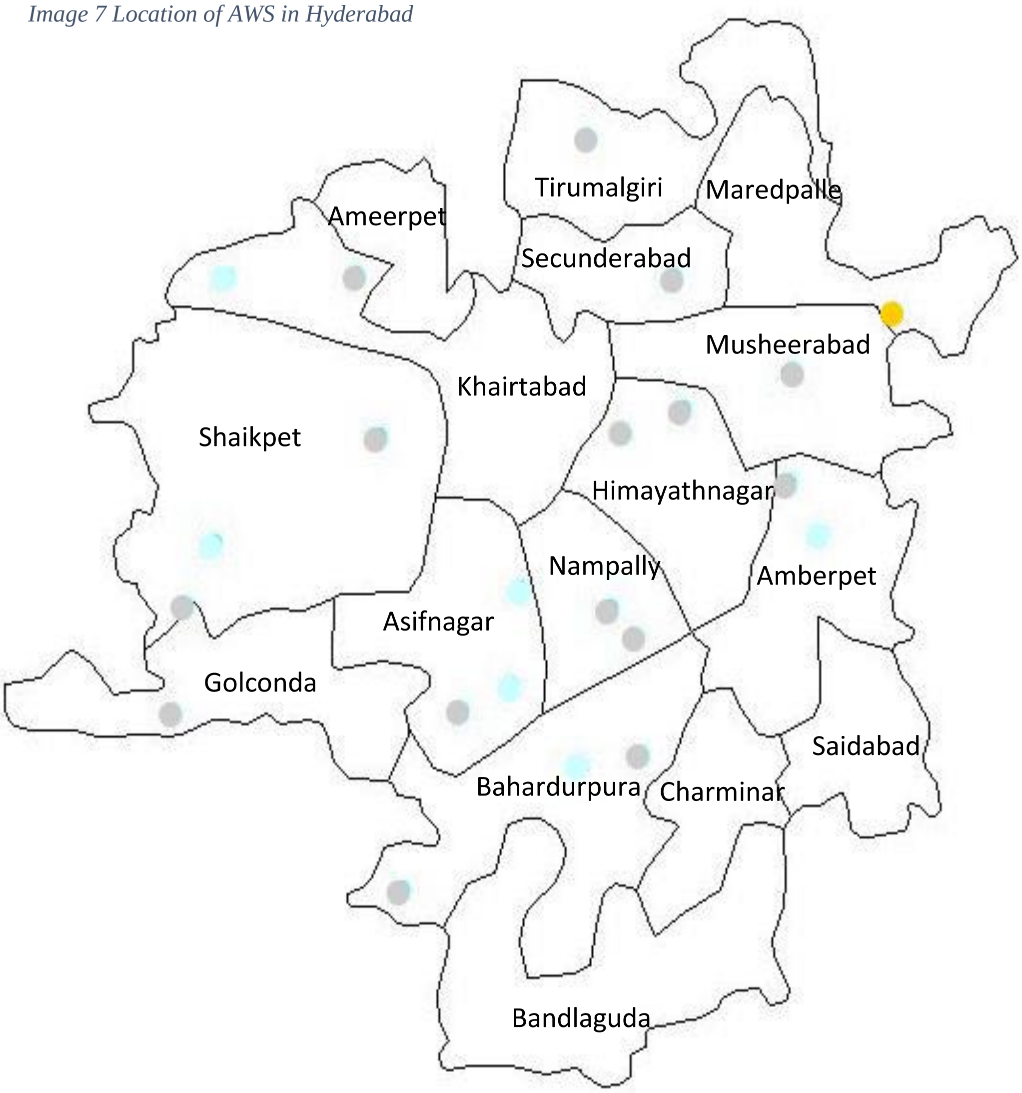



*Figure 2 Annual Mean Temperature of Hyderabad (1990-2011)*

## 4.3 Automatic Weather Stations in Hyderabad

- There are 23 AWS spread across the city of Hyderabad.
- These stations measure six weather parameters viz., rainfall, mean sea level pressure, wind, wind speed, wind direction, temperature, & humidity at any given interval of time and transmit the same immediately to central data server.

*Image 7 Location of AWS in Hyderabad*



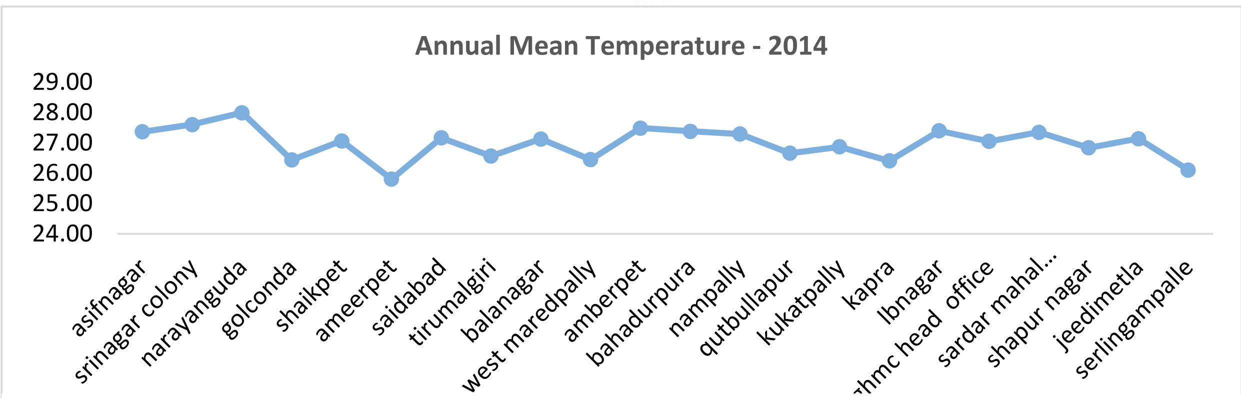




*Figure 3 Annual Mean Temperature - 2014*

Mean temperature is

- Highest: Narayanguda
- Lowest: Serilingampalle

The study area is selected based on the criteria:

- One area is the traditional part and the other is the modern part of the city.
- The next factor to be considered is the area with high growth rate linked up with the temperature levels.

| Area | Growth Rate | Annual Mean Temperature (2014) |
|---|---|---|
| Golconda | 85.48 | 33.4 |
| Srinagar Colony | 81.42 | 33.7 |

*Image 8 location map of study area*

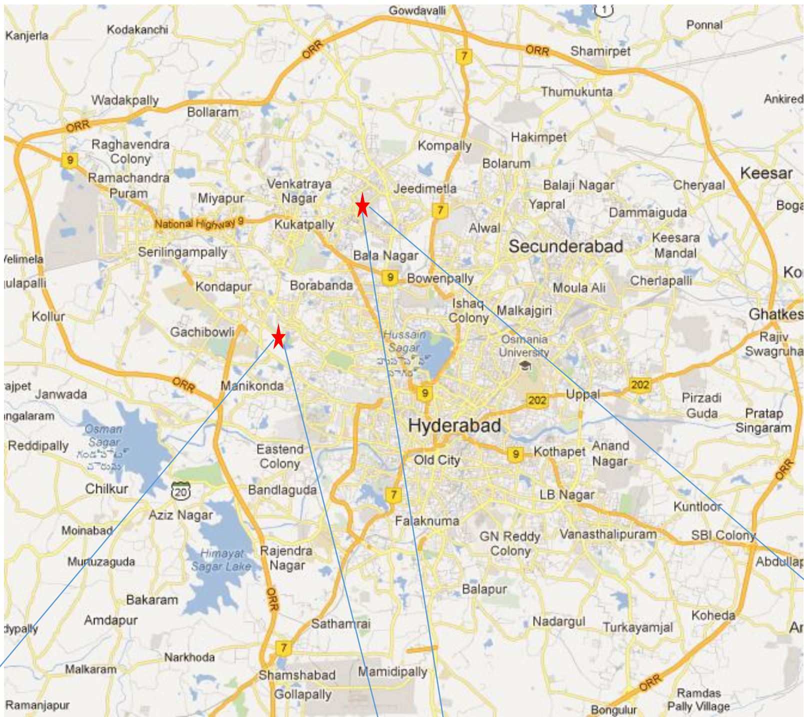
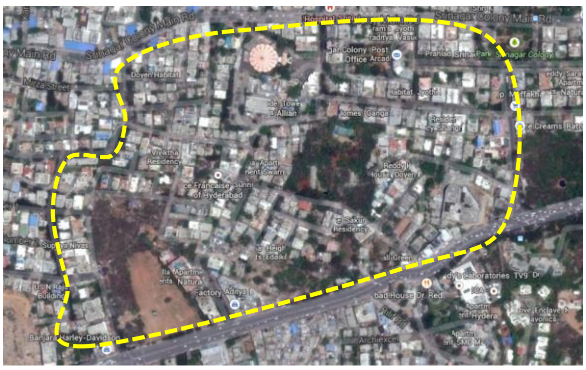



IMAGE 10 CHOTA BAZAAR

Image 9 AURORA COLONY



## 4.4 Aurora colony (in Srinagar colony)

General details: Housing type – flats/ apartments. A high density neighbourhood dominated by modern flats. The area has very little green space. There is a busy street with shops and services. The highest building height in this area is observed to be – 15 m. (i.e. G+5).

| Population | Area (In Hec) | Density Per Hec |
|---|---|---|
| 7300 | 33.7 | 216.6 |


Map 1 Figure Ground Map of Aurora Colony

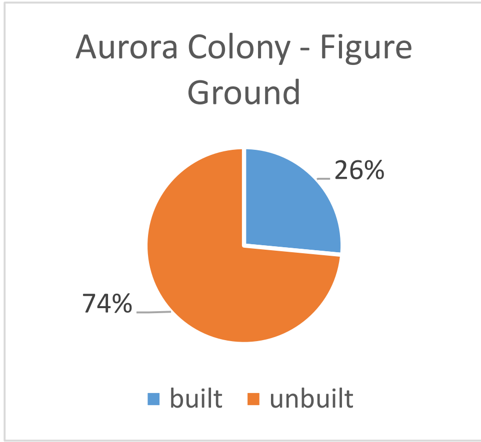
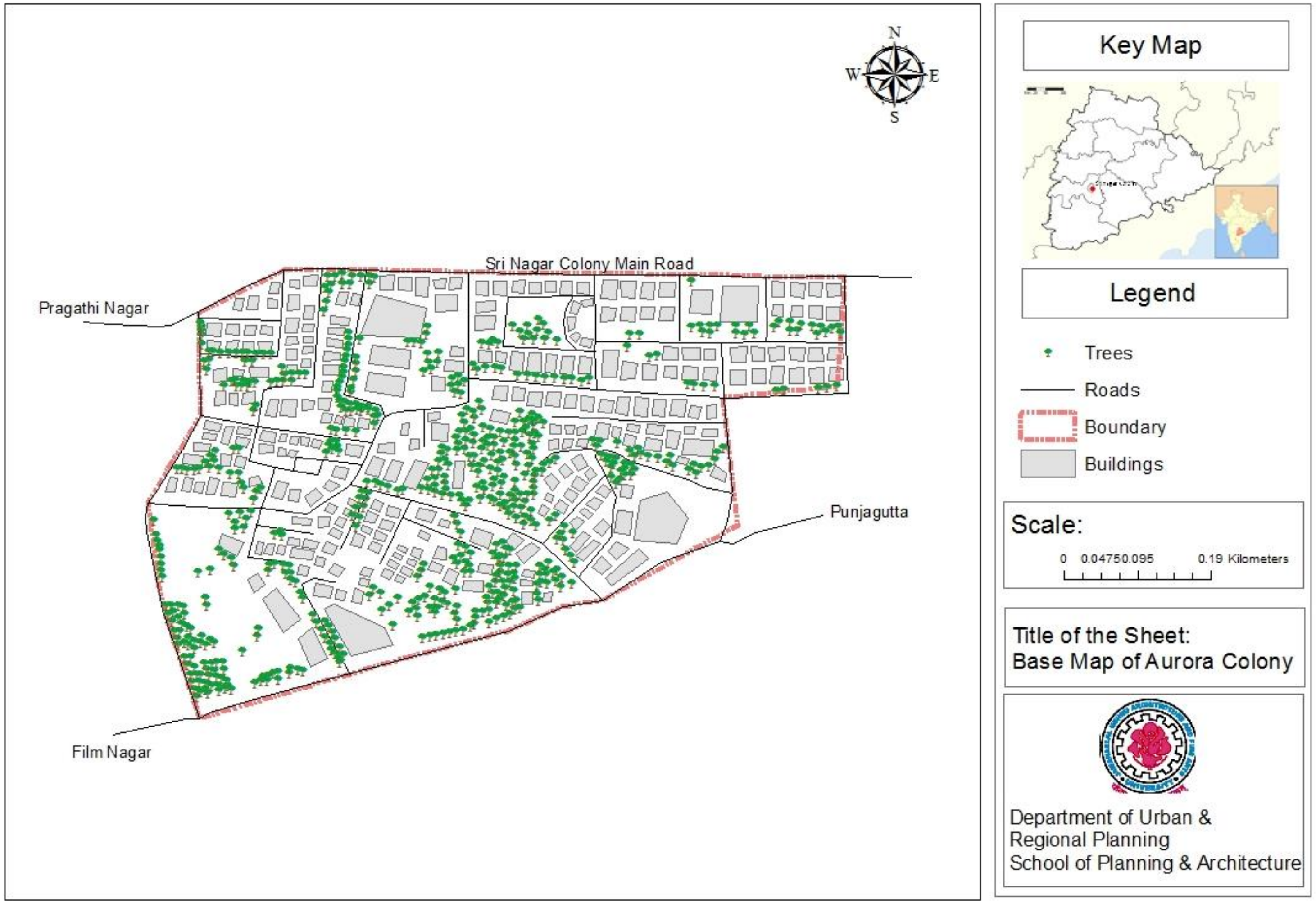
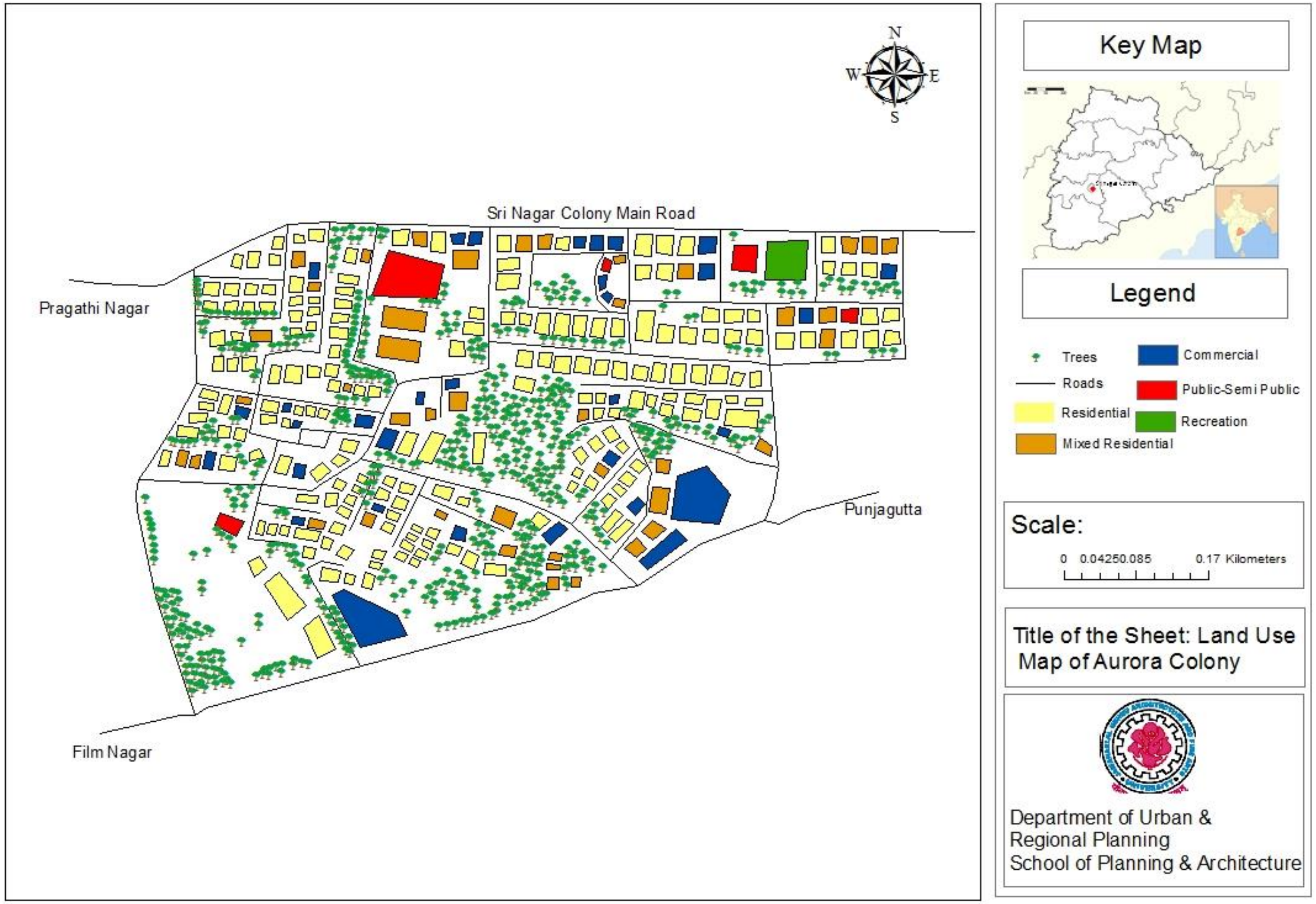



*Figure 4 figure ground analysis of Aurora Colony*




*Map 2 Base Map of Aurora Colony*



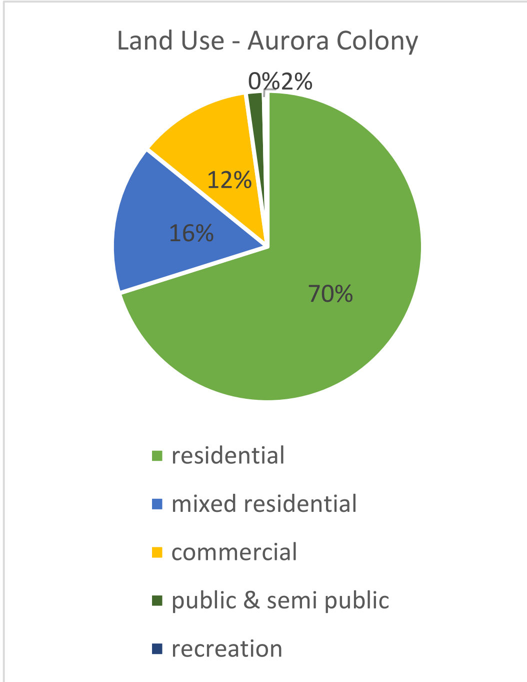




*Figure 5 Land Use Analysis - Aurora Colony*

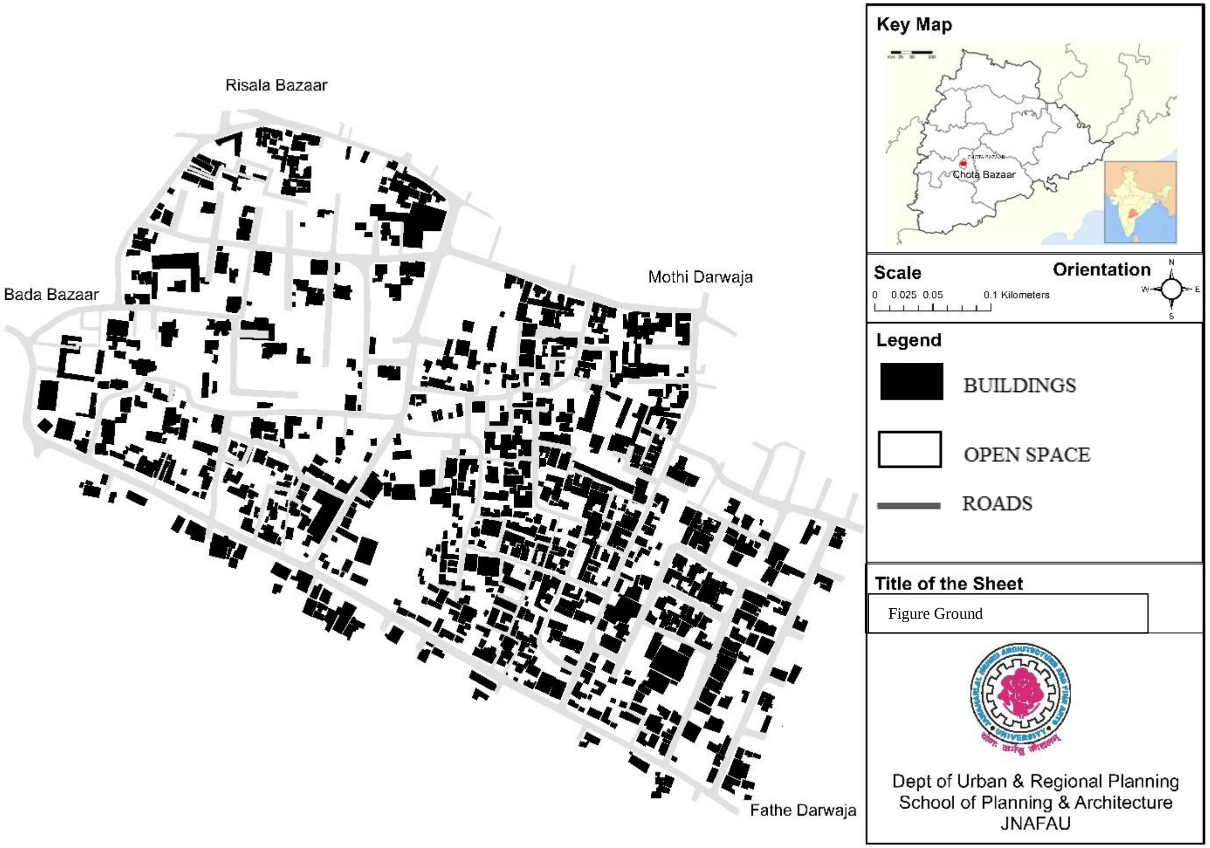
*Map 3 Land Use Map of Aurora Colony*

## 4.5 Chota Bazaar (In Golconda)

General details: Much of the area is characterized by attached housing. There are no green spaces in the neighbourhood but just vacant lands.

The highest building height observed in the area 9 m (i.e. G+2)

| Population | Area (In Hec) | Density Per Hec |
|---|---|---|
| 6200 | 29.7 | 303.9 |




*Map 4 Figure Ground Map of Chota Bazaar*

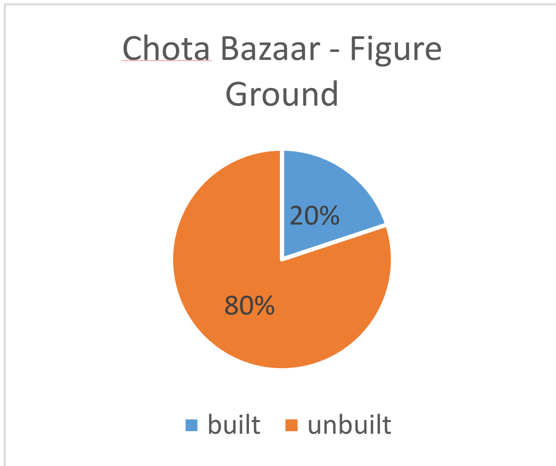
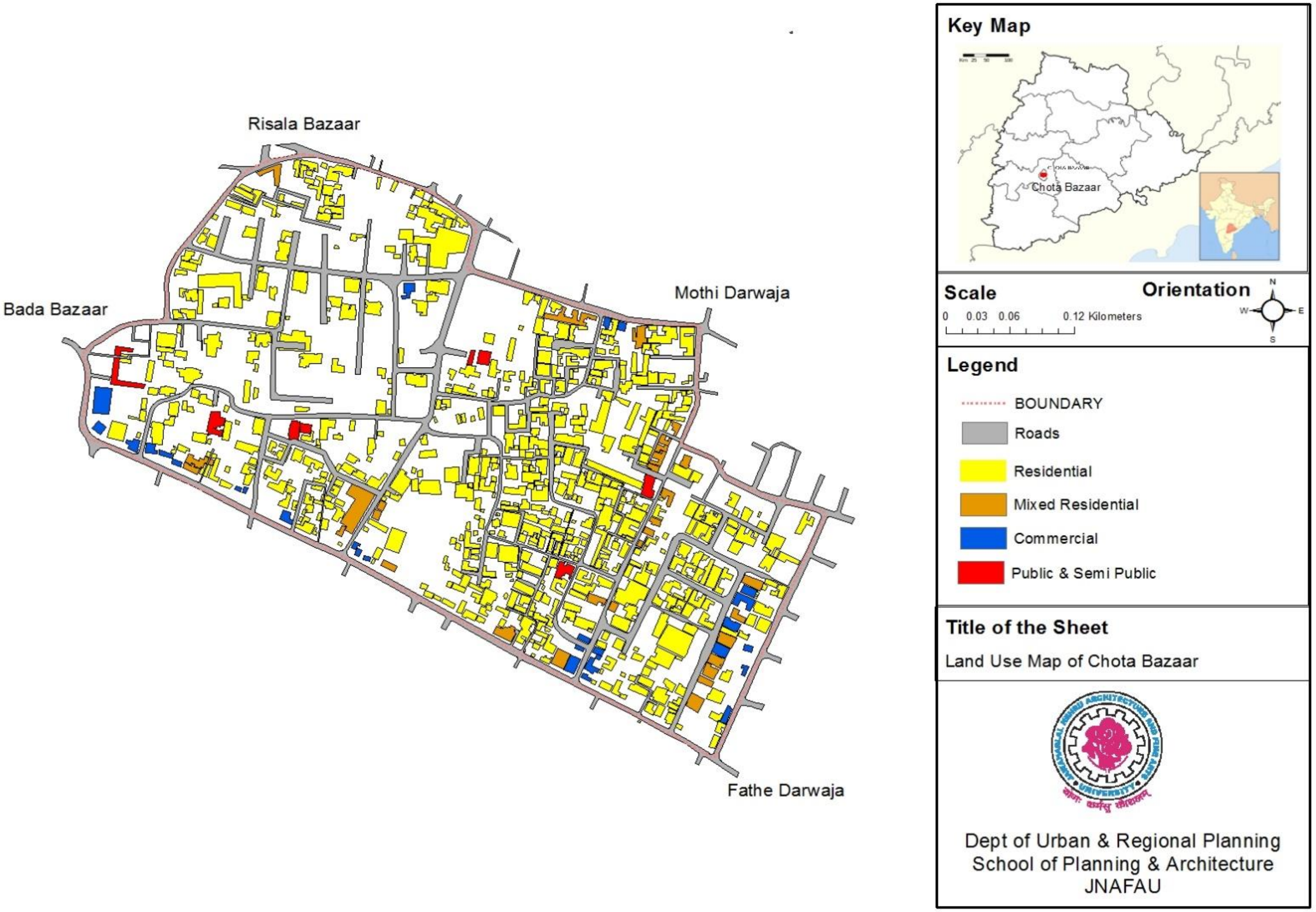



*Figure 6 Figure Ground Analysis - Chota Bazaar*


*Map 5 Base Map of Chota Bazaar*



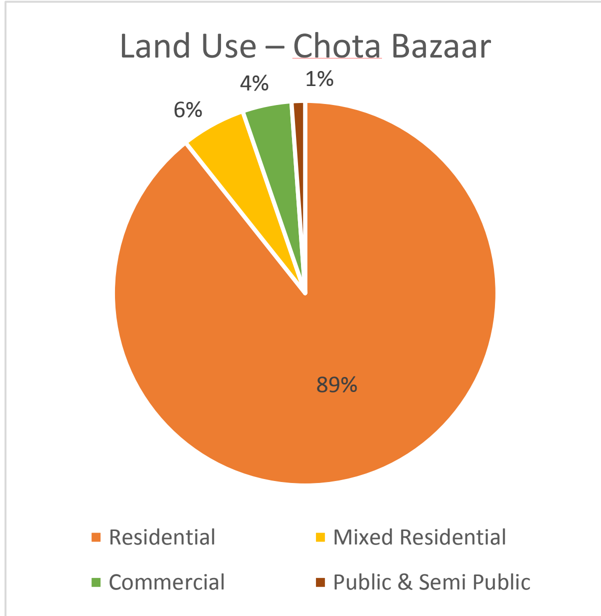
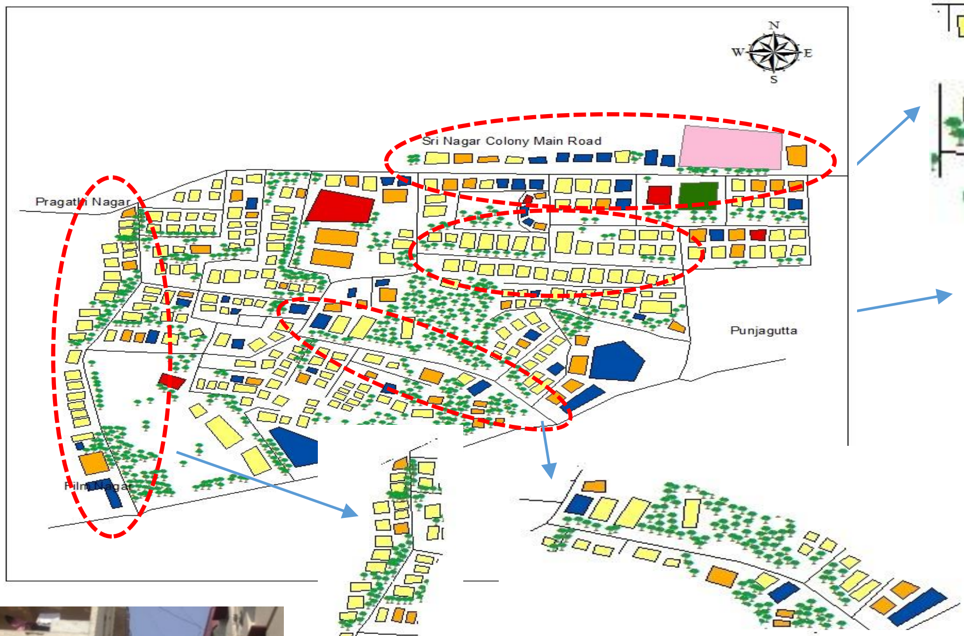




*Figure 7 Land Use Analysis - Chota Bazaar*

*Map 6 Land Use Map of Chota Bazaar*

## 4.6 Aurora Colony – Street Details

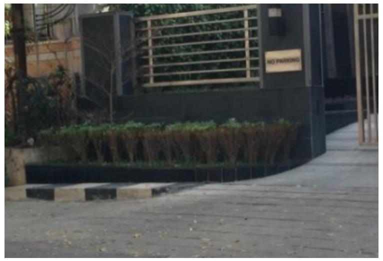
STREET 2


| Street no. | Length | Average Width (W) | Street Orientation | % of length covered with trees | Average Building Height (H) | Aspect ratio (H/W) |
|---|---|---|---|---|---|---|
| 1 | 470 m | 6.9 | E-W | 55.5 | 13.5 | 1.9 |
| 2 | 466 m | 9.3 | E-W | 37.5 | 12 | 1.2 |
| 3 | 356 m | 6.2 m | NW-SE | 54.2 | 14.1 | 2.2 |
| 4 | 404 m | 9.1 m | N-S | 72.7 | 12 | 1.3 |

STREET 3

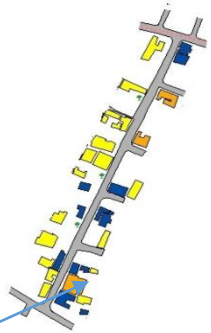

STREET 4



## 4.7 Chota Bazaar – Street Details

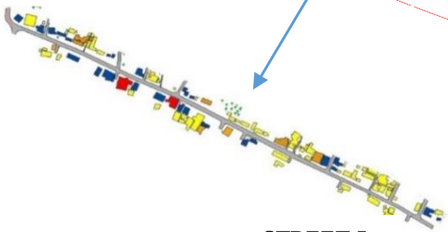
STREET 7

STREET 6




| Street no. | Length | Average Width (W) | Street Orientation | % of length covered with trees | Average Building Height (H) | Aspect ratio (H/W) |
|---|---|---|---|---|---|---|
| 5 | 556 m | 9 m | NW-SE | 22.5 | 6 | 0.6 |
| 6 | 253 m | 6.5 m | NE-SW | 14.2 | 6 | 0.9 |
| 7 | 252 m | 5.5 m | NE-SW | 10.7 | 4.5 | 0.8 |
| 8 | 298 m | 6.5 m | N-S | 6 | 6 | 0.9 |

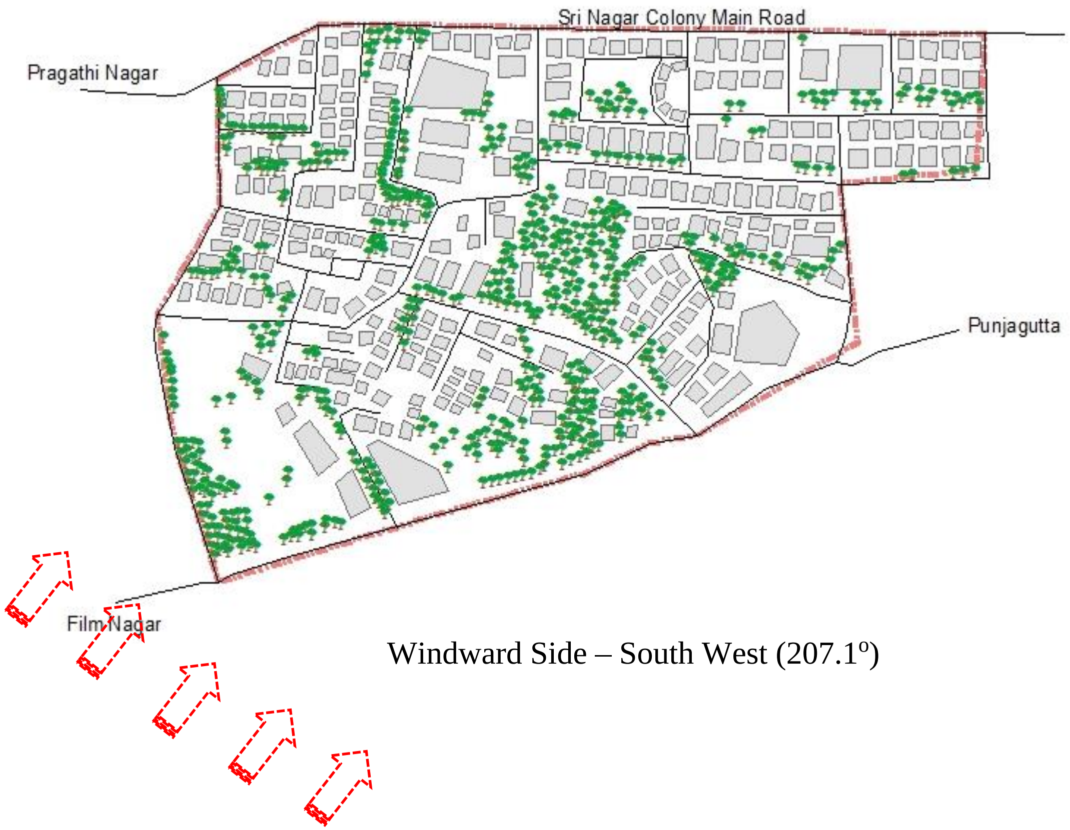
STREET 8

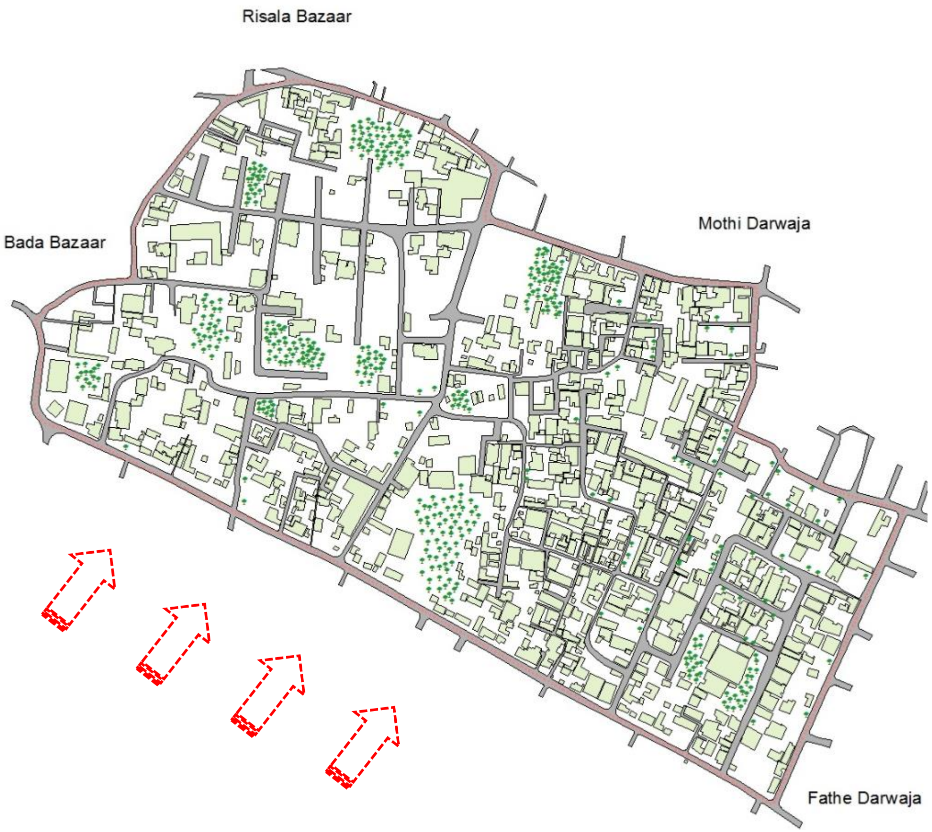


STREET 5

# 5 Data analysis

## 5.1 Observations




Windward Side – South West (207.1$^{o}$)

The wind flow in the street canyon depends on the road's orientation.

### 5.1.1 Climatic details – February 2015

*Table 6 climatic details of February 2015*

| Place | 17-02-2015 (12.00 P.M-3.00 P.M) | | | | 18-02-2015(12.00 P.M-3.00 P.M) | | | |
|---|---|---|---|---|---|---|---|---|
| | Temperature(°c) | Humidity (%) | Wind Direction (°) | Wind Speed (m/s) | Temperature(°c) | Humidity (%) | Wind Direction(°) | Wind Speed (m/s) |
| Golconda | 33.6 | 18.8 | 201.4(SW) | 6.6 | 33.9 | 24.3 | 258.8(SW) | 6.7 |
| Srinagar colony | 34.4 | 18.9 | 207.1(SW) | 1.9 | 35.8 | 21.5 | 190.9(SW) | 2.8 |

The climatic data of February 2015 have been taken up for analysis, as these two days (17-2-2015 & 18-02-2015) recorded a maximum temperature throughout the month.

### 5.1.2 Orientation Vs Aspect Ratio

*Table 7 Orientation vs Aspect Ratio*

| Place | Temperature | Orientation | | | |
|---|---|---|---|---|---|
| | | N-S | E-W | NW-SE | NE-SW |
| | | Aspect ratio | | | |
| Golconda | 33.9 | 0.9 | 0.6 | 0.6 | 0.8 |
| Srinagar colony | 35.8 | 1.3 | 1.9 | 1.3 | 2.2 |

Details of Different aspect ratios and orientation of streets are shown in the selected site areas.

### 5.1.3 Velocity & H/W ratio

*Table 8 Velocity vs H/W Ratio*

| Street no. | Wind velocity | H/W ratio |
|---|---|---|
| 1 | 2.8 | 1.9 |
| 2 | 2.8 | 1.2 |
| 3 | 2.8 | 2.2 |
| 4 | 2.8 | 1.3 |
| 5 | 6.7 | 0.6 |
| 6 | 6.7 | 0.9 |
| 7 | 6.7 | 0.8 |
| 8 | 6.7 | 0.9 |

| | Wind velocity | Aspect ratio |
|---|---|---|
| Wind velocity | 1 | |
| Aspect ratio | -0.81137 | 1 |

Correlation value of -0.8 has been observed, this shows a strong relation in inverse relation I.e., as aspect ratio Increases the wind speed decreases and vice versa.

### 5.1.4 velocity & temperature

*Table 9 wind velocity & temperature*

| Street no. | Wind velocity | temperature |
|---|---|---|
| 1 | 2.8 | 35.8 |
| 2 | 2.8 | 35.8 |
| 3 | 2.8 | 35.8 |
| 4 | 2.8 | 35.8 |
| 5 | 6.7 | 33.9 |
| 6 | 6.7 | 33.9 |
| 7 | 6.7 | 33.9 |
| 8 | 6.7 | 33.9 |

| | Wind Velocity | Temperature |
|---|---|---|
| Wind Velocity | 1 | |
| Temperature | -1 | 1 |

Correlation value of -1 has been observed. i.e., as wind speed increases the temperature values are observed to be lower

## 5.2 Statistical Test

| Street No. | Length | Average Width (in meters) (W) | Street Orientation (in degrees) | % Of Length Covered With Trees (in %) | Average Building Height ( in meters) (H) | Aspect Ratio (H/W) | T avg (in ° C) | H avg (In %) | Ws Avg (km/h) | Wd Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 470 | 6.9 | E-W(90) | 55.5 | 13.5 | 1.9 | 33.4 | 60.1 | 4.4 | 172.5 |
| 2 | 466 | 9.3 | E-W(90) | 37.5 | 12 | 1.2 | 33.4 | 60.1 | 4.4 | 172.5 |
| 3 | 356 | 6.2 | NW-SE(135) | 54.2 | 14.1 | 2.2 | 33.4 | 60.1 | 4.4 | 172.5 |
| 4 | 404 | 9.1 | N-S(0) | 72.7 | 12 | 1.3 | 33.4 | 60.1 | 4.4 | 172.5 |
| 5 | 556 | 9 | NW-SE(135) | 22.5 | 6 | 0.6 | 33.7 | 60.3 | 4.5 | 172.5 |
| 6 | 253 | 6.5 | NE-SW(45) | 14.2 | 6 | 0.9 | 33.7 | 60.3 | 4.5 | 172.5 |
| 7 | 252 | 5.5 | NE-SW(45) | 10.7 | 4.5 | 0.8 | 33.7 | 60.3 | 4.5 | 172.5 |
| 8 | 298 | 6.5 | N-S(0) | 6 | 6 | 0.9 | 33.7 | 60.3 | 4.5 | 172.5 |

The analysis is done based on:

a) Pearson's Correlation

b) Multiple Linear Regression Analysis

| Urban form Parameters | Correlation Values (against Mean Annual Temperature – 2014) | Regression values |
|---|---|---|
| Aspect ratio | - 0.8 | 0.3 |
| Building height | - 0.9 | -0.08 |
| Road width | - 0.3 | 0.06 |
| % of road length covered with trees | - 0.9 | -0.001 |
| Street orientation | - 0.2 | - 0.0008 |

The highest correlation analysis was observed for Aspect Ratio, Building Height, and % of vegetation cover.

Whereas, the Aspect Ratio is observed to have highest effect on temperature values.

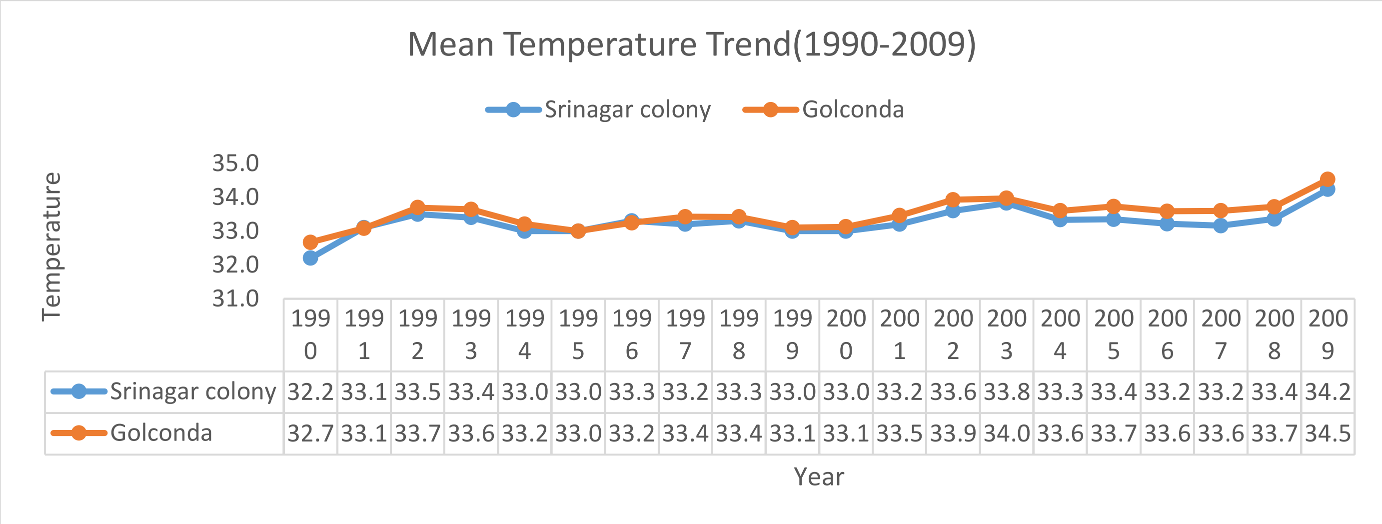



*Figure 8 Mean Temperature Trend (1990-2009)*

The temperatures is Srinagar colony are higher when compared to that is Golconda from 1990 to 2009 with an average difference of 0.2 to 0.5°C.

## 5.3 Thermal Comfort Indices:

### 5.3.1 Discomfort Index: DI = T – 0.55 X (1-0.01H) X (T-14.5)

Where T is the hourly of the mean air temperature in degrees Celsius and H (%) is the corresponding hourly value of the relative humidity. Discomfort increases as DI increases.

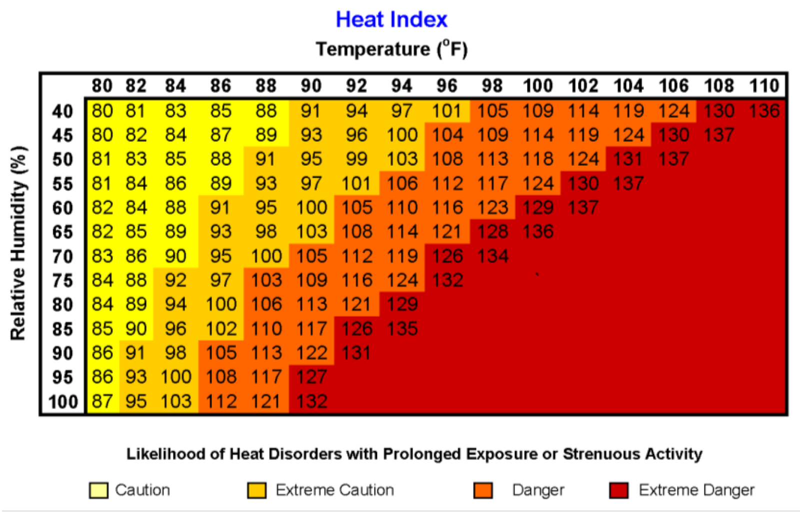
| **DI (°C)** | **Discomfort Conditions** |
|---|---|
| DI<21 | No discomfort |
| 21≤DI<24 | Less than 50% of total population feels discomfort |
| 24≤DI<27 | more than 50% of total population feels discomfort |
| 27≤DI<29 | Most of the population feels discomfort |
| 29≤DI<32 | The discomfort is very strong and dangerous |
| DI≥32 | State of medical emergency |

| Place | Humidity | DI | Discomfort Conditions |
|---|---|---|---|
| Aurora Colony | 33.4% | 29.3ºC | Everyone feels severe stress |
| Chota Bazaar | 33.7% | 29.5ºC | Everyone feels severe stress |

Based on the given humidity values of the site area, the condition in both the site areas is "severe stress".

### 5.3.2 Heat stress Index:

| Classification | Heat Index | Effect on the body |
|---|---|---|
| Caution | 27ºC – 32ºC | Fatigue possible with prolonged exposure and/or physical activity |
| Extreme Caution | 32°C - 39°C | Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity |
| Danger | 39°C - 51°C | Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity |
| Extreme Danger | 52°C or higher | Heat stroke highly likely |



**Heat Index**

Temperature (°F)

| Relative Humidity (%) | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 106 | 108 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 80 | 81 | 83 | 85 | 88 | 91 | 94 | 97 | 101 | 105 | 109 | 114 | 119 | 124 | 130 | 136 |
| 45 | 80 | 82 | 84 | 87 | 89 | 93 | 96 | 100 | 104 | 109 | 114 | 119 | 124 | 130 | 137 | |
| 50 | 81 | 83 | 85 | 88 | 91 | 95 | 99 | 103 | 108 | 113 | 118 | 124 | 131 | 137 | | |
| 55 | 81 | 84 | 86 | 89 | 93 | 97 | 101 | 106 | 112 | 117 | 124 | 130 | 137 | | | |
| 60 | 82 | 84 | 88 | 91 | 95 | 100 | 105 | 110 | 116 | 123 | 129 | 137 | | | | |
| 65 | 82 | 85 | 89 | 93 | 98 | 103 | 108 | 114 | 121 | 128 | 136 | | | | | |
| 70 | 83 | 86 | 90 | 95 | 100 | 105 | 112 | 119 | 126 | 134 | | | | | | |
| 75 | 84 | 88 | 92 | 97 | 103 | 109 | 116 | 124 | 132 | | | | | | | |
| 80 | 84 | 89 | 94 | 100 | 106 | 113 | 121 | 129 | | | | | | | | |
| 85 | 85 | 90 | 96 | 102 | 110 | 117 | 126 | 135 | | | | | | | | |
| 90 | 86 | 91 | 98 | 105 | 113 | 122 | 131 | | | | | | | | | |
| 95 | 86 | 93 | 100 | 108 | 117 | 127 | | | | | | | | | | |
| 100 | 87 | 95 | 103 | 112 | 121 | 132 | | | | | | | | | | |

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

| Place | Heat index | Effect on the body |
|---|---|---|
| Aurora Colony | 40.6ºC | **Heat cramps or heat exhaustion likely, and heat stroke** |
| Chota Bazaar | 41.4ºC | |

## 5.4 Mahoney table

The Mahoney tables are a set of reference tables, used as a guide to climate-appropriate design.

Table 1

| | |
|---|---|
| Location | Hyderabad |
| Longitude | 78.48$^0$E |
| Latitude | 17.37$^0$N |
| Elevation | 505 m |

| | Month | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chota Bazaar | Monthly mean max. | 29 | 31 | 34 | 39 | 39 | 37 | 32 | 32 | 31 | 33 | 31 | 29 |
| | Monthly mean min. | 16 | 17 | 21 | 24 | 25 | 26 | 24 | 23 | 28 | 21 | 18 | 15 |
| | Monthly mean range | 13 | 14 | 13 | 15 | 14 | 11 | 8 | 9 | 3 | 12 | 13 | 14 |
| Aurora Colony | Monthly mean max. | 29 | 23 | 34 | 39 | 39 | 38 | 31 | 33 | 32 | 33 | 32 | 30 |
| | Monthly mean min. | 19 | 20 | 23 | 27 | 27 | 27 | 24 | 24 | 24 | 23 | 21 | 18 |
| | Monthly mean range | 10 | 12 | 11 | 12 | 12 | 11 | 7 | 9 | 8 | 10 | 11 | 12 |

| High | AMT |
|---|---|
| 39 | 27 |
| 15 | 24 |
| low | AMR |

### 5.4.1 Temperature: Table 1 is used to assemble temperature, humidity, rainfall and wind data

### 5.4.2 Relative humidity: %

| | Month | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chota Bazaar | Monthly mean max. | 90.5 | 82 | 78.5 | 71 | 71 | 73 | 84 | 86 | 90 | 88 | 89 | 86 |
| | Monthly mean min. | 40 | 31 | 33 | 23.5 | 28 | 35.5 | 53 | 52 | 57 | 42 | 38 | 36 |
| | Average | 65 | 56.5 | 56 | 47 | 49.5 | 54 | 68.5 | 69 | 73.5 | 65 | 63.5 | 61 |
| | Humidity group | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 4 | 3 | 3 | 3 |
| Aurora Colony | Monthly mean max. | 82 | 72 | 67 | 57 | 62 | 68 | 86 | 84 | 84 | 78.5 | 74 | 74 |
| | Monthly mean min. | 40 | 30 | 32 | 22 | 27 | 33 | 55 | 51 | 53 | 42 | 35 | 35 |
| | Average | 61 | 51 | 49.5 | 39.5 | 44.5 | 50.5 | 70.5 | 67.5 | 68.5 | 60 | 54.5 | 54.5 |
| | Humidity group | 3 | 3 | 2 | 2 | 2 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |

| Humidity group | If average RH |
|---|---|
| 1 | Below 30% |
| 2 | 30-50% |
| 3 | 50-70% |
| 4 | Above 70% |

### 5.4.3 Rain and wind

| | Month | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chota Bazaar | Rainfall, mm | 0 | 0 | 0.7 | 0.2 | 1.2 | 0.9 | 2.6 | 1.6 | 2.2 | 0.8 | 1.3 | 0 |
| | Wind direction | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW |
| Aurora Colony | Rainfall, mm | 0 | 0 | 2.3 | 0.1 | 0.3 | 0.3 | 4.8 | 4.4 | 1.7 | 0.6 | 1.4 | 0 |
| | Wind direction | SE | SE | SE | SE | SW | SW | SW | SW | SW | SE | SE | SE |

Table 2- 5.4.4 Diagnosis: $^{0}$C

| | Chota bazaar | | | | | | | | | | | | Aurora colony | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
| Monthly mean max. | 29 | 31 | 34 | 39 | 39 | 37 | 32 | 32 | 31 | 33 | 31 | 29 | 29 | 32 | 34 | 39 | 39 | 38 | 31 | 33 | 32 | 33 | 32 | 30 |
| Day comfort : upper | 29 | 29 | 29 | 31 | 31 | 29 | 29 | 29 | 27 | 29 | 29 | 29 | 29 | 29 | 31 | 31 | 31 | 29 | 27 | 29 | 29 | 29 | 29 | 29 |
| lower | 23 | 23 | 23 | 25 | 25 | 23 | 23 | 23 | 22 | 23 | 23 | 23 | 23 | 23 | 25 | 25 | 25 | 23 | 22 | 23 | 23 | 23 | 23 | 23 |
| Monthly mean min. | 16 | 17 | 21 | 24 | 25 | 26 | 24 | 23 | 28 | 21 | 18 | 15 | 19 | 20 | 23 | 27 | 27 | 27 | 24 | 24 | 24 | 23 | 21 | 18 |
| Night comfort: upper | 23 | 23 | 23 | 24 | 24 | 23 | 23 | 23 | 21 | 23 | 23 | 23 | 23 | 23 | 24 | 24 | 24 | 23 | 21 | 23 | 23 | 23 | 23 | 23 |
| lower | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Thermal stress: day | O | H | H | H | H | H | H | H | H | H | H | O | O | H | H | H | H | H | H | H | H | H | H | H |
| night | C | O | O | O | H | H | H | O | H | O | O | C | O | O | O | H | H | H | H | H | H | O | O | O |

| | | AMT over 20$^{0}$C | |
|---|---|---|---|
| Comfort limits | | Day | Night |
| Humidity group | 1 | 26-34 | 17-25 |
| | 2 | 25-31 | 17-24 |
| | 3 | 23-29 | 17-23 |
| | 4 | 22-27 | 17-21 |

H (hot) – if mean is above limit

O (comfort) – if mean is within limits

C (cold) – if mean is below the limit

### 5.4.4 Indicators – Chota Bazaar

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Humid H1 | | | | | | | ★ | ★ | ★ | | | |
| H2 | | | | | | | | | | | | |
| H3 | | | | | | | | | | | | |
| Arid A1 | ★ | ★ | ★ | ★ | ★ | | | | | ★ | ★ | ★ |
| A2 | | | | ★ | ★ | | | | | | | |
| A3 | | | | | | | | | | | | |

Indicator details

| H1 | H2 | H3 | A1 | A2 | A3 |
|---|---|---|---|---|---|
| 3 | 0 | 0 | 9 | 2 | 0 |

### 5.4.5 Indicators – Aurora Colony

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Humid H1 | | | | | | | | ★ | ★ | | | |
| H2 | | | | | | | ★ | | | | | |
| H3 | | | | | | | | | | | | |
| Arid A1 | ★ | ★ | ★ | ★ | ★ | | | | | ★ | ★ | ★ |
| A2 | | | ★ | ★ | ★ | | | | | | | |
| A3 | | | | | | | | | | | | |

Indicator details

| H1 | H2 | H3 | A1 | A2 | A3 |
|---|---|---|---|---|---|
| 3 | 0 | 0 | 9 | 2 | 0 |

H1- Air movement essential

H2 – air movement desirable

H3 – rain protection necessary

A1 – thermal capacity necessary

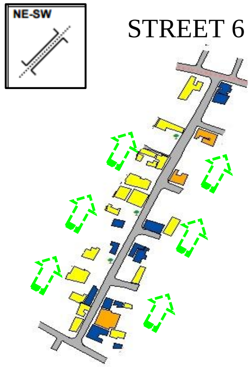
A2 – out door sleeping desirable

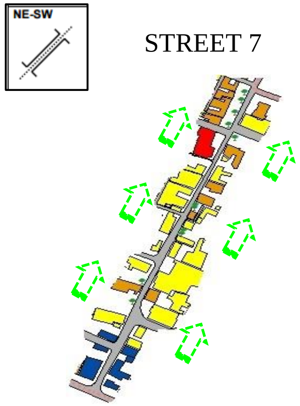
A3 – protection from cold

### 5.4.6 Recommended Specifications

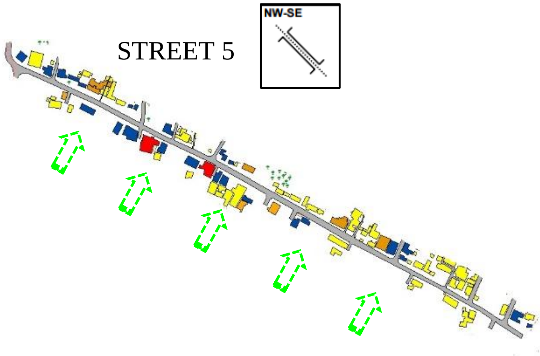
1. Layout - Orientation of building north – south – buildings should be oriented on an east-west axis, the long elevations facing north and south, to reduce the exposure of sun
2. Spacing - Open spacing for breeze protection , but protection from hot and cold wind
3. Air movement - Double banked rooms, temporary provision for air movement – plan should allow for temporary cross - ventilation
4. Openings - Large openings, 40-80% - large between north and south walls. These need not be fully glazed, but should be protected from the sun, sky glare and rain, preferably by horizontal overhangs
5. Walls -Heavy external and internal walls
6. Roofs - Heavy roofs – a heavy roof with thermal capacity

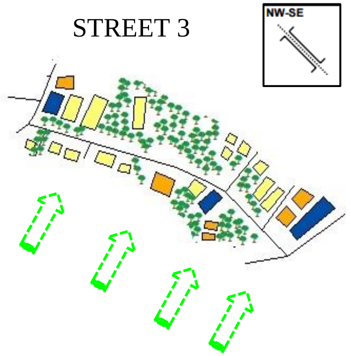
## 5.5 Overall Analysis



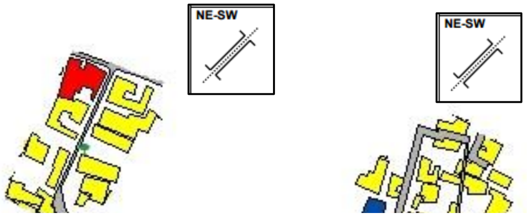

### 5.5.1 Wind Direction and Streets




- The wind flow in the street canyon depends on the road's orientation.
- Parallel and perpendicular winds reduce thermal stress.

### 5.5.2 Street Widths and Winds

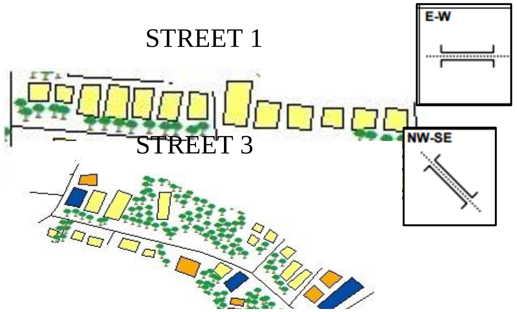



- Narrow streets reduce hot winds.
- Narrow street canyons (4m & less) increase wind speed.

### 5.5.3 Building Heights and Temperature

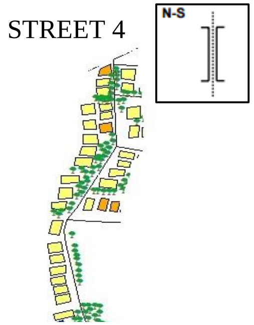
- Different building heights promote for better ventilation.

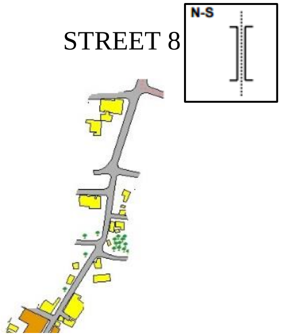
### 5.5.4 Aspect ratio And Streets




- Wind speeds are slower in deep canyon.
- Deep & narrow canyons (H/W$\geq$0.5) reduce solar access.

### 5.5.5 Street Orientation and Thermal Environment




- N-S orientation provide for better thermal environment.
- NE-SW & NW-SE provide for better comfort because shading effects of walls are more effective.

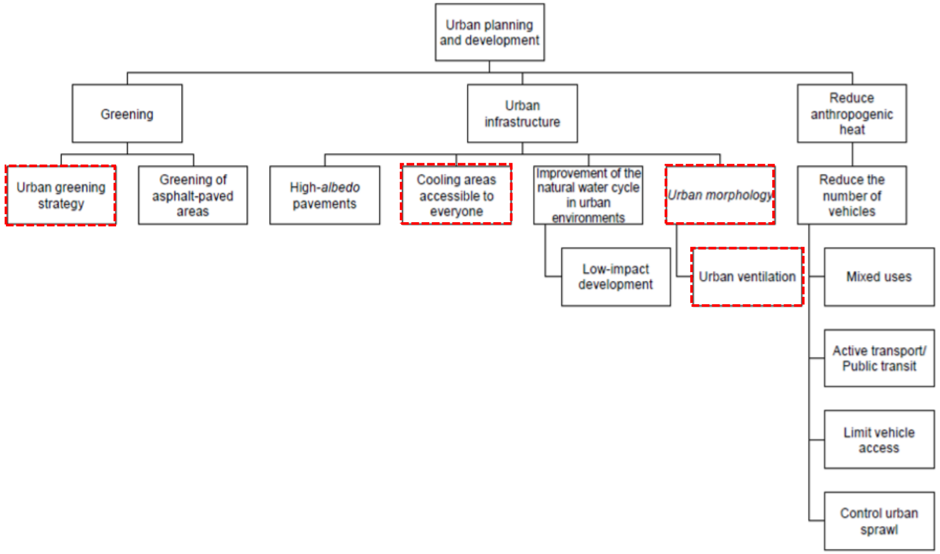
### 5.5.6 Discomfort Zones

- E-W street orientation are not appropriate for pedestrian comfort.
- Wide streets allow for the flow of hot winds.

# 6 Proposals

| **Objective** | **Buildings** | **Building Groups** | **Settlement** |
|---|---|---|---|
| Outdoor comfort | Local climate change:<br>• Emissions<br>• Materials/ surfaces<br>• Building dimensions – flow interference and shadow areas | • Building placement<br>• Outdoor landscaping, materials and surfaces<br>• Street dimensions & orientation | Guidelines on:<br>• Densities<br>• Heights<br>• Uses<br>• Green spaces |

## 6.1 Urban Planning & Development



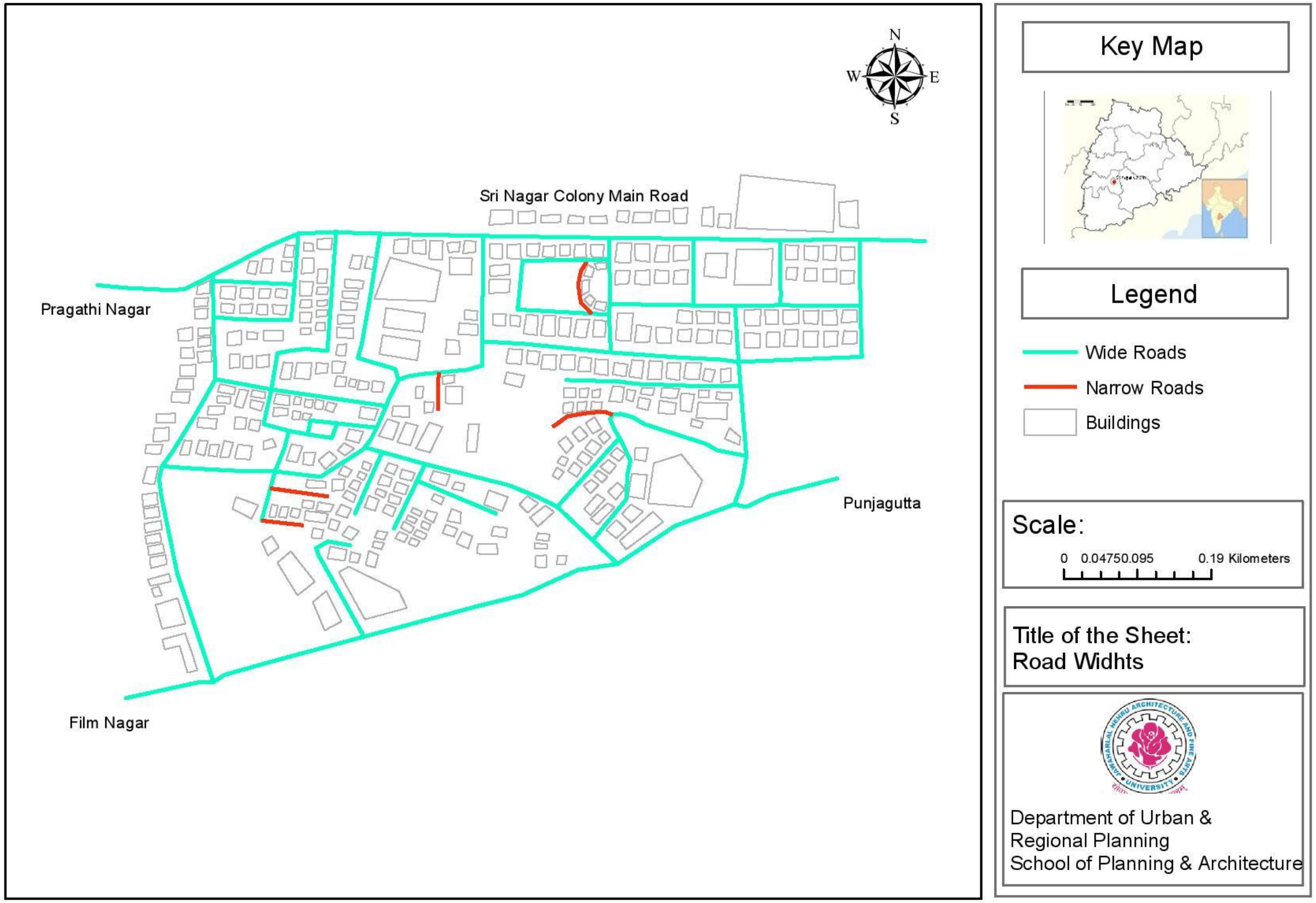

When considering urban planning & development, few aspects of climate related problems are also to be sorted out may be from the neighbourhood level to the regional level. Maintaining microclimate cooler or more comfortable at neighbourhood level could consider strategies like:

*Urban greening* – promote more green spaces like parks, playgrounds.

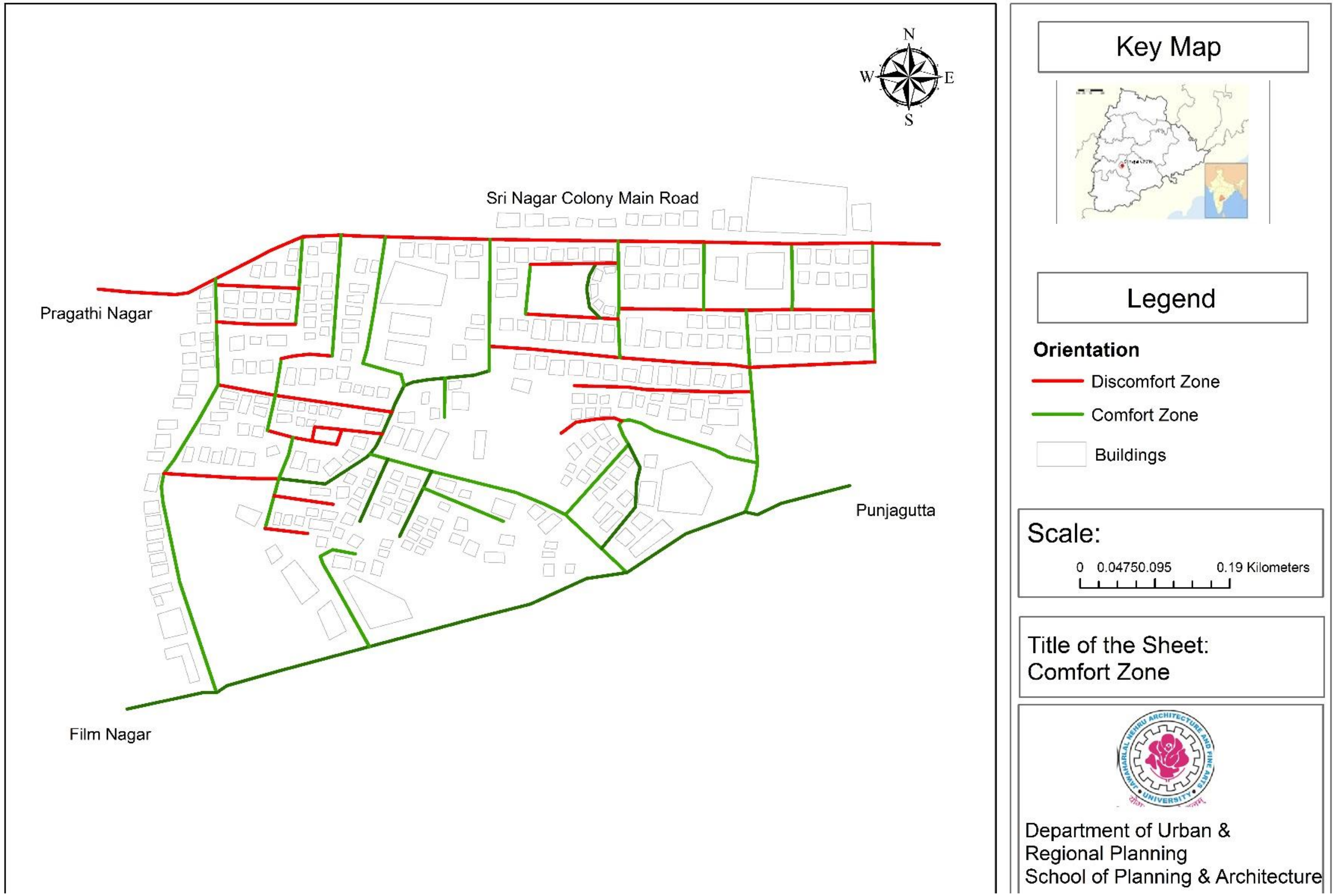
*Cooling areas accessible*- creating artificial water bodies

*Urban ventilation*- improving air flow through proper building spaces, building heights and also planting trees at appropriate locations.

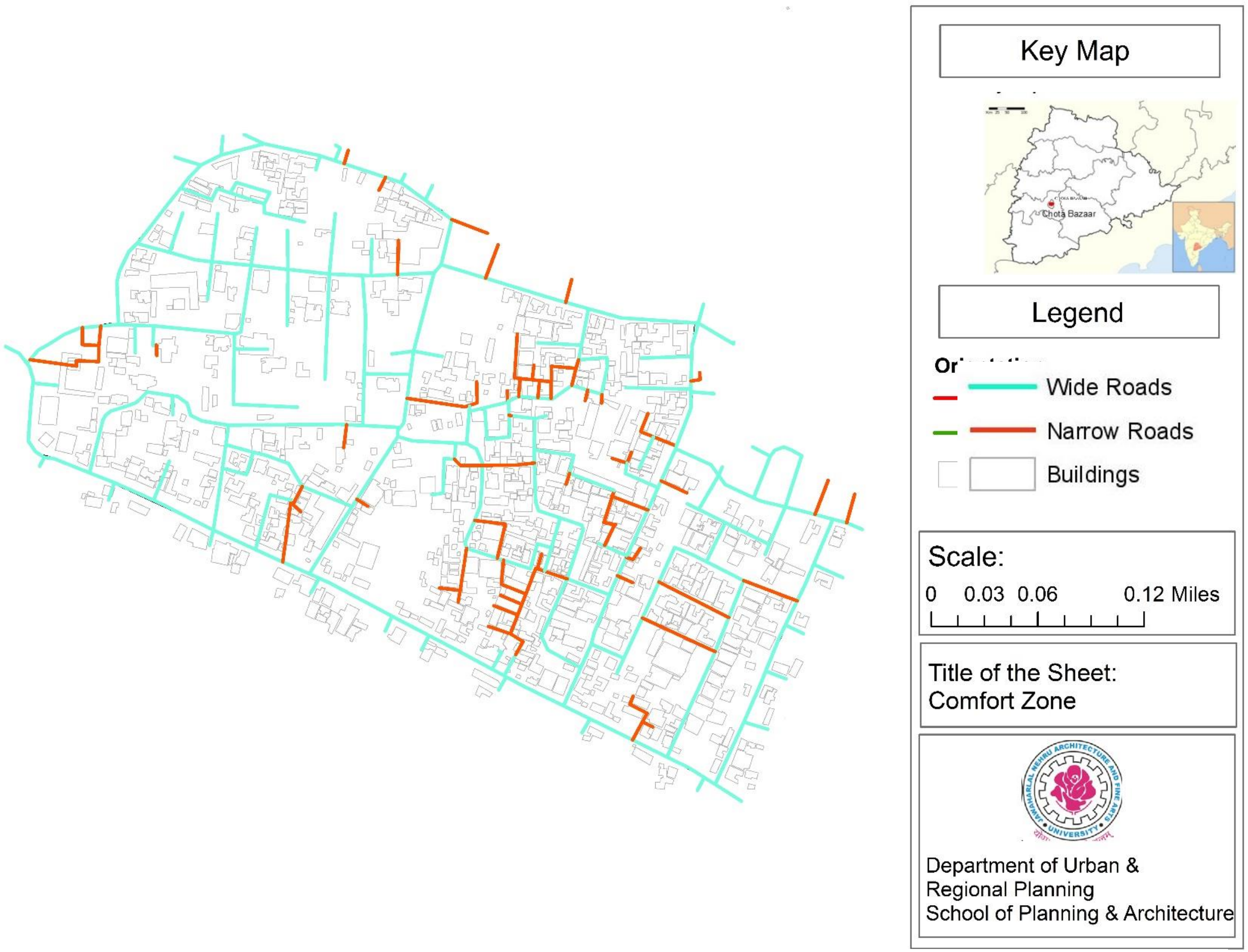
## 6.2 Strategic placement of trees



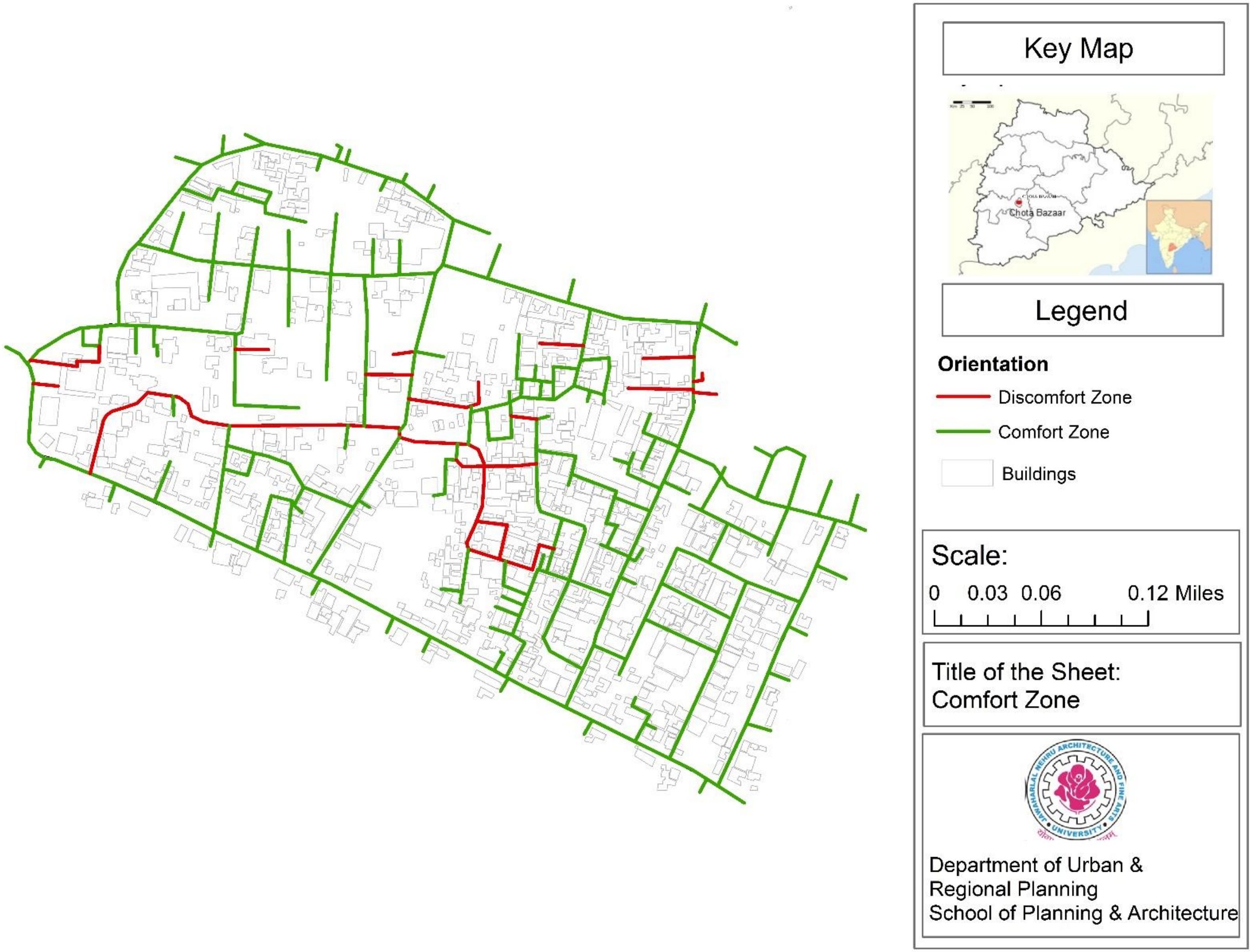

*Map 7 Aurora Colony - Road Widths*




*Map 8 Aurora Colony - Comfort Zones*




*Map 9 Chota Bazaar – road widths*




*Map 10 Chota Bazaar - Comfort Zones*

## 6.4 Landscaping

All unpaved surfaces must be appropriately landscaped or at least be planted with low-maintenance ground covers. The planting of street trees is recommended.

## 6.5 Environmental Building Guidelines for Greater Hyderabad

In all sites, with or without existing site vegetation, the following minimum number of trees have to be maintained.

- 250 Sq. Mtrs and below -2 trees
- Above 250 Sq. Mtrs. but below 750 Sq. Mtrs. - 3 trees
- 750 Sq. Mtrs. and above -1 tree for every 250 Sq. Mtrs.

The location of the open spaces has to be such that they are easily accessible to most of the occupants. The following guidelines are recommended:

- It has to be located in the centre of the site
- Open space should have a road around with plots facing it on at least 3 sides
- In case of a multiple open spaces in the layout, the location of the open spaces have to be such that they are spread out around the site
- Each open space should have a road around with plots facing it on at least 3 sides

## 6.6 Planting densities for various requirements

General Planting - It is recommended that a minimum of one (1) shade tree and five (5) shrubs be planted for every 1,000 square feet of open space area.

The following are recommended minimum sizes and heights of plant material at the time of planting:

*Table 10 Plant types and minimum dimensions*

| Plant/ Tree type | Dimensions |
|---|---|
| Shade Tree | 2½" - 3" cal., 12-14 ft. |
| Flowering Tree | 6-8 ft. ht. |
| Coniferous Evergreen Tree | 5-6 ft. ht. |
| Deciduous Shrub (upright) | 24"-30" ht |
| Deciduous Shrub (spreading) spread | 24"-30" |
| Broadleaf Evergreen Shrub | 24"-30" ht. |

## 6.7 Planning regulations

- Reducing front setbacks or to have none at all
- Planning narrower streets in the neighbourhood
- Increase the permissive number of floors
- Architectural elements – which provide shade for pedestrian at street level, such as balconies and horizontal shading devices should be encouraged.
- Introducing vegetation and landscaping in urban design.

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